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88

Niina Hämäläinen

Evaluation and Measurement in Enterprise and Software Architecture Management

JYVÄSKYLÄN YLIOPISTO

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UNIVERSITY OF JYVÄSKYLÄ

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ABSTRACT

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Companies need to develop their capabilities to operate in a highly dynamic competitive environment subject to internally and externally induced change. In order to meet this need nowadays, companies actively develop their capabilities in enterprise and software architecture planning and development. Needs to develop evaluation practices and metrics relating to these capabilities have arisen concurrently with this development work. However, there seems to be a need for more scientific knowledge about meanings of evaluation in architecture management and practices how to carry out evaluations. The purpose of this study is to produce new theoretical knowledge and develop practices for evaluations and measurement in architecture management. The key aims of this study were to define the purposes of evaluations in architecture management and produce knowledge and practices that ease the development evaluation practices and metrics for companies' architecture management capabilities (e.g. for enterprise architecture program). Firstly, in this study challenges met in architecture management and conceptions of factors that have an effect on the success of architecture are identified and categorized and a model of main factors affecting the success of software architecture is presented. Secondly, companies' triggers for evaluations and evaluation areas supported by evaluation methods are analysed and categorized. The resulting categorisations describing triggers and application areas of architecture evaluation are also described. Thirdly, practices for quality evaluation of architecture documentation and for measurement planning of enterprise architecture program are constructed. Furthermore, a goal oriented way to define metrics for enterprise architecture program and a framework for the quality evaluation of architecture documentation are presented. Quality management in architecture management context is also studied and the application of general quality management tasks to the context of software architecture management is presented. The main contributions of the thesis can be divided into contribution (1) to current theoretical knowledge about architecture management related evaluations and (2) to development of practices for architecture evaluation.

Keywords: enterprise architecture, software architecture, evaluation, measurement, metric

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III Hämäläinen, N., Ahonen, J. and Kärkkäinen, T. 2005. Why to Evaluate Enterprise and Software Architectures? - Objectives and Use Cases. In Dan Remenyi (Ed.) Proc. 12th European Conference on Information Technology Evaluation (ECITE '05), Turku, Finland, September 29-30, 2005, Reading, UK: Academic Conferences Limited, 213 - 222.

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V Hämäläinen N. 2007. Quality Management Activities for Software Architecture and Software Architecture Process. In W. Hasselbring (Ed.) Proc. The IASTED International Conference on Software Engineering (SE '07), Innsbruck, Austria, February 13-15, 2007, Anaheim: ACTA Press, 347-352.

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VII Hämäläinen N. and Kärkkäinen T. 2008. A Goal-Oriented Way to Define Metrics for an Enterprise Architecture Program. Journal of Enterprise Architecture 4 (1), 20-26.

1 INTRODUCTION

The worldwide trends of globalization, deregulation, technical evolution, and market liberalization are restructuring markets and traditional approaches to gaining competitive advantage (Chakravarthy, 1997; Montealegre, 2002). Today's company must operate in a highly dynamic environment subject to internally and externally induced changes (Arteta & Giachetti, 2004). How organisations can successfully deal with these unpredictable, dynamic and constantly changing environments provides a continuous challenge (Sherehiy *et al.*, 2007). To maneuver in this environment and even thrive requires companies to not only accommodate the changing environment but also to seize on the change, even turning it into a competitive advantage (Arteta & Giachetti, 2004). The current business environment thus requires companies to have capabilities to quickly develop new products and services as well as to have capabilities to take action in situations of change (e.g. outsourcing, company mergers and acquisitions).

Context awareness (understanding the company's internal and external environment) and organisational capabilities (diversifying and strengthening core competencies) are presented as strategies to cope with this turbulent environment, for example, by Chakravarthy (Chakravarthy, 1997). Context awareness and the development of organisational capabilities can be supported and enabled by architecture capabilities.

Enterprise and software architectures are structural approaches to describe and design organisation and its information systems. These architecture approaches are developed to support companies' ability to develop its services, products, and information systems cost-effectively, so that a company's information systems support a company's business. Currently, many companies actively develop their architecture planning and development capabilities, e.g. by developing processes, methods and practices based on various architecture approaches and establish architect teams.

FIGURES

TABLES

1.1 Why study evaluation in architecture management?

Evaluation is a means to generate information that assists in making judgments and decisions (for example, about a program, service, policy, organisation, person, or whatever else is being evaluated (Stufflebeam, 2001)). Evaluation generates qualitative (descriptive) information and quantitative (numerical) information. Generating quantitative information by using metrics is commonly referred to as measurement. Descriptive and numerical information can be used to supplement each other (Smith, 1991), for example, in decision making situations. In the development of architecture capabilities, especially those based on enterprise and software architecture approaches, evaluation and measurement practices and skills are seen as important by both industry and academia, as the following statements demonstrate.

> *"Being able to measure, in the meaning of having skills and capability to measure, is essential at all stages of the EA* [enterprise architecture] *adaptation."*
> By Christiansen and Gotze, Journal of Enterprise Architecture (Christiansen & Gotze, 2007)
>
> *"EA groups must invest in developing a metrics program and roll up metrics into an EA scorecard."*
> In "Trends 2006: Enterprise Architecture" by Forrester Research (Cullen, 2005)
>
> *"Measurements need to be integrated with architecture processes so that architecture baselines can be formed and maturity tracked, architecture effectiveness and resulting business value can be measured."*
> In "Enterprise Architecture: Governance Framework" by Infosys, (Aziz *et al.*, 2006)
>
> *"A formal software architecture evaluation should be a standard part of the architecture-based software development life cycle.* "
> In "Software architecture evaluations", by SEI (SEI, 2007)

The development of metrics and evaluation practices for the companies' architecture capabilities seem to be an emerging trend.

> "*We will begin to see metrics become an integral part of EA* [enterprise architecture] *and SOA* [service-oriented architecture] *programs.*"
> In "Enterprise Architecture Trends 2007", by Cutter Consortium, (Cutter Consortium, 2007)

However, guidance and support for the definition and development of evaluations and metrics for architecture capabilities seems to be needed. In addition, there exist challenges related to the existing evaluation and metric definition techniques. These are exemplified in the following remarks.

"*Currently, there is very little guidance on metrics that can be captured to help assess the EA* [enterprise architecture]."
By Kaisler et al. , Proceedings of HICSS 2005, (Kaisler *et al.*, 2005)

"*…identifying and defining useful and convincing IT and even business-related metrics is not easy and probably is one of the more challenging tasks for today's EA groups*"
In "EA Groups in Europe: Metric Challenge", by Forrester Research, (Hoppermann, 2007)

"EA measurement programs are difficult to successfully implement"
In "Why Enterprise Measurement Programs Fail: The Common Pitfalls" by Gartner (Weiss, 2006)

"Definitions for architectural measures are needed that provides insight into how software practitioners can determine the appropriate measures to use in their specific contexts and for their specific software architectures "
By Chastek and Ferguson (Chastek & Ferguson, 2006).

One consequence of this is, as the following observations reveal, that industrial organizations are not utilizing metrics and evaluation practices for architecture capabilities although they are considered important.

"*A recent Forrester survey of more than 50 European enterprise architects revealed that while many enterprise architects were working to achieve specific goals, metrics related to those efforts often did not exist or were not clearly defined.*"
In "EA and metrics: For maximum impact, measure business value", by Forrester Research, (Wollmer, 2007)

"*A limited effort is currently done to measure, for example EA* [enterprise architecture] *progress and value in organizations.*"
By Christiansen and Gotze, Journal of Enterprise Architecture, (Christiansen & Gotze, 2007)

"Many EA teams have not analyzed their measurement needs."
In "Why Enterprise Measurement Programs Fail: The Common Pitfalls" by Gartner (Weiss, 2006)

"… existing [architecture evaluation] techniques have too many limitations for a widespread application, such as, the inappropriate representation of an architecture and ambiguities in the evaluation process"
By Choi & Yeom, Proceedings of APSEC'02 (Choi & Yeom, 2002)

In summary, companies have concerns and pressures to develop evaluation practices and metrics for architecture capabilities. However, knowledge and practices in order to realize this development seem to be lacking, at least in part. In particular, one needs to establish a common view about what measurement and evaluation mean and what should be measured and evaluated in architecture management. The purposes of evaluation and measurement are unclear. This situation especially impedes the planning metrics and evaluations for architecture capabilities. Scientific research is thus needed to establish the concepts in this area.

1.2 What is studied in this dissertation?

This dissertation is based on the work and studies carried out during 2002-2007 in the three different research projects (Larkki, Koteva, and AISA) organized by the Information Technology Research Institute, University of Jyväskylä. The research foci of these projects related to architecture management and/or architecture management related evaluations. The needs to solve and study relevant questions related to these projects' research areas and consortiums (e.g. cooperating companies) have been a driving force in these projects, and in turn the topics studied in this dissertation as well. During this dissertation's author's work in Larkki (2002) and Koteva (2003-2004) projects, questions regarding how and why to carry out architecture evaluations arose repeatedly in discussions with practitioners from companies. At the same time, while scanning through scientific articles and other sources an observation was made that scientific research was focusing more and more on the architecture management context and development of evaluation practices. These factors were interpreted as signals of an emerging area by the author of this dissertation. These were reasons for the author's decision to study meanings of evaluation and measurement in architecture management and to develop practices for these in this dissertation study.

The main objective of this study is to describe and define purposes of evaluation in the context of enterprise and software architecture management and to develop some practices for this. More precisely, the first aim is to increase the understanding of challenges that are met in architecture management in companies and factors affecting the success of architecture. Secondly, purposes of evaluation in architecture management are considered. Thirdly, an aim is to develop evaluation practices for the architecture management domain. These practices are related to the quality evaluation of architecture documentation, the metrics planning for enterprise architecture program, and the quality management in software architecture management. The main contributions of the thesis can be divided into contribution (1) to current theoretical knowledge about evaluation in the architecture management context and (2) to development of practices for architecture management related evaluations.

The main research approaches used in this study are the qualitative research approach and the constructive research approach. Case study and grounded theory approaches are used as qualitative research methods for defining companies' current architecture management and in identifying purposes and aspects of evaluation in architecture management. A constructive research approach is used in the development of practices. In this dissertation, practitioners' experience and conceptions are seen as a valuable source of knowledge. This has affected research method choices. Practitioners' experiences and conceptions about architecture management related evaluations were gathered in focus group interviews (Kontio *et al.*, 2004; Krueger & Casey, 2000) and in the analysis of companies' public and internal documents and reports.

Table 1 describes at a broad level the main phases of the research and questions studied in this dissertation as well as their connections to the research projects. The subsequent sections describe these in more detail. The research methods in particular are described more precisely in one of these sections.

TABLE 1 Main phases of research and questions studied in this dissertation and relation to the research projects.

Research Phase	Studied research question	Related article	Related research project and the point of time of the study
Phase 1: Context of evaluation and measurement in architecture management	• What challenges exist in architecture management in companies? • What factors affect the success of architecture?	I II	Larkki (Spring 02) AISA (Autumn 05)
Phase 2. Purposes of evaluation and measurement in architecture management	• What evaluation purposes and possibilities do existing architecture evaluation methods support? • What are triggers (information needs) for architecture evaluations in companies? • In which aspects could evaluation and measurement be carried out relating to a company's architecture capabilities?	III IV VII	Koteva (Autumn 04) AISA (Autumn 06) AISA (Autumn 06)
Phase 3. Practices development	• How can quality management be carried out as a part of architecture management? What activities should be carried out to achieve architecture of good quality? • How to carry out the quality evaluation of architecture documentation? • How to define metrics for an architecture program?	V VI VII	AISA (Autumn 05) AISA (Autumn 06) AISA (Spring 07)

This dissertation focuses on the needs of the private sector organisations which may operate in a quite turbulent business environment. Therefore, potential aspects that are essential for such organisations are highlighted. This study focuses on enterprise and software architecture approaches and carrying out evaluations relating to these approaches. This selection was done to define the scope of the research and these architecture approaches were seen to be currently essential for companies. The assessment of applicability and application of these results to other architecture approaches (e.g. service-oriented architecture) are left for future research.

The structure of the thesis is the following. Section 2 will discuss why current business environment drives companies to develop architecture capabilities and present existing architecture approaches. Section 3 explores enterprise and software architecture management and related concepts and practices. Section 4 discusses evaluation and measurement fundamentals and research and views on evaluation and measurement in the architecture management. Then, Section 5 describes research problems and questions studied in this dissertation. In addition, Section 5 will present the research approach, including a description of the research phases and methods used. A summary of the included articles and results will be presented in Section 6. Section 7 will present conclusions, recommendations and future work directions. Finally, the original articles are presented.

2 A NEED FOR ARCHITECTURE CAPABILITIES IN THE CURRENT BUSINESS ENVIRONMENT

This section describes characteristics of the current business environment to provide background about why architecture capabilities are developed in companies. In addition, systems architecting and existing architecture management approaches are shortly discussed.

2.1 The current business environment

Companies do not operate in a vacuum. That is, many people, conditions, and other forces affect company's operations and the development of company's information systems. Some of these factors are internal, while others are external to the company. A company's internal environment consists of the company's resources, its capabilities and competencies. A company's external environment consists of those external forces that affect the company indirectly and often beyond the control of the company's managers (Kuhlman *et al.*, 2005). The environment of most companies includes socio-cultural, economic, global, technological, and political-legal dimensions (Kuhlman *et al.*, 2005). Relating to these dimensions, business trends comprise e.g. globalization, mergers and acquisitions, e-commerce, and customer-relationship and supply-chain management (Shah & Kourdi, 2007) and IT trends comprise e.g. advances in internet technologies, hardware platforms, and workflow servers (Shah & Kourdi, 2007). A company's information systems are developed and operate within a company's environment that in turn has a significant effect on them (Avison & Fitzgerald, 2006). Therefore, many factors have an effect on the environment and context in which a company's information systems exist and are developed (Avison & Fitzgerald, 2006). In the following, some specific factors are discussed.

Globalization. Globalization means that most companies must operate in worldwide markets. They produce and sell their products and services in many countries. For companies seeking growth, overseas markets represent new market segments, which they may be able to serve with their existing range of products (Palmer & Hartley, 2006).

Constant change. Companies must be able to adapt quickly in reaction to their changing environment. De Michelis et al. (De Michelis *et al.*, 1998) say that dealing with change is one of the most fundamental challenges facing organisations today. The change drivers faced by organisations include (1) ubiquitous availability of technology, (2) accelerated pace of technology development, (3) rapid expansion of technology access, (4) globalization of markets and business competition, (5) global wage and job skill shifts, (6) environmental responsibility and resource limitations, and (7) increasing customer expectations (St. John *et al.*, 2001).

Emergence of resource-based strategy approach. The resource-based view of the company sees a company as a bundle of resources and capabilities (Montealegre, 2002). The resource-based strategy is a view of strategy that focuses on these company resources (Bannock *et al.*, 2003). It is distinctive from previous dominant strategy approaches, which have emphasized the importance of the market and a firm's position in it (Bannock *et al.*, 2003). In particular, it suggests that a firm's competitive advantage is dependent on its ability to develop and acquire knowledge, skills, and technology (Bannock et al., 2003). In the resource-based view, resources are company-specific assets and competencies, controlled and used by companies to develop and implement their strategies (Montealegre, 2002). They can be either tangible (e.g. financial assets, technology) or intangible (e.g. managerial skills, reputation) (Barney, 1997).

Growing complexity of information systems. The growing complexity in companies' information systems is also one of the current factors affecting a companies' operation (Ross *et al.*, 2006). Nowadays companies have more and more information systems and the sizes of systems have grown. In addition, needs to integrate these systems as well as needs to provide new interfaces to these systems have also increased. So there exist many dependencies between company's different information systems. Developing and testing new capabilities for the company in such a complex environment is time consuming, and every change becomes a risky, expensive adventure (Ross et al., 2006). Any change requires individually rewiring systems to all the other systems they connect to (Ross et al., 2006).

Changes in customer needs. Customer needs and expectations have changed and increased. Customer satisfaction requires that e.g. products need to be customized to individual specifications.

2.2 Needs for capabilities to handle and manage change and complexity

Capabilities can be defined as a company's abilities to integrate, build, and reconfigure internal and external assets and competencies enabling to perform distinctive activities (Teece *et al.*, 1997). As the previous section described, many different factors currently affect companies' operations and the development of their information systems. Companies have, therefore, needs for capabilities that support operating in the changing and complex business environment. They also need ways to implement new strategy approaches which, for example, encourage the development of core business capabilities and management of company's resources (such as resource-based view of strategy). Companies, especially their managers, need to be skilled and supported in how to analyze and improve the ability of an organisation to survive and grow in a complex and changing world. This means that managers and the company's other personnel (especially information system developers) need to have a set of means that enable them to grasp the complexity of the company's internal and external environment. Architecture capabilities are developed as the means to achieve this end.

Architecture capabilities are a company's abilities to utilize architecture management approaches to integrate, build, and reconfigure internal and external assets and competencies so that they enable it to perform distinctive activities. Architecture capabilities consist of architecture work related organisational structures, skills, practices, principles, tools, and models as well as the architecture work's relationships to the other organisational processes. [1]

Companies develop architecture capabilities based on different architecture management approaches. These approaches are described in the next section.

2.3 Approaches for architecture management

Architecture management approaches are based on the systems thinking and architecting concepts (e.g. (Maier & Rechtin, 2000), (Rechtin, 1999), (Chekland, 1981), (Kossiakoff & Sweet, 2003)). The function of systems engineering is to guide the engineering of complex systems (Kossiakoff & Sweet, 2003). In the fol-

[1] Definition for architecture capabilities is developed by Niina Hämäläinen and Jouni Lähteenmäki based on definitions for capability (Teece et al., 1997) and architecture management approaches (e.g. definitions for enterprise architecture).

lowing, systems architecting concepts are considered first, and then architecture approaches are briefly discussed.

2.3.1 Systems architecting

In the architecting of organisations, organisations are seen as complex systems, people-based, but nonetheless systems (Rechtin, 1999). At the most fundamental level, systems are collections of different things which together produce results unachievable by the elements alone (Maier & Rechtin, 2000). A systems approach is one that focuses on the system as whole, particularly when making value judgments (what is required) and design decision (what is feasible) (Maier & Rechtin, 2000).

Every system and organisation has an architecture, or "structure" broadly defined which largely determines what the system can and can not do (Rechtin, 1999). ISO standard/IEEE standard 1471-2000 (ISO, 2007) (IEEE, 2000) defines architecture 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*".

Systems architecting can be as applicable to the structural problems of organisations as it is to the problems of the hardware and software products the organisations create and support (Rechtin, 1999). Systems architectural insights and techniques, heuristics and metaphors in particular, can be used to sustain the excellence of organisations, their people, and their product lines – especially during times of global competition and unavoidable change (Rechtin, 1999).

Systems architecting is a process driven by a client's or stakeholders purpose or purposes (Maier & Rechtin, 2000). If a system is to succeed, it must satisfy a useful purpose at an affordable cost for an acceptable period of time. The explicit value judgments in these criteria consist of a useful purpose, an affordable cost, and a acceptable period of time (Maier & Rechtin, 2000).

2.3.2 Architecture approaches

Companies develop their architecture capabilities based on different architecture management approaches. Currently, a variety of approaches for architecture management are studied, developed and applied by industry and academia. These are, among others, enterprise architecture (EA), service-oriented architecture (SOA), service-oriented enterprise architecture (SoEA), integration architecture, and software architecture (SA).

Each of these architecture management approaches has its particular scope, aspects that it highlights and architecting activities related to it. Some of these cover as wide part of company structures and describe those in a high level (e.g. enterprise architecture). Others focus on a particular area and aspects and describe these more detailed levels (e.g. software architecture). Utilization of results (e.g. enterprise models) produced by these approaches also vary. Some can be used in the management of company and some results are used to support the design and development of information systems.

There is no single agreement in the industry and in academia on the meaning of these architecture management approaches. This means that concepts relating to them are not stabilized yet. In addition, there is no agreement about their relationship to one another. A consequence of this is that some approaches may have the same meanings, either partially or completely. Some approaches may thus be overlapping. An example of overlap is the discussion about whether service-oriented architecture (SOA) is part of enterprise architecture (EA), or enterprise architecture is a part of service-oriented architecture (SOA). This question is discussed, for example, by Knipple and Skytte (Knippel & Skytte, 2007). Thus distinctions between these approaches are not completely clear. So the question of how then to handle this situation of unclearly defined concepts arises. One example of a recommendation to handle this situation in companies is the following. "*For now, you should simply be aware that these different terms exist, but that there is no consistent definition of these terms in the industry and how they relate. The recommendation, therefore, is for you to select the terms relevant to your organization and define them appropriately. You will then achieve some consistency at least and reduce the potential for miscommunication.*" (Eeles, 2006b)

3 ENTERPRISE AND SOFTWARE ARCHITECTURE MANAGEMENT

This section discusses enterprise and software architecture management. Enterprise and software architecture management are different parts and aspects of company's architecture capabilities. These have a different scope and different aims. Enterprise architecture capabilities are typically developed to be used as an instrument in managing a company's daily operations and future development (Lankhorst, 2005). Enterprise architecture is seen as "*a planning, governance, and innovation function that enables an organization to progress toward its vision of its future state*" (Leganza, 2007). Usually enterprise architecture deliverables are closely aligned to the strategic enterprise plan of the company (Subramanian et al., 2006). As Figure 1 describes, enterprise architecture is quite commonly defined as consisting of at least four viewpoints (business, information/data, application and technology architecture). Software architecture focuses on one area of enterprise architecture describing more detailed structural decisions, especially concerning technical structures of information systems. Software architecture is utilized quite commonly in system development projects. Commonly accepted software architecture viewpoints (that software architecture viewpoint models seem to define one way or another) are the functional, behavioural, external and deployment viewpoint (May, 2005). In addition to these, *information* and *operational viewpoints* are also viewpoints of software architecture (Rozanski & Woods, 2005).

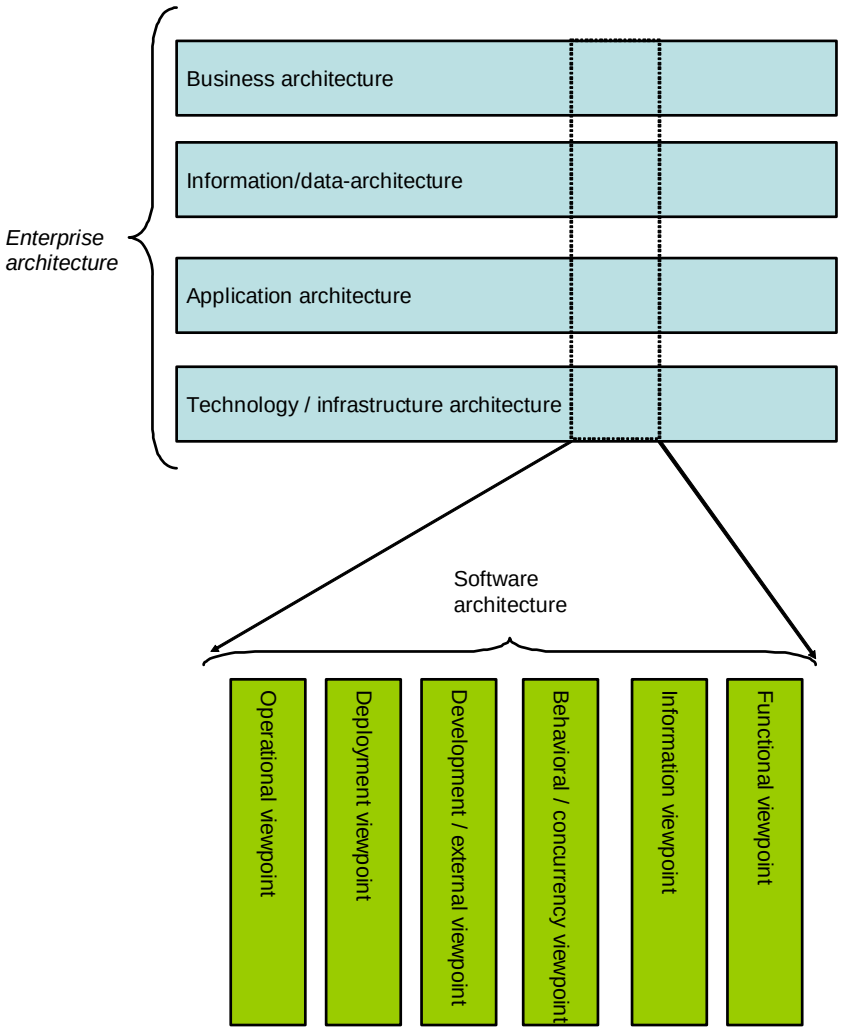

FIGURE 1 Relationship between enterprise architecture and software architecture (cf. (Hämäläinen *et al.*, 2007)).

In this section, concepts relating to enterprise and software architecture management, the expected benefits these bring to companies and the existing methods, practices and other resources for realize these are discussed.

3.1 Enterprise architecture management

Enterprise architecture is an adopted means for coping with companies' ever-increasing complexity and for ensuring that companies appropriately use and optimize their technical resources (Shah & Kourdi, 2007). Several different definitions for enterprise architecture are presented by academia and industry. Enterprise architecture is defined, for example, as follows.

" *the main components of the organization, its information systems, the ways in which these components work together in order to achieve defined business objectives, and the way in which the information systems support the business processes of the organization*".
(Kaisler et al., 2005)

"*enterprise architecture is a coherent whole of principles, methods and models that are used in the design and realisation of an enterprise's organisational structure, business processes, information systems, and infrastructure.*"
(Lankhorst, 2005)

"*the vision, principles, standards and processes that guide the purchase, design and deployment of technology within an enterprise. EA describes the interrelationships between business processes, information, applications and underlying infrastructure for that enterprise, and provides best practices for technology purchase, design and deployment.*"
(Leganza, 2003a)

"*The organizing logic for business processes and IT infrastructure reflecting the integration and standardization requirements of the company's operational model*"
(Ross et al., 2006)

"*the set of plans that describes how all parts of the IT infrastructure need to behave or currently behave to support the enterprise needs and goals – this includes all the data, the functions, the technology, and the people that constitute the infrastucture*"
(Carbone, 2005)

The author of this dissertation sees that there is no current definition of enterprise architecture that has been used consistently and which covers all aspects of enterprise architecture. In other words, different definitions for enterprise architecture describe and highlight different aspects of enterprise architecture. The author of this dissertation sees that, currently, several definitions for EA need to be considered in order to understand different aspects of the enterprise architecture –concept. Therefore, in this dissertation, one definition for enterprise architecture is not strictly adhered to. Different definitions are used to describe and define various aspects of enterprise architecture. Nevertheless the definitions presented by Kaisler et al. and Lankhorst play a central role in this work in conceptualizing EA (Kaisler et al., 2005) (Lankhorst, 2005).

Enterprise architecture management is a continuous and iterative process identifying a company's business strategy needs and controlling and improving the existing and planned IT support for an organization (Ernst *et al.*, 2006). EA management should be driven by and adjusted to the business strategy. In addition, an EA supports company's IT, which plays the role of a supporter or even an enabler for the business strategies and goals. So the enterprise architec-

ture work not only considers the information technology (IT) of the enterprise, but also business processes, business goals, strategies, etc. are considered in order to build a holistic and integrated view on the enterprise (Ernst et al., 2006). Thus EA management is the discipline of managing the whole enterprise architecture and the artifacts building the enterprise architecture.

The activities of enterprise architecture management relate to the cooperation with business and IT. There does not seem to exist a common accepted group of activities or tasks that are related to the enterprise architecture management. The view of the author of this dissertation is that company's enterprise architecture management activities depends mainly on the benefits that a company aims to achieve through its enterprise architecture capabilities. The activities carried out should support the achievement of these benefits. However, generic activities can be naturally defined (e.g. identifying business needs for architecture development, architecture principles development, architecture evaluations and validations).

Organisations' drivers for and expectations of benefits of enterprise architecture capability development varies. Both business- and IT-related benefits are expected to achieve. Business-related benefits are (Shah & Kourdi, 2007)

- Reduction in impact of staff turnover: Capture knowledge from employees and consultants. Provide business solutions from third party organizations consistently so they can conform to the current models.
- Faster adaptability: Facilitate knowledge acquisition necessary for changing systems and adopting new components.
- Operating procedures improvement: Understand and model business processes, review and reengineer processes.
- Decision making: Represent an enterprise layers and components modularly to let the organization make business decisions in the context of a whole instead of a stand-alone part.

IT-related benefits are among others (Shah & Kourdi, 2007)

- Complexity management: Facilitate the scoping and coordination of programs and information systems projects. Manage complexity and describe the interdependencies in a usable manner.
- Technical resource oversight: Identify and remove redundancy.
- Knowledge management: Manage and share knowledge modularly so it can be visualized across different levels.
- IT visibility: IT resources and systems are more aligned to business strategies and are better placed for responsiveness.

In addition, the expected benefits vary depending on the viewpoint. From a company management point of view, expected benefits are enhanced strategic business outcomes (better operational excellence, more customer intimacy, greater product leadership, more strategic agility, which means the ability to respond rapidly to competitor initiatives and new market opportunities), increased managerial satisfaction (the confidence of non-IT executives in the IT unit's ability to deliver business value), improved risk management, increased

IT responsiveness and reduced IT costs (Ross et al., 2006). From an IT governance (especially from CIO) point of view, benefits of enterprise architecture are seen to be useful in making decisions, managing change, improving communications and ensuring that information technology is acquired and information resources are managed to be consistent with business planning (IT Governance Institute, 2005).

IFEAD has investigated why enterprise architecture is important for companies (IFEAD, 2005). The benefits of EA capabilities that companies' expect are that EA delivers insight into, and an overview of, business and IT; it is helpful in mergers and acquisitions; it supports (out/in) sourcing and systems development as well as manages an IT portfolio and delivers roadmaps for change. In addition, EA is expected to be helpful in decision making, managing complexity, business and IT budget prioritization. Enterprise architecture is seen as one of the solutions for these challenges and development needs.

3.2 Software architecture management

Since the late 1980s, software architecture has emerged as the principled understanding of the large-scale structures of software systems (Shaw & Clements, 2006). It offers guidance for complex software design and development (Shaw & Clements, 2006). Software architecture management is thus utilized in information system development.

A definition of software architecture is provided by Bass et al. (Bass *et al.*, 2003): "*The software architecture of a program or computing system is the structure or structures of the system, which comprise software elements, the externally visible properties of those elements, and the relationships among them.*" The architecting of a system contributes to the development, operation, and maintenance of a system from its initial concept until its retirement from use (ISO, 2007). So architecting is not a single activity at one point in the development of an information system. Rozanski and Woods (Rozanski & Woods, 2005) describe architecture definition as a process by which stakeholder needs and concerns are captured, an architecture to meet these needs is designed, and the architecture is clearly and unambiguously described via an architectural description. The activities involved in architecting of software architecture encompass, therefore, capturing architectural requirements of the system/software and understanding them, designing, analyzing/evaluating, realizing, maintaining, improving, and certifying the architecture as well as documenting it (IEEE, 2000, Bass et al., 1998). In addition, the co-operation with enterprise architecture planning relates to software architecting (e.g. communicating and giving feedback about company wide principles). A good architecture definition process is one that leads to a good architecture, documented by an effective architectural description, which can be realized in a time-efficient and cost-effective manner. Documenting software architecture facilitates communication between stakeholders,

documents early decisions about high-level design, and allows reuse of design components and patterns between projects (Bass et al., 2003).

Drivers and expectations of benefits of software architecture capability development vary but not so much as expectations of benefits of enterprise architecture capability. A key premise of software architecture is that important decisions may be made early in system development in a manner similar to the early decision-making found in the development of civil architecture projects (IEEE, 2000). From a practitioners' point of view, the expected benefits of software architecting are described, for example, as follows. "*… several different benefits are expected to achieved through software architecting. These benefits are, for example, addresses system qualities, drives consensus, supports the planning process, drives architectural integrity, helps manage complexity, provides a basis for reuse and supports impact analysis*." (Eeles, 2006a) and "*…a system's architecture is an important article of governance… intentionally devising software-intensive architecture is essential to building systems that are resilient to change… focusing on a system's architecture provides a means of intentional simplification…intentional architectures preserve critical intellectual property and reduce the quantity of tribal memory…*" (Booch, 2007)

3.3 Enterprise and software architecture management as a part of an organisation's planning activities

Companies have many different planning activities such as strategic planning, portfolio planning and information systems planning. Architecture management is not a separate and independent entity in companies so it is linked to, and co-operates with, a company's other processes and activities such as planning activities. Architecture management relationships and co-operation with other organisation's processes and activities are described, for example, by Submarian et al. (Subramanian *et al.*, 2006). Figure 2 has been produced based on ideas presented by Submarian et al.

Enterprise Architecture management usually captures the information technology architecture of the organization, including hardware, software, and networking standardizations, that serves as the basis for all information systems developed within an organization (Subramanian et al., 2006). Enterprise architecture defines principles and guidelines for any information system developed in an organization. These principles and guidelines are a part of the requirements for any developed information system. Applying enterprise guidelines and principles is the realization of enterprise architecture principles.

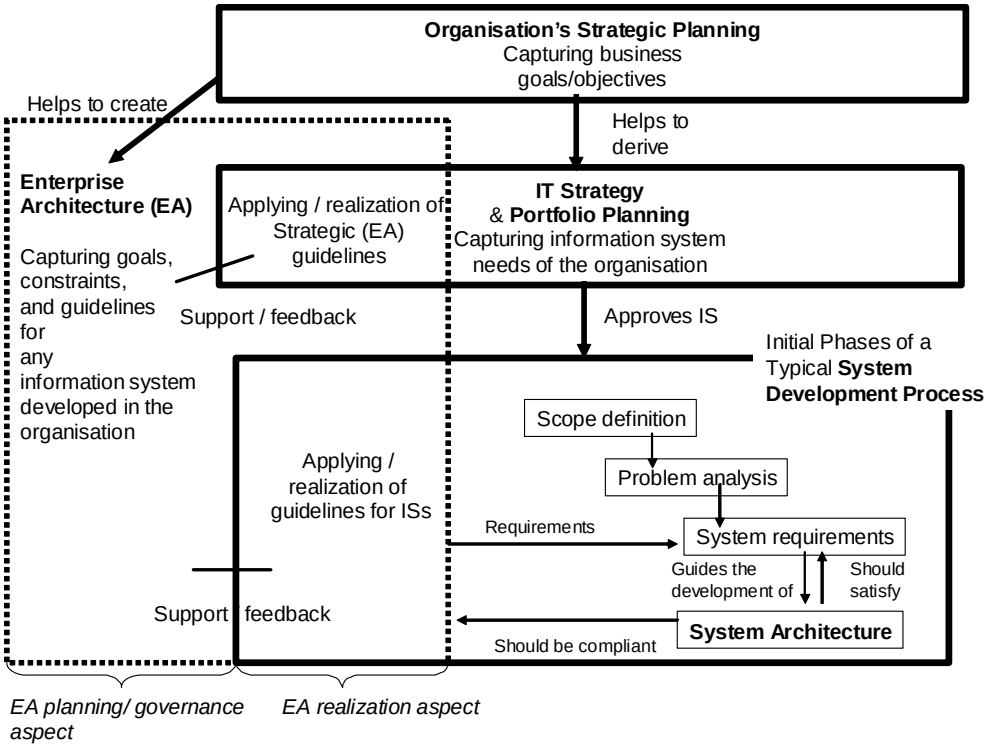

FIGURE 2 Relationships between a company's ICT-planning activities and architectures of a company. [2]

Any information system developed within the organization is derived from the strategic information systems plan of the organization (Subramanian et al., 2006). The typical initial stages of developing an information system, after approval by the executive sponsors, includes the scope definition, problem analysis and the requirements analysis phases (Subramanian et al., 2006). It is during the requirements analysis phase that the requirements of the new system are elicited from the stakeholders and analyzed – the analysis includes, among other aspects, the development of candidate system architectures that considers different ways of allocating the requirements between hardware, software and the network (Subramanian et al., 2006). System architecture should be compliant with enterprise architecture principles and guidelines. Compliance can and should be evaluated before the implementation of the system according to the defined architecture.

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2 Developed by Hämäläinen Niina, Andersin Ari and Lahtinen Jarkko based on Sub manian et al., Figure 1 (Subramanian et al., 2006).

3.4 Resources for architecture management

This section describes existing methods, practices and other resources that are developed to support the development of architecture management in companies. There are not yet many standards in the architecture management domain. A group of architecture concepts has been standardized by the ISO/IEC 42010 standard (ISO, 2007), which was earlier accepted as the IEEE 1471-2000 standard (IEEE std 1471-2000). In the following, existing resources (e.g. methods, practices, studies, tools) for enterprise architecture are presented firstly and resources for software architecture secondly.

3.4.1 Resources for enterprise architecture

Currently, the field of enterprise architecture is evolving rapidly. Academia and ICT-industry actively develop methods and practices for the designing and management of enterprise architecture. Frameworks and maturity models for EA in particular have been introduced. Resources for enterprise architecture management are presented in Table 2.

TABLE 2 Resources for enterprise architecture management.

Resource	Description	Examples
Literature	Several books have been published in the enterprise architecture field.	(IT Governance Institute, 2005; Lankhorst, 2005; McGovern *et al.*, 2003; Ross et al., 2006; Schekkerman, 2004; Whittle & Myrick, 2005).
Frameworks	Architecture frameworks identify and sometimes relate different architectural domains and the modelling techniques associated with them (Steen *et al.*, 2004). They typically define a number of conceptual domains or aspects to be described (Steen et al., 2004). Companies use these frameworks or develop their own ones.	• Zachman's Framework for Enterprise Architecture (Zachman, 1987), • The Open Group Architecture Framework (TOGAF) (The Open Group, 2002), • Archimate framework, • ISO Reference Model of Open Distributed Processing (RM-ODP) (ISO, 1994), • Federal Enterprise Architecture Framework (FEAF) (CIO Council, 1999), • The Department of Defense Architecture Framework (DoDAF) (Department of Defence, 2007), and • Generalised Enterprise Reference Architecture and Methodology (GERAM) (IFIP-IAC, 1999)
Evaluation and measurement practices	Maturity models and practices for the evaluation of enterprise architecture are developed and can be used to support the development of EA management work in organizations.	Examples are presented in more detail in the next section.

(continues)

TABLE 2 (Continues)

Modelling languages and tools	A number of languages and tools for modelling organisations, business processes, applications, and technology are developed. These can also be utilized in the enterprise architecture planning.	IDEF, Business Process Modelling Notation (BPMN), Testbed, ARIS and Unified Modeling Language (UML).
Studies of current use	Companies and organisations' usage and development of EA processes examined to a certain extent. A few case studies on companies' EA processes have also been carried out. Challenges relating to enterprise architecting (e.g. relating to modeling, managing, and maintaining EA) are also examined.	• EA development situation in governmental organisations and departments is investigated o by NASCIO and GAO in the United States (GAO, 2002; NASCIO, 2005) and o Gotze and Christianssen in several countries (Christiansen & Gotze, 2007). • IFEAD (Institute For Enteprise Architecture Developments) have gathered information about EA usage and implementations in organisations all over the world (IFEAD, 2005). • EA Case studies: o governmental organisations (Hjort-Madsen, 2006) (Martin *et al.*, 2004), o UML-modeling (Armour *et al.*, 2003), o Service-oriented architecture (SOA) practices development (Wong-Bushby *et al.*, 2006) and o relating to specific companies like Subaru by Merriman et al., (Merriman *et al.*, 2006) and Finnish teleoperator Elisa (Andersin & Hämäläinen, 2007). • Challenges relating to enterprise architecting: Kaisler et al. (Kaisler et al., 2005) and Hämäläinen and Ylimäki (Hämäläinen & Ylimäki, 2004).
Journals, conferences and societies	The enterprise architecture domain includes journals, conferences for practitioners and researchers, and professional societies and communities.	• Journals: Journal of Enterprise Architecture • Conferences: Enterprise Architecture Conference Europe (by IRM UK Strategic IT Training Ltd) and The Open Group Enterprise Architecture Practitioners Conference • Professional societies and communities: Association of Enterprise Architects, Global Enterprise Architecture Organisation, Association of Open Group Enterprise Architects
Education and certification.	The number and variety of certification schemes is increasing all the time.	• GEAO certification by the Global Enterprise Architecture Organisation (GEAO), • The Open Group – IT architect certification program by The Open Group and • Certification program for enterprise architects by the FEAC Institute.

3.4.2 Resources for software architecture

Resources available for software architecture management are, for example (Kruchten *et al.*, 2006; Shaw & Clements, 2006) :

- Off-the-shelf industrial training and certification programs: what software architecture is and why it is a critical discipline (e.g. training

and courses organized by SEI, in Finland architecture courses and seminars are organized by, for example, Tieturi and IIR Finland).

- Software architects have access to career tracks and professional societies. Associations and working groups are, for example, World-Wide Institute of Software Architects, IFIP WG 2.10 Software Architecture, The International Association of Software Architects and IEEE Standards Association WG 1471.
- An active pipeline of journals and conferences devoted to software architecture serves as a conduit between the research and practice communities (e.g. Working IEEE/IFIP Conferences on Software Architecture, European Workshop on Software Architecture, The Conference on the Quality of Software Architecture, software architecture is also present, often in the form of a specific session or a distinct track, in other conferences)
- Standard architectures for different domains and applications and catalogs of architectural patterns and tactics.
- Tool environments for developing designs.
- Architecture evaluation and validation methods. These are discussed in the following section.
- Practical approaches to architecture documentation build on standards for artifacts and standards for languages in which to render the artifacts (e.g. (P. Clements *et al.*, 2002)).

In summary, there exist many resources for both enterprise and software architecture management, especially for the planning of them. The evaluation and measurement aspect in architecture management is not as well covered. This aspect is discussed in the following section.

4 EVALUATION AND MEASUREMENT IN ENTERPRISE AND SOFTWARE ARCHITECTURE MANAGEMENT

The investigation into evaluation in the context of enterprise and software architecture management requires reviewing different domains. In addition to enterprise and software architecture domain, the following domains were observed during this study to be useful at least: program evaluation, quality management, performance evaluation/assessment and software engineering. This chapter discusses firstly motivation and reasons for evaluation and measurement. Secondly, evaluation and measurement concepts and approaches that are chosen to be used in this dissertation are discussed. Thirdly, related research and views in evaluation in enterprise and software architecture management will be commented on.

4.1 Motivation and reasons for evaluation and measurement

Evaluation and measurement pervades almost every facet of our lives and daily activities. You and I measure and evaluate a great variety of things (e.g. weight, temperature, compare products, distance to the holiday town). At one time or another, we and our work are measured and evaluated by various people (e.g. supervisors, teachers, managers, doctors) on a wide range of things (e.g., blood pressure, achievement, productivity, attitudes). In short, much of what we do, decisions we make, and decisions made about us involve measurement or evaluation of one kind or another.

A discipline of evaluation is needed because companies as well as societies in general require systematic, unbiased means of knowing if their products, processes, programs, and personnel are good (Shadish *et al.*, 1991). Evaluation and measurement are thus not ends but means to generate information that assist in making judgments and decisions (for example about a program, service,

policy, organisation, person, or whatever else is being evaluated or measured (Stufflebeam, 2001)). Nowadays, practitioners use the concept of "fact-based management". This requires descriptive and numerical information to support critical organisational and project business and technical decisions. Information is needed in the development and in the work of companies' architecture capabilities as well.

Evaluation and measurement concepts and practices are developed in different domains (e.g. program management, software engineering, quality management). Evaluation and measurement mean different things to different people in different contexts. It seems that there is no general evaluation theory. However, different domain areas define their own measurement and evaluation concepts and practices. For example, in the software engineering domain evaluation and measurement concepts, practices and standards for the software quality are developed (e.g. ISO 9126 quality model and metrics and software quality evaluation related studies e.g. (B. W. Boehm *et al.*, 1976; Claes Wohlin, 1994)).

In the literature, some authors present the concept of measurement as a part of the concept of evaluation and others present evaluation as a part of measurement. In this dissertation, evaluation is chosen for the main concept because, as the author of this dissertation sees it, it is more descriptive of the current practice in architecture management area than the measurement concept. So measurement is seen as one way to implement evaluation in this dissertation. Evaluation generates qualitative (descriptive) information and/or quantitative (numerical) information. Qualitative (descriptive) and quantitative (numerical) information supplement each other (Smith, 1991). Generating quantitative information is commonly referred to as the measurement.

Evaluation and measurement are carried out for many different purposes in companies. The purposes of evaluation especially consists of the followings (Behn, 2003):

- Evaluate (how well is the organization/unit/team/people performing?)
- Control (how to ensure that the subordinates are doing the right thing?)
- Budget (on what programs, people or projects should resources be allocated?)
- Motivate (how to motivate e.g. line staff, middle managers, stakeholders?)
- Promote (marketing/public relations aspect; how to convince stakeholders that the organization/unit/team is doing a good job?)
- Celebrate (what accomplishments are worthy of the important organizational ritual of celebrating success?)
- Learn (what is working or not working and why?)
- Improve (what exactly should be done differently to improve performance and who should do it?)

The reasons for generating quantitative information (i.e. measurement) of processes, products and resources are to characterize, assess, predict and improve (Park *et al.*, 1996). The aim of characterization is to gain understanding of processes, products, resources, and environments, and to establish baselines for comparisons with future assessments (Park *et al.*, 1996). The aim of assessing is to determine status with respect to plans. Measures are the sensors that let know when projects and processes are drifting off track, so that those can be brought back under control. The achievement of quality goals and the impacts of technology and process improvements on products and processes can also be assessed.

We predict so that we can plan (Park *et al.*, 1996). Measuring for prediction involves gaining understanding of relationships among processes and products and building models of these relationships, so that the values we observe for some attributes can be used to predict others. We do this because we want to establish achievable goals for cost, schedule, and quality – so that appropriate resources can be applied. Predictive measures are also the basis for extrapolating trends, so estimates for cost, time, and quality can be updated based on current evidence. Projections and estimates on historical data also help us analyze risks and make design/cost tradeoffs.

We measure to improve when we gather quantitative information to help us identify roadblocks, root causes, inefficiencies, and other opportunities for improving process quality and process performance (Park *et al.*, 1996). Measures also help plan and track improvement efforts. Measures of current performance give baselines to compare against, so that we can judge whether or not our improvement actions are working as intended and what the side effects may be. Good measures also help us communicate goals and convey reasons for improving. This helps engage and focus the support of those who work within our processes to make them successful.

Different general purposes of evaluation were described. So, several different purposes exist. This is currently a problem in the architecture management area. It is unclear, in which purposes evaluations could and should be carried relating to companies' architecture capabilities.

4.2 Fundamentals in evaluation and measurement

Over the past forty years, evaluation has developed out of a variety of activities to become a specialized field that relies on many different approaches for generating information (Stufflebeam, 2001). In this section, evaluation concepts chosen to be used in this dissertation are introduced.

4.2.1 Definitions for evaluation and measurement

Evaluation is defined as *the process of determining the merit, worth, and value of things, and evaluations are the products of that process* (Scriven, 1991) and *a study*

designed and conducted to assist some audience to assess an object's merit and worth (Stufflebeam, 2001).

Measurement is defined as *the assignment of numbers to aspects of objects or events to one or another rule or convention* (Stevens, 1968) and as *the process by which numbers or symbols are assigned to attributes of entities in the real world in such a way as to describe them according to clearly defined rules* (Fenton, 1994). So in the measurement numbers are assigned to aspects of objects, not to the objects themselves (Pedhazur & Schemelkin, 1991). Thus, for example, one can measure the duration, budget and person-workdays used, and so on for a project, but not a project *itself.* When a given aspect of objects is measured, their differences in all other aspects (e.g. duration, budget) are ignored because they are presumably irrelevant to the task at hand.

4.2.2 Prerequisites for evaluation planning

As Scriven (Scriven, 1991) describes: "*….evaluation has two arms, only one of which is engaged in data-gathering. The other arm collects, clarifies, and verifies relevant values and standards.*" In the following, the aspects of a company and its values (such as goals relating to architecture capabilities) that is relevant to know before the planning evaluation and measurement are described. Every evaluation and measurement must be tailored to a specific set of circumstances. The basis for the planning of evaluation is the understanding of the rationale for the work, the information needs relating to it, the characteristics of company as well as the theories and concepts relating to the phenomenon.

Rationale of work/activity/capability/program. The rationale and plans of work (e.g. company's rationale for architecture capability) provide the infrastructure for work (Chen, 2004). The rationale is a foundation for planning, for communication and for a basis of outcome evaluation (Chen, 2004). Containing as it does statements of the determinants, interventions, and outcomes agreed upon by stakeholders, the rational is a base from which to conduct evaluations and measurements of various kinds (Chen, 2004). In architecture work, a company's rationale and goals for architecture capabilities are essential to understand and describe. In addition, company's goals (business and IT goals) are also essential to understand.

Information needs. Only those metrics and evaluation data should be collected which will actually be used. Therefore, information needs are essential to understand and define before and during the planning evaluations and metrics. What are the problems and decisions that require evaluation and measurement information (Mock & Grove, 1979)? Who are the potential users of the data (Mock & Grove, 1979)? This gives ideas of the evaluation and measurement data needed and the justification for further measurement and evaluation planning. Therefore, in the case of architecture capabilities, the information needs of the architecture team and the stakeholders of architecture capabilities need to be investigated.

Characteristics of company and its projects. In addition, a company's evaluation and measurement possibilities and constraints need to be understood.

Available resources (time, staff, skills) in particular need to be understood so that evaluations and metrics that cannot be used in a company will not be planned or chosen. In addition, many companies already gather measurement information. Therefore, it needs to be discovered if the existing information could be utilized.

Understanding of the phenomenon and concepts relating to the phenomenon. What is relevant to measure can be determined within an implicit or explicit theory about the phenomenon one wishes to study (e.g. performance of company's architecture capability) (Pedhazur & Schemelkin, 1991). The building blocks of theory are concepts and definitions. A theoretical definition of a concept is defined in terms of other concepts that are already well understood (Kan, 2002) and accepted in a company. Operational definitions are definitions that spell out the metrics and the procedures to be used to obtain data (e.g. concrete target and criteria in real world). Therefore, theory and concept definitions relating to it not only determine what attributes or aspects are to be measured but also how they are to be measured. In other words, theory conceptualizes the aspects from which measurement operations follow (Pedhazur & Schemelkin, 1991).

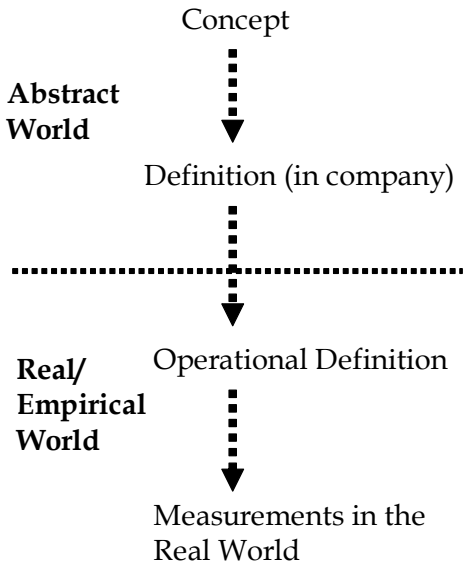

FIGURE 3 Abstraction hierarchy (Kan, 2002).

In an architecture management context, unestablished architecture theories and concepts are one of the real challenges in evaluation and measurement because the conceptions of a concepts' definitions in a company are needed in the metrics and evaluation criteria definition. In addition, the goals of architecture work are quite often intangible (e.g. to increase agile of company, to improve business-it alignment). The evaluation and measurement of these goals requires the operational definitions of the meanings of these concepts in a company (thus operational definitions of agility and business-it alignment). So the ques-

tion of whether the architecture concepts are clearly defined in the company is met at the beginning of planning evaluations and metrics.

4.2.3 Evaluation planning and implementation

The most common type of evaluation involves determining criteria of merit (usually from a needs assessment), standards of merit (frequently as a result of looking for appropriate comparisons), and then determining the performance of the target so as to compare it against these standards (Scriven, 1980). Evaluation planning and implementation consist of three key activities – criteria determination, setting standards, and measuring performance (Shadish et al., 1991). Criteria determination identifies the dimensions the target must meet. Standards of merit tell how well the target must do on each dimension to be good – one can use absolute standards such as the certain minimum safety level that all automobiles must attain, or comparative standards comparing the target to available alternatives (Shadish et al., 1991).

Assessing performance requires measuring the target and comparing the results to the standards of merit. Prior to these activities, the evaluator selects an object to be evaluated. After the performance tests the evaluator summarizes results in an evaluative judgment. So fundamental evaluation concepts (e.g. (Lopez, 2000)) consist of:

- *target*: the object under evaluation,
- *criteria*: the characteristics of the target that are to be evaluated,
- *yardstick or standard*: the ideal target against with the real target is to be compared in evaluations,
- *data-gathering techniques*: the techniques needed to obtain data to analyze each criterion,
- *synthesis techniques*: techniques used to judge each criterion and, in general, to judge the target, obtaining the results of the evaluation,
- *evaluation process*: series of activities and tasks by means of which an evaluation is performed.

So evaluation design specifies (1) the set of evaluation questions, (2) the data that will be collected and analyses undertaken to answer the evaluation questions, (3) the estimated costs and time schedule for the evaluation study, and (4) how the evaluation information will be used (Wholey *et al.*, 2004). The activities of the measurement/evaluation process are seen in the next figure.

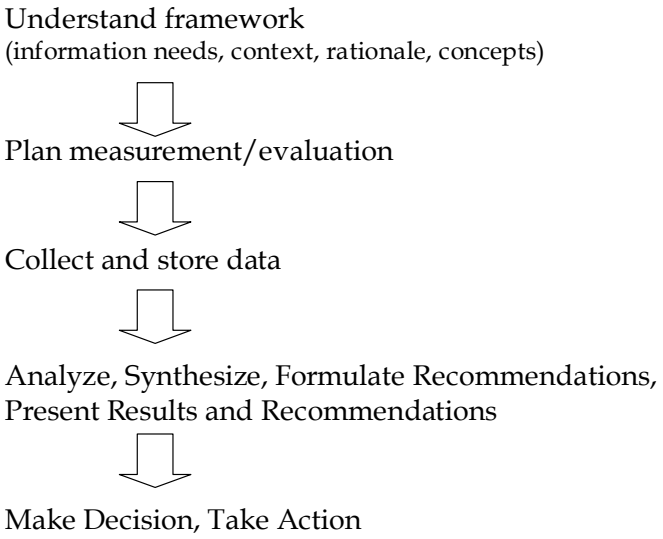

FIGURE 4 Evaluation/measurement process acts (Juran & Godfrey, 2000).

A company's business and IT goals are suggested as the starting points for planning evaluations (Cullen, 2005; Weiss, 2006). Business goals are the foundation on which software system is justified, analyzed, and built (Kazman & Bass, 2005). Software systems are constructed to realize business or mission goals (Kazman & Bass, 2005). Goal-driven software measurement should be used for the deployment of architectural measures in a specific system, either directly or to verify that a measure adapted from the literature is meaningful and useful in the specific organisational context (Chastek & Ferguson, 2006). A company's business and IT goals are also a foundation for both enterprise and software architecture evaluation. A goal-oriented approach is recommended for use in defining evaluation criteria and metrics, both for the enterprise architecture and for the software architecture (Chastek & Ferguson, 2006; Forrester Research, 2005).

4.3 The status of evaluation in architecture management

This section considers evaluation in an organisation's architecture management. A brief overview of the related work is provided. Existing practices and methods for evaluation are presented.

4.3.1 Evaluation in enterprise architecture management

Views about enterprise architecture evaluation meanings do not seem to have stabilized yet. Roughly categorizing, however, evaluation approaches and techniques in the enterprise architecture management area are seemingly developed related to two aspects:

- approaches and techniques that generate information relating to a company's enterprise architecture program and its results (e.g. EA program's efficiency, effectiveness, maturity, quality of results) to support planning, improvement, marketing (showing value), organization and management of enterprise architecture work in a company. A company's business and IT goals are quite commonly used as the starting points in these evaluations.
- approaches and techniques that generate information to support decision making on enterprise-wide information system issues through the analysis of the enterprise architecture models. In the following text, this is referred to as property oriented enterprise architecture evaluation.

Evaluation of enterprise architecture program. In the development, improvement, management and value marketing of an enterprise architecture program, evaluation is an essential means. "*Regular evaluation of the effectiveness of the enterprise architecture program is crucial to understanding the net effect of the varied and complex architecture processes on the environment and to provide recommendations for continuous improvement* (Leganza, 2003b)". Metrics are seen as an important part of the EA plan (Cullen, 2006b). "*Metrics are crucial to both managing the development of Enterprise Architecture and to justifying its existence* (Aziz et al., 2006)." The interests in evaluations and measurement are especially the maturity of enterprise architecture program, the benefits, the impacts and the use of it (the value of architecture program, the resulting business value), the progress of architecture work and the quality of deliverables (Cullen, 2006b; Hämäläinen & Kärkkäinen, 2008).

A variety of methods are being developed for evaluation of enterprise architecture programs. Some these methods are, for example, the following enterprise architecture maturity models:

- *OMB Enterprise Architecture Assessment Framework* (U.S. Office of Management and Budget, 2007) (Federal Enterprise Architecture Program Management Office, US FEAPMO),
- *The Enterprise Architecture Maturity Model*, EAMM (NASCIO, 2003) (National Association of State Chief Information Officers , NASCIO)
- The Extended Enterprise Architecture Maturity Model, E2AMM (IFEAD, 2004) (Institute for Enterprise Architecture Developments, IFEAD).
- A Framework for Assessing and Improving Enterprise Architecture Management, EAMFF (GAO, 2003) (US General Accounting Office, GAO)
- IT Architecture Capability Maturity Model, ACMM (DoC, 2003) (US Department of Commerce, Doc).

In addition, many companies have produced material relating to evaluations and metrics planning for enterprise architecture programs. These are developed, for example, by Forrester Research (Cullen, 2005, 2006b; Hoppermann,

2007; Leganza, 2003b; Wollmer, 2007), Gartner (Weiss, 2006), Cutter Consortium (Cutter Consortium, 2007) and Infosys (Aziz et al., 2006).

Property oriented evaluation of enterprise architecture. The discipline of enterprise architecture advocates the use of models to support decision-making on enterprise-wide information system issues. The purpose of having enterprise architecture models and conducting analysis of these is to facilitate the making of rational decisions about information systems in an organization (Johnson *et al.*, 2007). In property oriented evaluation, enterprise architecture evaluation is seen as the application of property assessment criteria to enterprise architecture models (Johnson *et al.*, 2007) and the process of analyzing data about enterprise architecture and drawing conclusions about how well it supports the enterprise (Carbone, 2005). For instance, one investigated property might be the security of enterprise information (Johnson *et al.*, 2007).

In order to provide support for analysis, enterprise architecture models should be amenable to analyses of various properties e.g. the level of enterprise information security (Johnson *et al.*, 2007). In addition, evaluation helps to clarify how the current architecture contributes to perceived business problems or positively supports goals (Carbone, 2005).

Most related work on property oriented evaluation techniques of enterprise architecture either focus on the technical details of one analysis approach or addresses the analysis of one specific layer of the enterprise architecture, leaving out the interrelationships between the various enterprise architectural layers (Winter et al., 2007). For example, techniques may focus on critical path analysis of one specific layer of enterprise architecture or on the analysis of software architectures (Winter et al., 2007). A categorization of property oriented enterprise architecture evaluation techniques is presented by Winter et al. (Winter et al., 2007):

- *Dependency analysis* exploits the associations between the various EA artifacts to derive direct and indirect dependencies between these artifacts. Typical analysis questions of this technique are "Which business processes are affected if we switch-off a certain server? Which applications are required to facilitate the value chain of a product offered at the marketplace?"
- *Coverage analysis* usually spawns two or more EA layers. The results of this analysis technique are often represented as matrices relating the two dimensions of interest. The cells of such a matrix may either just be checked (e.g. to indicate which applications are deployed on which platform environment), or may represent more complex information (e.g. to illustrate which applications are in use to support the business processes for the individual products.)
- *Interface analysis* focuses on the interfaces within a class of EA artifacts. A typical example is the analysis of technical interfaces between software components specified within software architecture. The general design goal that lies behind interface analysis aims at minimizing the coupling between, and maximizing the cohesion within, the artifacts under consideration.

- *Heterogeneity analysis* tries to identify those architecture elements which should be reconsidered and re-factored to improve overall architecture homogeneity. Homogenous structures are in turn desirable to reduce costs for maintenance activities, software and hardware licenses, and to ensure that similar concerns are treated equally.
- *Complexity analysis* is strongly related to interface analysis. The design goal is to reduce the overall EA complexity.
- *Compliance analysis* determines whether certain policies (like process and data ownership) are defined at a certain organizational level of abstraction or if certain mechanisms (like authorization and recovery) have been implemented at a certain software system level of abstraction.
- *Cost analysis* calculates and reports the costs induced by creation and maintenance of various EA artifacts (e.g. the cost for launching a new product or for implementing a new sale channel). An important application of cost analysis techniques is the calculation of IT-related costs and the allocation of these costs to products, services, processes, organisational units and other artifacts on the strategy layer and on the organisational layer.
- *Benefit analysis* is complementary to cost analysis. It exhibits the contributions of individual organizational units, products, application systems and similar artifacts to the overall goals of the organization.

In summary, evaluations in enterprise architecture management relate, on one hand, to the enterprise architecture program (e.g. management, improvement, impacts and benefits evaluations) and, on the other hand, to the producing information for the decision-making and planning.

4.3.2 Evaluation in software architecture management

A formal software architecture evaluation is seen as an essential standard part of the architecture-based software development life cycle (SEI, 2007). Companies are now adopting architecture evaluations as part of their standard software engineering development practice, and some are including these evaluations as part of their contracting language when dealing with subcontractors (Kazman & Bass, 2002).

Views about why architecture evaluations are valuable are presented, for example, by Maranzano et al. (Maranzano et al., 2005). Software architecture evaluations are seen as valuable because they find design problems early in development when they are expensive to fix; leverage experienced people by using their expertise and experience to help other projects in the company; let the companies better manage software components suppliers; and provide management with better visibility into technical and project management issues. In addition, evaluations generate problem descriptions by having the evaluation team critique them for consistency and completeness; evaluations rapidly identify knowledge gaps and establish training in areas where errors frequently occur; and evaluations promote cross-product knowledge and learning and keep

experts engaged. Moreover, they spread knowledge of proven practices in the company.

The software architecture evaluation is designed to answer the question: "Will the information system to be built from this architecture satisfy its business goals?"(Kazman & Bass, 2002). A definition of the evaluation in the architecture management context is provided by (ISO, 2007) , (IEEE 1471-2000): "The purpose of evaluation is to determine the quality of an architectural description and to predict the quality of systems whose architectures conform to the architectural description." In addition, software architecture evaluation is defined, among other aspects, as the testing of a software architecture for its fitness for purpose and for the presence of possible defects (Rozanski & Woods, 2005). Also, it is defined as the analysis of the architecture in order to identify potential risks and verify that the quality requirements have been addressed in the design (Dobrica & Niemelä, 2002). It is further suggested that metrics be used in the design of software architectures. To the architect, an architectural measure is a diagnostic device used to determine the source of a problem in the software architecture (what has to be changed in that architecture to address the identified problem?), to provide quantitative rather than qualitative design decision support and to monitor the design process (Chastek & Ferguson, 2006). To the project manager, an architectural measure is a diagnostic or monitoring "device" to determine sources of problems in a software development that require a change in the software architecture (Chastek & Ferguson, 2006).

The scope of architecture evaluations is growing to include far more than just the technical issues (Kazman & Bass, 2002). When dealing with architecture, business issues are the driving factors in design. By considering the relations between business goals and architecture, and considering them early in the software development (or redevelopment) process, they might be dealt with in a way that provides the greatest benefit for the system's many stakeholders. Asking whether an architecture satisfies business goals cannot simply assume clarity of the business goals. If the business goals are not clear, then one portion of the architecture evaluation process is to operationalize the business goals.

The outputs from an architecture evaluation vary. Outputs describing risks are especially (Kazman & Bass, 2002):

- *technical risks* (e.g. "Given the current characterization of peak load and the existence of only two Web servers, we might not meet the architecture's latency goals."),
- *information risks* involving areas of the architecture lacking information (e.g. "We haven't thought about that."),
- *economic risks (cost, benefit, and schedule)*, which are not directly technical in nature but are about money and deliverables. (e.g. "Can we deliver this functionality to our customer by August? Will we lose market share if our performance isn't quite as good as our competitor's?"
- *managerial risks,* which involve having an architecture improperly aligned with the organisation's goals. Examples of other kinds of

> managerial risks include the architecture's structure and the development organisation's structure, or dependence on suppliers whose reliability is unknown or suspect.

Materials to teach and support the practice of architecture evaluations have been increasing (Kazman & Bass, 2002). Evaluation in software architecture management is studied, while books and studies are being published (e.g. (Bass & John, 2001; P. Clements *et al.*, 2001; Kazman & Bass, 2002; Lee & Choi, 2005)) Metrics and measurement of software architecture is also studied and public reports are published (e.g. (Chastek & Ferguson, 2006; Dias *et al.*, 1999; Shereshevsky *et al.*, 2001; Tvedt *et al.*, 2002)) The proposed techniques for software architecture evaluation can be divided into two classes: techniques producing qualitative information about software architecture (e.g. by using questioning techniques) and measuring techniques producing quantitative information about software architecture (Tvedt *et al.*, 2002). These methods can be combined to supplement each other (e.g. (Lee & Choi, 2005)).

An array of methods is also being developed for evaluation of software architectures. Software architecture evaluation methods are evaluated and compared in some studies (e.g. (Babar & Gorton, 2004; Dobrica & Niemelä, 2002; Ionita *et al.*, 2002)). Software architecture evaluation methods may include for example the following: the Scenario-based Architecture Analysis Method, SAAM (Kazman *et al.*, 1994), the Architecture Trade-off Analysis Method, ATAM (Kazman *et al.*, 1998), Active Reviews for Intermediate Design, ARID (P. C. Clements, 2000), SAAM for Evolution and Reusability (Lung *et al.*, 1997), Architecture-Level Modifiability Analysis, ALMA (P. Bengtsson *et al.*, 2004), Architecture-Level Prediction of Software Maintenance (PerOlof Bengtsson & Bosch, 1999), Scenario-Based Architecture Reengineering (PerOlof Bengtsson & Bosch, 1998), SAAM for Complex Scenarios (Lassing *et al.*, 1999), and MITRE's Architecture Quality Assessment (Hilliard *et al.*, 1997; Hilliard *et al.*, 1996). In addition, the application of methods, in total or in part, from other software development areas to the software architecture area are also studied (e.g. (Immonen & Niemelä, 2008)), as are analysis techniques relating specific architecture development approaches, such as the software product line/family architectures (e.g. (Dobrica & Niemelä, 2000, 2007; Niemelä *et al.*, 2004)). Metrics that could be utilized in the development of software architecture are also studied and developed (e.g. (Kalyanasundaram *et al.*, 1998; Shereshevsky et al., 2001)). In addition, different checklists have been developed to evaluate architecture and its description during its design. For example, Rozanski and Woods (Rozanski & Woods, 2005) present checklists for architecture viewpoints. These checklists are lists of items to consider when developing the architecture viewpoint and when reviewing it to help ensure correctness, completeness, and accuracy.

In summary, software architecture evaluation focuses mainly on the quality of architecture itself, not on the quality of architecture design or planning processes as in the case of enterprise architecture evaluation.

5 RESEARCH OBJECTIVES, APPROACH AND METHODS

This section describes the research problem and objectives of this dissertation. In addition, research approaches and research methods used are presented.

5.1 Research problem and objectives

Previous sections described companies' architecture capabilities and measurement and evaluation practices relating to them. Challenges and open questions in these areas were also described. This section summarizes the situation and existing challenges.

Architecture capabilities are maturing in companies (Cutter Consortium, 2007; Hoppermann, 2007; IFEAD, 2005; NASCIO, 2005). Companies develop their architecture capabilities based on enterprise and software architecture approaches, among others. The processes and practices for architecture management are actively being developed. Evaluation and measurement are commonly seen as an important issue in this development work. Companies need to decide what measurement and evaluation work is carried out in architecture work, and what the aims of it are. This leads to the first identified challenge in this area: the lack of understanding of evaluation and measurement purposes in the architecture domain. Different studies and experts point out that challenges exist related to the development of evaluation practices and metrics especially for enterprise architecture program and for software architecture e.g. (Chastek & Ferguson, 2006; Choi & Yeom, 2002; Forrester Research, 2005; Hoppermann, 2007). In particular, it is not clear for what purposes evaluations and metrics should be developed and how evaluation practices and metrics can be developed and used. Research on measurement and evaluation in the architecture management domain seems to focus more on the development of methods and practices for it than on defining purposes of evaluation and measurement. A

holistic view of evaluation purposes and rationales seem to be lacking in this domain. The possibilities evaluations offer are not always obvious and nor is it clear on what areas or aspects architecture management related evaluations should be focused. Thus, there exist needs to identify purposes of evaluation in the architecture management context.

In addition to this holistic problem related to lack of understanding of evaluation purposes in architecture domain, there are needs for metrics definition and evaluation practices. In this dissertation, we focus on three different practices-related problem areas, which were identified to impede architecture management in companies.

The first challenge identified and tackled in this study is the challenge of how to define metrics for an enterprise architecture program. Currently, companies have needs to define metrics for their architecture capabilities, especially for enterprise architecture programs. Several metrics definition approaches and practices exist. However, there does not seem to be public guidelines on how to apply these practices and approaches for metrics definition of an enterprise architecture program.

The second problem considered in this study is how to evaluate and assure quality of architecture documentation. Observations have been made that enterprise architecture documentation quite often does not meet its users' needs in companies (Cullen, 2006a). "*EA's documentation is a weakness. Stakeholders saw the EA group's documentation as hard to find and hard to use, and staff below senior management feel that it is not specific enough.* (Cullen, 2006a)". An warning example about bad quality architecture documentation is presented also by Rosen (Rosen, 2006) "… *"shelfware"- the architecture documents look spiffy on the shelf, and having them there demonstrates how smart you are to be able to understand the architecture. Unfortunately, in many cases they are never opened again, and certainly not by the development organisation*". It is not, however, clear what good quality architecture documentation precisely is and how the quality of architecture documentation could be evaluated. Evaluation criteria are thus especially needed for the evaluation of quality of the architecture documentation.

The third open question studied in this dissertation is the question of what is a good architecture definition process. A good architecture definition process is one that leads to a good architecture, documented by an effective architectural description, which can be realized in a time-efficient and cost-effective manner. However, it is not actually clear what a "good architecture definition process" is and how the quality is taken into account especially in the design of software architectures. So there exists a need to identify activities that promote the achievement of a good architecture. The identification of these activities would support the quality evaluation of architecture processes.

The main objective of this dissertation was to describe and define purposes of evaluation and measurement in the context of enterprise and software architecture management and to develop some practices for it. More precisely, the first objective is to increase the understanding of challenges that are met in architecture management in companies and factors affecting the success of architecture. Secondly, purposes of evaluation in architecture management are

considered. Thirdly, an objective is to develop evaluation practices for the architecture management domain. Practices are developed for the quality evaluation of architecture documentation, the metrics planning for enterprise architecture program, and the quality management in software architecture management (the development of architecture process of good quality).

5.2 Research phases and methods

This dissertation discusses both enterprise and software architecture management. Therefore, this dissertation relates to both information system (IS) and software engineering (SE) research areas. The research approaches and methodologies used in this study are influenced by both the IS and SE research approaches and methodologies. The research approach and method choices of this study have especially been affected by the information systems research framework by Hevner (Hevner *et al.*, 2004), action research and empirical software engineering.

Hevner's framework (Hevner et al., 2004) suggests that framing research activities to address the business needs of environments assures research relevance. The identification of business needs for research in this dissertation corresponds to the view that business needs are a starting point for the research presented by Hevner's framework (Hevner et al., 2004). The following research activities were framed to address identified business needs in this dissertation. Because this dissertation was a part of research in three different research projects, the co-operating companies of these research projects formed the main environment for this dissertation. Business needs were thus identified in this environment. General development trends (e.g. scientific results) in the architecture management area were also taken into account. Given a business need, information system research proceeds in two complementary activities (Hevner *et al.*, 2004). Behavioral (or traditional) science attempts to explain and give means for predicting phenomena related to the identified business need, which may lead to development and justification of theories (Hevner *et al.*, 2004). In turn, design science attempts to meet the business needs by building and evaluating artifacts, which are classified into concepts, models, methods, and instantiations (Hevner *et al.*, 2004).

Action research is also used here, as the research was done with the companies. Action research focuses particularly on combining theory and practice (Greenwood & Levin, 2006). It attempts to provide practical value to the client organization while simultaneously contributing to the acquisition of new theoretical knowledge (Sjoberg *et al.*, 2007). Actions taken are intended to change situations in ways that are seen as better, either by the researcher or by groups in the research situation, and to draw some theoretical conclusions from this process (Mumford, 2001). An action research approach requires the researcher to obtain an understanding of the situation being addressed before taking any action directed at solving identified problems (Mumford, 2001). Empirical sci-

ence concerns the acquisition of knowledge by empirical methods (Sjoberg et al., 2007; C. Wohlin *et al.*, 2003). Empirical methods were used in data gathering in this dissertation.

Hevners' framework and other research approaches were used here for structuring the research into phases. This study consists of three phases described in Figure 5.

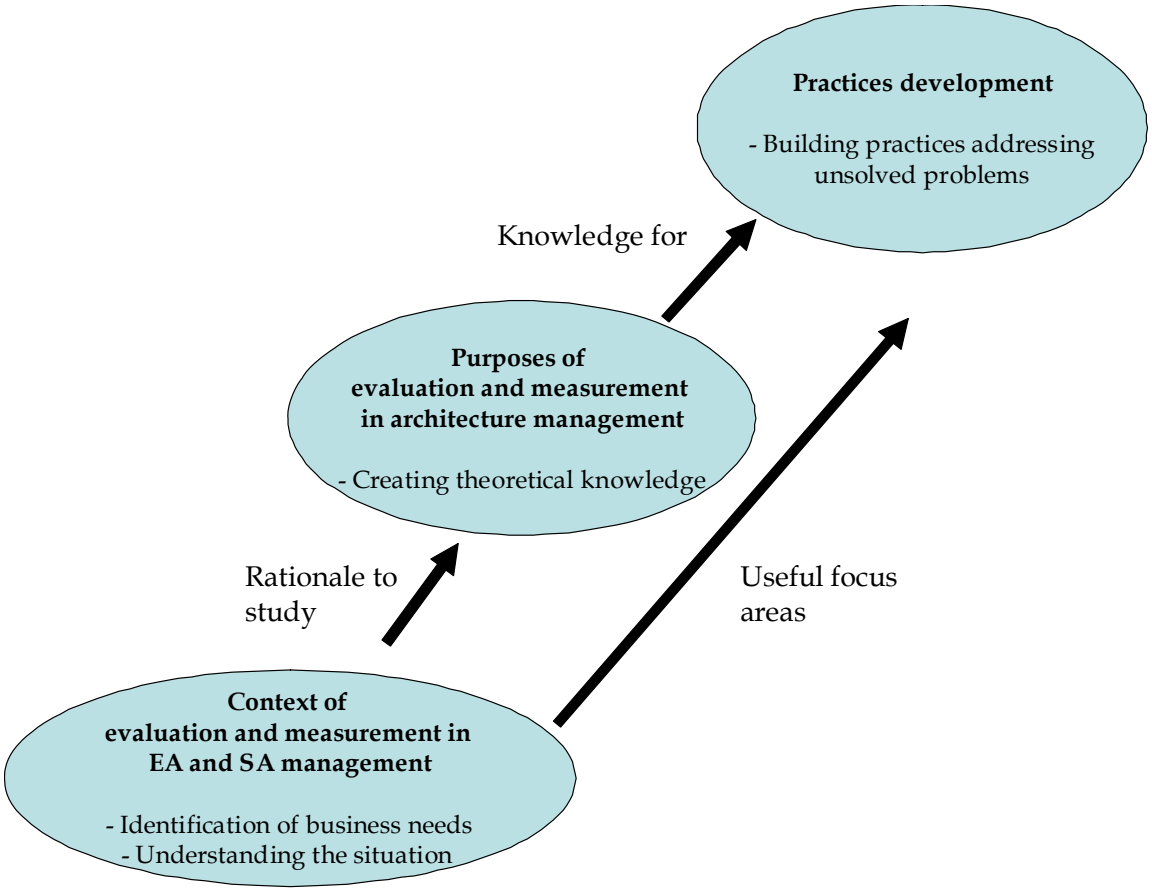

FIGURE 5 Research phases of the dissertation.

The research problems and objectives presented in the previous section were specified in more detail under the phase structure, with associated specific research questions. Objectives and research questions relating to these phases are the following. Because this dissertation considers both enterprise and software architecture approaches the architecture approach (EA/SA) from which point of view each research question is studied is identified.

Phase 1: Context of evaluation and measurement in architecture management
Objective:

- To describe context in which architecture work related evaluations and measurement are carried out.
- To ensure the appropriateness of the research problem and to ensure if it useful to focus on this area.
- To identify what areas are essential to study and develop practices for.

Research questions:

- What challenges exist in architecture management in companies? (EA, SA)
- What factors affect the success of architecture? (SA)

Phase 2: Purposes of evaluation and measurement in architecture management
Objective:

- To describe purposes of evaluations in architecture management
- To define and categorize companies' triggers for evaluations and evaluation areas supported by evaluation methods
- To define evaluation/measurement aspects in which evaluations could be carried out relating company's architecture capabilities

Research questions:

- What evaluation purposes and possibilities do existing architecture evaluation methods support? (EA, SA)
- What are triggers (information needs) for architecture evaluations in companies? (EA, SA)
- In which aspects could evaluation and measurement be carried out relating to a company's architecture capabilities (EA)?

Phase 3: Practices development
Objective: To develop evaluation and measurement practices to the architecture management domain.

Research questions

- How can quality management be carried out as a part of architecture management? What activities should be carried out to achieve architecture of good quality? (SA)
- How to carry out the quality evaluation of architecture documentation? (EA, SA)
- How to define metrics for an architecture program? (EA)

Phase 1. Context of evaluation and measurement in EA and SA management.

The aims of this phase were 1) to obtain an understanding of the situation being addressed (enterprise and software architecture management in companies) before taking any action directed at solving identified problems and 2) identification of business needs in this area for research.

Case study and grounded theory methods were utilized to obtain an understanding of the situation and to identify business needs. The case study –method was used in the description and identification of challenges that are met in architecture management in companies. A case study examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities (people, groups, or organization) (Benbasat *et al.*, 1987). A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 1994). A case study was seen to be suitable research method for the describing challenges in architecture management because the boundaries of the architecture management in companies are not clearly evident at the outset of the research (i.e. other companies' processes and activities) (Benbasat *et al.*, 1987). In this study, the three different companies were studied in the case study. Multiple-case designs are desirable when the intent of the research is description and/or theory building such as in this study (Benbasat et al., 1987). Multiple cases are expected to yield more general research results (Benbasat et al., 1987). Multiple data collection methods are typically employed in case research studies (Benbasat et al., 1987). In this study, group interviews and company documents were used as data sources (e.g. relating companies' architecture management processes and practices). Evidence from different sources was used to support the research findings (Benbasat et al., 1987).

Grounded theory –method was used in the description and identification of success and failure factors for software architecture. The use of this method is described in the description of the next phase, in which grounded theory-method was also utilized.

Phase 2. Purposes of evaluation and measurement in architecture management.

This phase related to behavioral science (according to Hevner et al. framework), which attempts to explain and give means for predicting phenomena. In the previous phase, a need for theoretical knowledge of architecture evaluation purposes was identified. A new theory may be needed, if there is no previous knowledge about a matter or phenomenon (Järvinen, 2001). Theory-creating research methods can be used when a new theory grounded on the gathered data is being developed (Järvinen, 2001). Several different conceptions about evaluation purposes existed in the architecture management area. However, a theory or model of the evaluation purposes did not exist. Therefore, the theory-creating methods were used in this study to create theoretical knowledge of

evaluation purposes grounded on the empirical (e.g. focus group interviews of practitioners) and non-empirical data (e.g. previous studies, method descriptions). In this study, grounded theory method, which is a method for creation of theory (Järvinen, 2001), was utilized for the creation of theoretical knowledge.

In order to produce knowledge about purposes of evaluation in architecture management and to describe success and failure factors of software architecture (phase 1), grounded theory was applied. The grounded theory method is a qualitative approach to inductively distil theory from a dataset (Corbin & Strauss, 1998) (Charmaz, 2000). It seeks thus to develop theory that is grounded in data systematically gathered and analyzed and provides a method for distilling a theory from collected data. In this study, there was an interest in studying both the perspectives of practitioners and the scientific community. Therefore, focus group interviews of practitioners (Kontio *et al.*, 2004; Krueger & Casey, 2000) and document analysis focusing especially on previous studies and methods descriptions were chosen for data gathering techniques. Different data collection techniques were used because triangulation across various techniques of data collection is particularly beneficial in theory generation as it provides multiple perspectives on an issue, supplies more information on emerging concepts, allow for cross-checking, and yields stronger substantiation of constructs (Glaser & Strauss, 1967; Pettigrew, 1990).

Data collection carried out through focus group interviews focused on the practitioners' conceptions on success and failure factors for software architecture and companies' triggers for architecture evaluations. Focus groups are carefully planned discussions, designed to obtain the perceptions of the group members on a defined area of interest (Kontio et al., 2004; Krueger & Casey, 2000). There are typically 3 to 12 participants and the discussion is guided and facilitated by a moderator, who follows a predefined structure so that the discussion stays focused (Kontio et al., 2004; Krueger & Casey, 2000). In the focus group interviews of this study, there were 5-7 participants in each focus group interview. A predefined structure and content about the discussion subject was used to structure and to focus discussions.

Gathered data was analysed iteratively (Glaser & Strauss, 1967) with the early stages of the analysis being more open-ended, and later stages being directed by the emerging concepts and categories. Accordingly to the basic idea of grounded theory, the collected data was read and reread, and evaluation purposes and success and failure factors for software architecture were identified iteratively.

Phase 3. Practices development

This phase related to the design science (according to Hevner et al. framework) which attempts to meet the identified business needs by building artifacts (e.g. concepts, models, methods and instantiations). As such design science addresses unsolved problems (Hevner *et al.*, 2004), some identified unsolved problems related to evaluations in the architecture management area were addressed in this phase of study. This phase attempted to provide practical value

to the companies and practitioners accordingly to the basic idea of action research (Sjoberg *et al.*, 2007). As described earlier, unsolved problems were identified to relate to the quality evaluation of architecture documentation, metrics planning for enterprise architecture programs and quality management in architecture management. This study focused on developing practices for these questions. A constructive approach and methods were used to develop practices for these areas.

Artifacts can be built or evaluated (Järvinen, 2001). In this study, evaluation practices for architecture management were built. In addition, these developed practices are partially evaluated. During building evaluation practices for architecture management, existing knowledge from the architecture management domain, other domains and results produced in the earlier phases of this dissertation were utilized. Developed evaluation criteria for architecture documentation and quality management activities for software architecture were evaluated by practitioners in the focus group interviews. In addition, a questionnaire for assessing the usefulness of the evaluation criteria for architecture documentation was organized for the focus group participants. In the questionnaire, the practitioners assessed the importance of each criterion on a four point scale (1 = important to evaluate, 2 = useful to evaluate, 3 = not necessary to evaluate, 4 = useless to evaluate). Improvement of the practices was carried out according to the comments. The metric planning process for the enterprise architecture program was tested in the definition of metrics proposals for two case companies.

As was described in the previous section, this study consists of three research phases (Figure 5). In Table 3, the research methods and data gathering techniques used in these phases are summarized. Table 3 summaries basic information of articles related to this dissertation and illustrates their relationships to the research phases and research methods (including data gathering methods) used in the studies presented in the dissertation's articles.

TABLE 3 Original articles and their relationships to research phases and used research methods.

Research phases / Original article	**Context**	**Purposes of evaluation and measurement**	**Practices development**
Article I: Architecture Management in Three IT Companies – Problems and Characteristics	Case study ▪ Interview ▪ Document analysis		
Article II: Success and Failure Factors for Software Architecture	Grounded theory ▪ Literature and document analysis ▪ Focus group interview		

(Continues)

TABLE 3 (Continues).

Article III: Why to Evaluate Enterprise and Software Architectures? – Objectives and Use Cases		Grounded Theory ▪ Literature and document analysis ▪ Practitioners' comments	
Article IV: The Role of Architecture Evaluations in ICT-companies		Grounded Theory ▪ Focus group interview	
Article V: Quality Management Activities for Software Architecture and Software Architecture Process			Artifact-building ▪ Literature and document analysis ▪ Application to other domain (construction) ▪ Evaluation: Focus group interview
Article VI: Quality Evaluation Question Framework for Assessing the Quality of Architectural Documentation			Artifact-building ▪ Literature and document analysis ▪ Construction ▪ Evaluation: 1) Focus group interview 2) Questionnaire
Article VII: A Goal-oriented way to define metrics for enterprise architecture program		Grounded theory ▪ Literature and document analysis ▪ Focus group interview	Artifact-building ▪ (Literature and document analysis) ▪ Construction ▪ Evaluation: two case studies

In the following, research data that was used is described in more detail. Firstly, Table 4 describes empirical data used in this study by introducing from which companies practitioners participated in this dissertation study and how companies and practitioners related to each study. Participating practitioners were responsible for, or related to, the development and utilization of the enterprise and software architecture management methods and practices in their companies. They were mainly architects, consultants and architecture management related managers in their companies. Some of interviewed practitioners were the same and some of them changed during the whole study. In addition, the role of some interviewees changed in their company during the study.

TABLE 4 Empirical data gathered in this study.

	Studies / Articles						
Companies	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
ICT service providers							
Company A A part of an international IT solution group	⊕ 3 group interviews (persons 3, 4, 3)		•, 2				
Company B A part of an international IT technology and solution vendor Business and IT consulting and development company	⊕ 4 group interviews (persons 4, 3, 3, 3)			∇, 2	∇, 1	∇, 2 □, 1	∇, 2
Company C A part of a group providing comprehensive telecommunication services and solutions	⊕ 3 group interviews (persons 3, 3, 3)						
Company D Architecture consultation company		∇, 3		∇, 2	∇, 2	∇, 2 □, 1	∇, 1
ICT user organizations							
Company E Telecommunication company		∇, 1	•, 1	∇, 1	∇, 2	∇, 1 □, 1	∇, 1 ⊕
Company F Banking, finance and insurance company		∇, 1		∇, 1	∇,2	∇, 1 □, 1	∇, 1 ⊕
Company G Retail and service company				∇, 1		∇, 1	

⊕ Case company in a case study
∇, [number] Practitioners from this company were in a focus group interview and number of participants from this company
•, [number] Practitioners' from this company have given interview comments and number of persons that have been interviewed
□, [number] Practitioners' from this company answered to the questionnaire and the number of practitioners that answered

In addition, the literature and other documents, such as public reports published in internet or companies' internal documents, were used in all the studies. These were especially used to find what solutions and conceptions were presented earlier in answer to questions studied. Companies' internal documents were mainly descriptions of companies' own architecture management practices and descriptions of their organizational structures and processes. Literature sources were especially models, methods, practices, findings and salient issues raised in the literature of the enterprise and software architecture field

and in literature of other relevant fields as well as comments and recommendations presented in articles and reports published in the internet.

The empirical data used and literature data sources were chosen because these were expected to support the answers found for the defined research questions.

6 SUMMARY OF ARTICLES AND RESULTS

This section gives an overview of the results of this dissertation and the original articles constituting the basis of this dissertation. The main contributions of this thesis can be divided into contribution (1) to current theoretical knowledge about architecture management related evaluations and (2) to development of practices for architecture evaluations. A summary of contributions and results of this study is presented in Table 5.

The following sections discuss the considerations, observations, results, and contributions of the articles. Finally, the author's contribution to the articles is described in the cases of joint articles.

TABLE 5 Summary of contributions and results of this study.

Research phase	Contributions of the studies related to the research phase	Results
Phase 1: Context of evaluation and measurement in architecture management	The studies contribute to the understanding of architecture management and its utilization in companies.	• Identified features of architecture management challenges in companies • Identified architecture management areas which need methods and tools to be developed, improved and/or introduced from practice point of view • Identified system development areas that affect the success of software architecture • A model of main factors affecting the success of software architecture
Phase 2. Purposes of evaluation and measurement in architecture management	The studies contribute to the knowledge of architecture evaluations.	• A categorization of companies' triggers for architecture evaluations • A categorization of application areas of architecture evaluations • Measurement aspects for an enterprise architecture program
Phase 3. Practices development	The studies contribute to the development of evaluation practices for the architecture management. More precisely, the studies contribute to • the quality management in software architecture management, • the quality evaluation of architecture documentation, and • the practices of metrics definition for enterprise architecture program.	• An application of general quality management activities to the context of software architecture management. Results can be seen as the quality model for software architecture process and as the quality model for the software architecture. • A group of evaluation questions, criteria and metrics for the quality assessment of architectural documentation and models • A framework for the quality evaluation of architecture documentation. • An iterative and goal-oriented measurement planning process for EA program • Information that should or could be gathered, used and produced in the definition of metrics for EA program

6.1 Context of evaluation and measurement in architecture management

6.1.1 Arcticle I: Architecture management in three IT companies - Problems and characteristics

This article was published in Proceedings of 8th International Conference on Empirical Assessment in Software Engineering (EASE 2004), Edinburgh, Scotland, May 24-25, 2004, Herts: IEE, 97-109.

The objective of the study

Article I presents a case study of three IT solution provider companies and their architecture management capabilities. The aim of this study was to increase understanding of challenges IT practitioners are experiencing in their architecture management efforts and to identify what should be improved. The aim of this study is to help practitioners and researchers to understand what needs to be improved and developed in architecture management practices.

Results and Contribution

This study identified a group of areas related to challenges in the architecture management of IT service provider companies. These are the big resources needed in the gathering of requirements, the lack of descriptions of customer's legacy systems / existing architectures, the incomplete requirements gathering (e.g. carried by customer), conflicting requirements, and changes to the requirements. In addition, expertise and visual architecture descriptions were identified as especially essential in architecture management. Furthermore, the selection of the best architecture for the customer and the verification of suitability of the selected architecture seem not yet to have been stabilized practices.

This study also identified a group of architecture management areas for which methods and tools need to be developed, improved and/or introduced for IT service providers. The areas are architecture selection and evaluation (appropriate processes for architecture selection and evaluation) and architecture requirements management (formalized ways to describe the requirements, change management of architecturally significant requirements, completeness checking of the requirements gathered, handling conflicting requirements and description of legacy systems). It was found essential that methods and practices are economical to use, easy to learn and flexible for different kinds of customer projects. The results of this study support the views that the implementation of evaluations should be studied and practices for it should be developed in the architecture management domain.

This study contributed to the understanding of architecture management of companies. The contributions of this study are 1) the identification of features of architecture management challenges in companies and 2) the identification of architecture management areas which need methods and tools to be developed, improved and/or introduced from practice point of view. Studies and especially case studies about the problems faced in practice in the architecture management efforts within the IT industry, such as this study, are still quite rare, although the number of them is increasing all the time. Thus this study produces knowledge in an area, which is still rarely studied.

6.1.2 Article II: Success and failure factors for software architecture

This article was published in Khalid S. Soliman (Ed.) Proceedings of 6th International Business Information Management Association Conference (IBIMA '06), Bonn, Germany, June 19-21, 2006, IBIMA, 1-8.

The objective of the study

Currently, a concern of many ICT-service providers and user organizations in their system development work is the planning of a good software architecture. However, it has not been clear what factors affect the success of software architecture. Article II reviews literature and practitioners' experiences and conceptions about factors that cause success and failure for software architecture. This study demonstrates that success of software architecture depends on multiple factors.

Results and contribution

The study identified six system development areas that seem to affect the success/failure of software architecture. These are presented in Figure 6. Also success and failure factors relating to these areas were described.

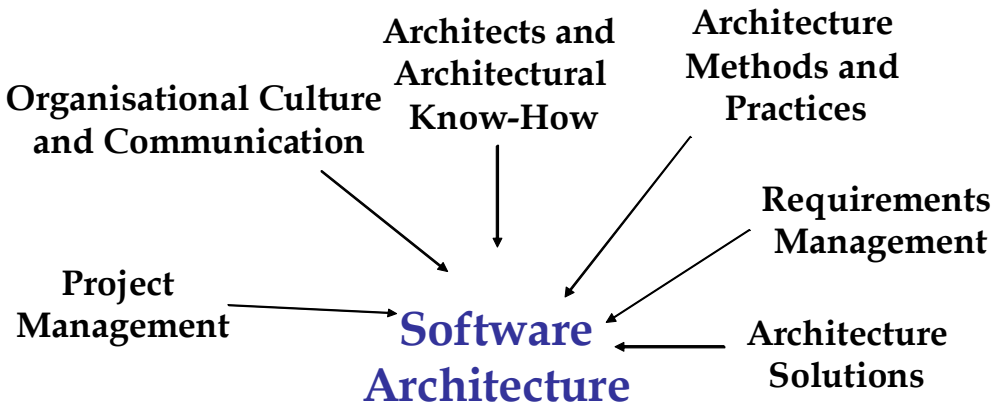

FIGURE 6 System development areas affecting the success and failure of software architecture (Hämäläinen *et al.*, 2006).

Based on the analysis of the identified factors, a model of the main factors affecting the success of software architecture is introduced (see Figure 7).

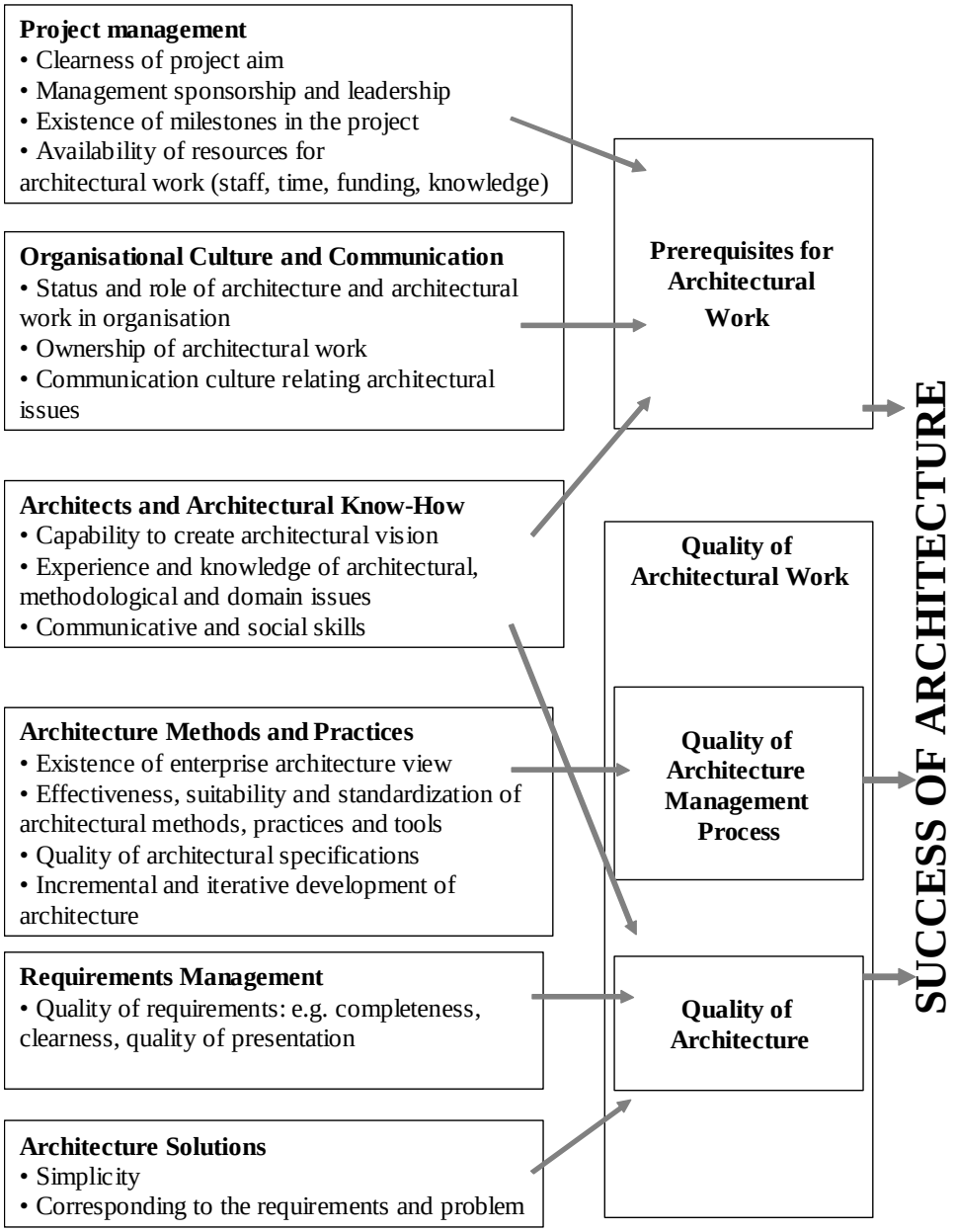

FIGURE 7 Main factors affecting the success of software architecture (Hämäläinen *et al.*, 2006).

Evaluation of architecture before its implementation was identified to be a success factor for the architecture and the omitting of architecture evaluations to be a failure factor for software architecture. These results thus support the view that evaluations are an essential activity in the software architecture planning process and that omitting evaluations may be a risk for the success of architecture. This study reveals that the quality of the architecture process is essential for the success of architecture. This observation encouraged us to study what a good quality architecture process is and especially what activities relate to it. This study is presented in article V. In addition, this study revealed that the bad quality of architecture documentation may be a risk in software architecture

development. This observation encouraged us to develop practices for the quality evaluation of architecture documentation. This study is presented in Article VI.

This study contributes to the knowledge of architecture management by 1) identifying system development areas that affect the success of software architecture and 2) introducing a model of main factors affecting the success of software architecture. Success and failure factors for software architecture are described and discussed by a few previous studies and public reports organized and produced by some research institutes and the ICT industry (e.g. (van der Raadt *et al.*, 2004), (Avritzer & Weyuker, 1999), (B. Boehm, 1994)). However, a detailed analysis and comprehensive view of these factors is lacking. These factors were, as yet, far from having been fully investigated in detail. The results of this study contribute to this investigation and analysis work.

6.2 Purposes of evaluation and measurement in architecture management

6.2.1 Article III: Why to evaluate enterprise and software architectures? - Objectives and use cases

This article was published in Dan Remenyi (Ed.) Proceedings of 12th European Conference on Information Technology Evaluation (ECITE '05), Turku, Finland, September 29-30, 2005, Reading, UK: Academic Conferences Limited, 213 - 222.

The objective of the study

Article III considers purposes of evaluation and measurement in the architecture management context by examining existing evaluation methods. Article III describes a study in which objectives and use cases of evaluations were identified mainly based on objectives and use cases presented in evaluation method descriptions. Both enterprise and software architecture methods were studied.

Results and contribution

As main results, this study identified main architecture evaluation application areas especially supported by evaluation methods. In addition, evaluation purposes related to each application area were identified.

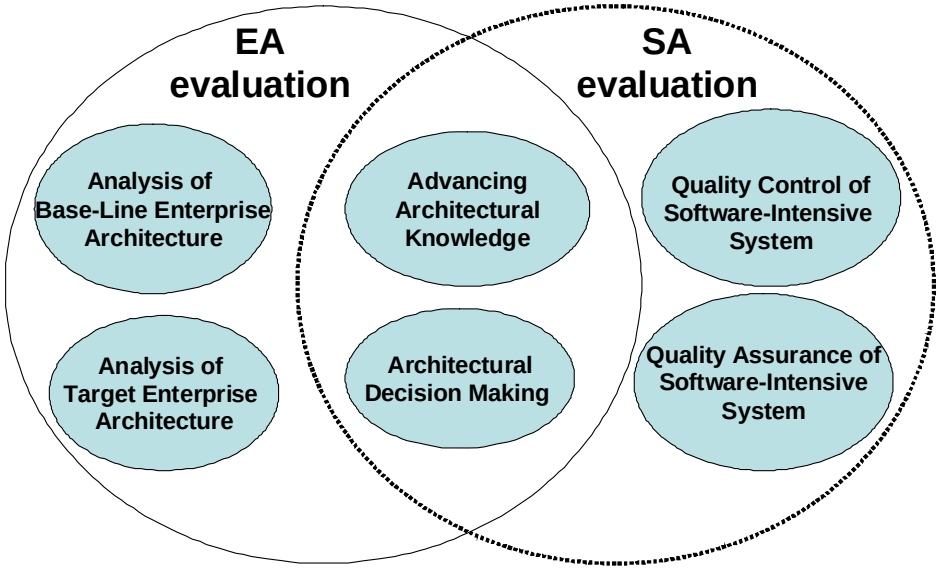

FIGURE 8 Application areas for enterprise and software architecture evaluation (Hämäläinen *et al.*, 2005).

This study reveals that objectives and use cases of architecture evaluation are presented quite narrowly in many studies and method descriptions in previous research. In turn, this article also shows that the use opportunities of evaluation are wider than many enterprise and software architecture evaluation method descriptions and comparisons suggest. In addition, this study reveals that different evaluation purposes are highlighted in the enterprise and software architecture context. Therefore, based on results of the study this article suggests that architecture evaluation has different aspects and application areas, and both enterprise and software architecture evaluation should be understood to offer more extensive possibilities to support companies' management, development and planning work than have been carried out so far.

This study contributes to knowledge of architecture evaluations by identifying and presenting a categorization of application areas of architecture evaluations. Previous studies in this area seem to only briefly identify and analyze application areas of software architecture evaluation methods. There exist some methods comparisons (e.g. (Dobrica & Niemelä, 2002),(Babar & Gorton, 2004)) which describe and name application areas. However, the detailed analysis, identification and categorization of application areas seems not to be provided by previous research. This study produces knowledge to address this question.

6.2.2 Article IV: The role of architecture evaluations in ICT-companies

This article was published in W. Grudzewski, I. Hejduk and S. Trzcielinski (Eds.) Proceedings of 11th International Conference on Human Aspects of Advanced Manufacturing, Poznan, Poland, July 9-12, 2007, Madison: IEA Press, 559-571.

The objective of the study

After the study presented in Article III, the practical needs and triggers for evaluations were seen as essential in order to define the purposes of architecture evaluations and measurement in more detail. Therefore, article IV examines companies' triggers for evaluations. Practitioners from five ICT user and service provider organisations were interviewed for this purpose.

Results and contribution

This study revealed a couple of triggers for architecture evaluations. As a result, the article presents a categorization of companies' triggers for architecture evaluations:

- Company and business management: Support needs for an organisation's structural design (e.g. business process design) and for the distribution of the work (e.g for outsourcing).
- Holistic view: Needs to understand the current status of an organisation's business and ICT-environment.
- IT cost management: Financial information needs relating to a company's ICT (applications and technical infrastructure).
- Change management: Change pressures relating to architectures and architectural principles – identification of the probability and nature of changes that should be made and decision making about changes.
- Quality management: Quality questions relating to architectural documentation, the company's information/data structures, application and technical infrastructure, as well as systems solutions.
- Architecture management: Confirming that architecture related work meets expectations e.g. investments correspond to the architectural principles.
- Architectural choices: evaluation of architectural alternatives against quality, cost and other aspects.

This study reveals that meanings of architecture evaluation may be to enhance the understanding of a company's business and ICT-environments from financial and structural viewpoints. In addition, it can be used as a tool in change management, quality assurance, process planning, IT cost management, and architectural choice making.

One observation of this study was that a particular challenge for the implementation of evaluations is the bad quality of architectural documentation. This observation supported a need to study quality evaluation of architecture documentation (Article VI). During studies presented in Article III and IV, a need to define measurement and evaluation aspects for a company's architec-

ture capabilities was identified. The results of these studies were the basis information for the development of measurement aspects. Measurement aspects are presented in Article VII.

This study contributes to knowledge of architecture evaluations by presenting a categorization of companies' triggers for architecture evaluations. Previous studies seem not to systematically identify and analyze companies real architecture evaluation needs or companies' triggers for evaluations seem not to be identified and gathered from practitioners and specialists in ICT companies. This study produces knowledge on this rarely studied area.

6.3 Practices development

6.3.1 Article V: Quality management activities for software architecture and software architecture process

This article was published in W. Hasselbring (Ed.) Proceedings of The IASTED International Conference on Software Engineering (SE '07), Innsbruck, Austria, February 13-15, 2007, Anaheim: ACTA Press, 347-352.

The objective of the study

As mentioned earlier, a good architecture definition process is one that leads to a good architecture, documented by an effective architectural description, which can be realized in a time-efficient and cost-effective manner. However, architecture processes are considerably new parts of organisations' processes so that there exists no stabile conceptions of what kind of good architecture process leads to a good architecture. The activities which promote this aim are thus not clearly defined yet. Article V reviews literature and practitioners' experiences on quality management activities that could be suggested to promote the achievement of good software architectures and software architecture processes of good quality. These activities are proposed to be taken into account in the software architecture process design, development, and capability assessment.

Results and contribution

This study contributes to the development of evaluation practices in the architecture management area. The contribution of this study is an application of general quality management activities to the context of software architecture management. This study identified that quality management activities of software architecture management can be divided into:

- Activities that relate to the quality management software architecture process. These activities concentrate on the quality of the software archi-

tecture process. The main areas of these activities are presented in Figure 9.

- Activities that relate to the quality management of software architecture. These activities concentrate on the achievement of software architecture of good quality. Architecture management areas to which these activities are related to are described in Figure 10.

Activities relating to these aspects are identified and presented. These results can be seen as a quality model for software architecture management (Figure 9) and as a quality model for software architecture (Figure 10).

In the software architecture domain, there exists a quite large variety of studies related to quality. However, the quality management in the software architecture context is approached from the point of view of a software system's quality criteria and metrics in many studies. Many previous studies therefore address how to design and to achieve software architecture that supports achieving a software system that corresponds to the necessary quality requirements (e.g. performance, reliability, portability, testability). The studies and practices on how to ensure and to develop the quality of software architecture processes seem to be very rare. This study focuses on this not often studied question. General quality management theories are applied to the software architecture context. This study highlights the process quality aspect rather than the product quality aspect which many previous studies in software architecture domain seem to highlight. The study thus contributes to the alternative quality management approach and solutions in software architecture management domain.

FIGURE 9 Main areas related to quality management of software architecture process.

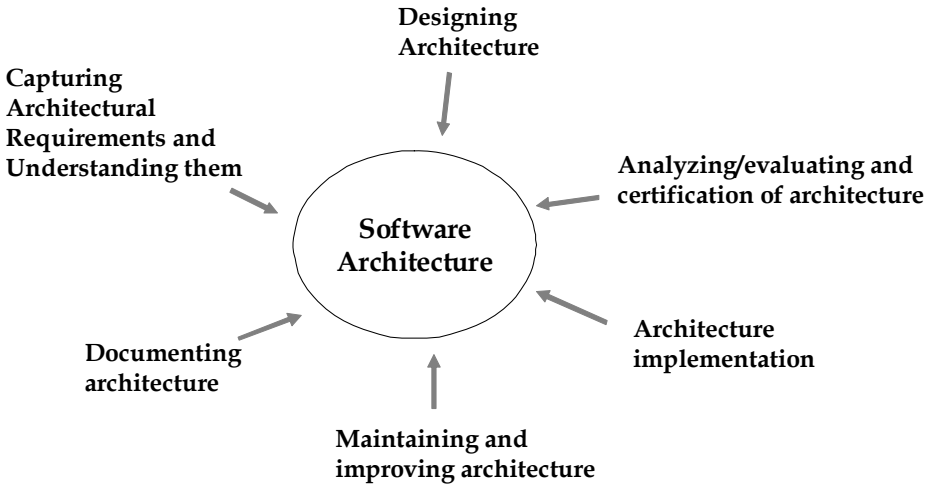

FIGURE 10 Main architecture management areas relating to which quality management activities of software architecture were identified.

6.3.2 Arcticle VI: Quality evaluation question framework for assessing the quality of architectural documentation

This article was published in E. Berki, J. Nummenmaa, M. Ross and G. Staples (Eds.) Proceedings of International BCS Conference on Software Quality Management (SQM '07), Tampere, August 1-2, Tampere, Finland, Tampere: University of Tampere.

The objective of the study

Architecture documents have an increasingly central role in the company management, IT governance and system development. For example, enterprise architecture core documents are suggested to be used in the company management. Architecture documents are used especially to support communication. Examples of use situations of architectural documentation are business planning for transition from a legacy business or ICT structure to a new structure and communication between acquirers and developers as a part of contract negotiations. The quality of architectural documents is crucial for the usefulness of those documents which in turn is crucial to the company's business and ICT development work. As one solution to the architecture documentation quality question, the architecture documentation quality evaluation question framework is presented in this article. This framework was validated by practitioners. The results of this study aim to help enterprise and software architects to produce architectural descriptions and models of good quality.

Results and contribution

Article VI contributes to the quality evaluation of architecture documentation by 1) identifying and defining a group of questions, criteria and metrics that can

be used in the quality assessment of architectural documentation and models, and based on these
2) by introducing a framework for the quality evaluation of architecture documentation.

Questions, criteria and metrics relate to the stakeholder and purpose – orientation and the quality of content and visualization as well as to the architecture documentation management.

Previous studies and literature introduces some guidelines and practices (mainly checklists consisting of questions) for the quality evaluation of architecture documentation. However, these guidelines and practices seem to be limited to one or a few quality aspects of documentation, or they do not clearly provide aspects that should be evaluated. Therefore, quality evaluation criteria for architecture documentation seem not to be well identified and analysed by previous research and literature. This study contributes to this identification and analysis work, which is an additional benefit that this study provides compared with previously developed architecture documentation quality evaluation guidelines and practices. This study aims to develop a systematic approach for architecture document evaluation which takes into account the different relevant aspects of document quality. In addition, knowledge about the importance of each evaluation criterion for practitioners was also produced.

We suggest including the checking of quality of architecture documents in architecture reviews. We suggest that quality evaluation checklists should be developed in companies. The results of this study can be used in the producing these checklists. These checklists are suggested to be used in architecture design by architects and in architecture reviews by reviewers.

6.3.3 Article VII: A Goal-oriented way to define metrics for enterprise architecture program

This article was published in Journal of Enterprise Architecture, February 2008, 4 (1), 20-26.

The objective of the study

Metrics are becoming more and more important in the development of enterprise architecture (EA) programs. Therefore, guidelines and support to define metrics for EA programs are needed. Article VII aims to support the planning of metrics for EA programs. In order to achieve this aim, this article presents measurement aspects and phases of an iterative and goal-oriented metrics development process. In addition, experiences of metrics definition are presented. These were developed and tested during the development of proposals of EA program metrics for two companies. An iterative approach to develop metrics for EA program was found to be useful.

Results and contribution

This study contributes practices of metrics definition for enterprise architecture program by presenting:

1) Measurement aspects for enterprise architecture programs

- Benefits of an EA program for the organisation
- Impacts and use of an EA program and its results
- Progress and Operations of an EA program: an EA team's and architects' accomplishments, particularly progress toward pre-established goals
- Quality / Maturity
  Maturity of an EA program capabilities
  Quality of results produced by EA program
- Architecture structures in an organisation: evaluation of architecture alternatives and solutions

2) Information gathered, used and produced in the definition of metrics for an EA program (see Figure 11).

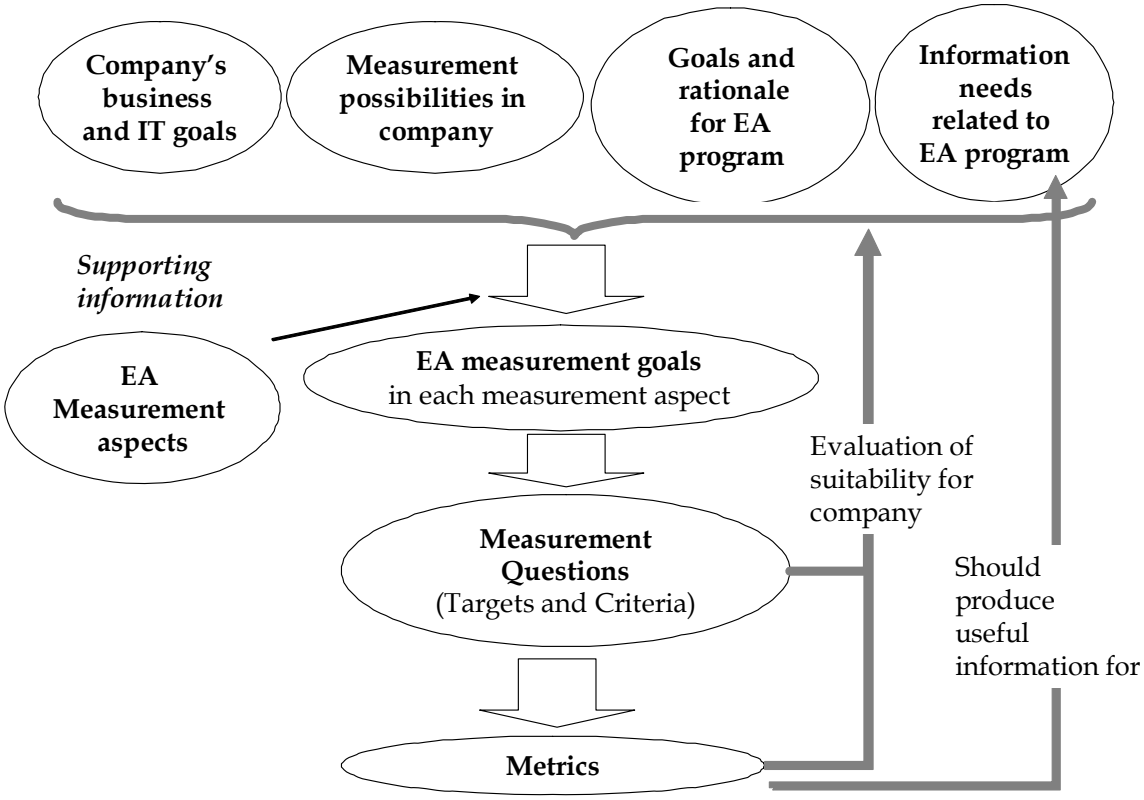

FIGURE 11 Information gathered, used and produced in the definition of metrics for an EA program (Hämäläinen & Kärkkäinen, 2008).

3) An iterative and goal-oriented measurement planning process for an EA program (developed based on measurement aspects and GQM-approach and validated in two cases)

TABLE 6 The phases of one iteration of a metrics defining process for an EA program.

Phase	**Tasks and results**
Phase 1. Company's goals, EA goals and information needs	• Identifying and documenting information and EA program's stakeholders' conceptions about goals and rationale for company's EA program and team • Identifying company's business and IT goals from EA program point of view • Identifying information needs related to EA program (what information should metrics produce?)
Phase 2. Measurement possibilities	• Identifying company's and EA group's resources and capabilities for the measurement (e.g. existing practices and metrics, resources for measurement)
Phase 3. EA measurement goals	• Defining EA goals that are decided to be measured
Phase 4. Measurement questions	• On based measurement goals, identifying measurement questions including measurement targets and criteria which will be measured
Phase 5. Metrics	• Choosing metrics suitable for measurement questions (for target & criteria) • Choosing only a few critical metrics • Choosing useful metrics that – produce information that is useful in the current situation and – suitable for the goals of the organisation and for the goals of architecture work (in the short and long term)
Phase 6. Feedback	• The feedback gathering from stakeholders about o Used measurement goals: Are the metrics suitable for the goals? o Defined measurement questions, targets, criteria and metrics: Are the metrics possible to be used in company? • Utilization feedback in the next development iteration of metrics
Phase 7. Use metrics	• Defining responsibilities in measurement (Who will collect the metrics? Who will analyze the metrics? Who will use the information gathered? To whom will the results be reported?) • Timetable (When and how the metrics should be collected and analyzed?) • Change needs (What needs to be done before it is possible to collect and analyze metrics (e.g. changes in processes and tools)?) • Do the measurement. Collect metrics and analyze them and report results. • Update measurement goals, questions and metrics when needed. Start thus a new development iteration of metrics.
Phase 8. Utilization of results	• Making decisions or planning actions based on measurement results. • Achieving benefits of measurement by utilizating information produced by it.

Different sources highlight the importance of goal-oriented metrics for enterprise architecture work. Several metrics definition approaches and practices exist. However, there does not seem to be public guidelines on how to apply these practices and approaches for metrics definition of an enterprise architec-

ture program. Moreover, public guidelines or solutions on how to handle the problem of unclearly defined goals for an EA program in the measurement planning seem not to exist. The results of this study provide, thus, solutions for these unhandled questions.

6.4 Notes on joint authorship and on the included articles

The author's contribution for the articles is described in Table 7. In the table, contributions of the articles' authors and persons mentioned in articles' acknowledgement sections are described. However, language reviewers are not included.

In addition, many of the articles are commented on by practitioners from co-operating companies. These comments have been valuable in the editing and improvement of the articles. These articles were produced during three different research projects: Larkki (Architecture planning of large information systems), Koteva (Testing and Quality Assurance of Software Components), and AISA (Quality Management of Enterprise and Software Architectures) organized by Information Technology Research Institute, University of Jyväskylä. Several persons from the University of Jyväskylä and from the participating companies have contributed to building these projects.

TABLE 7 Contribution of author.

Original Article	**Own contribution**	**Others' contribution: Participation in or carrying out**
Article I	• Research planning • Data gathering, analysis and reporting results (1 case company) • Writing article	Veikko Halttunen and Mirja Pulkkinen • Research planning • Data gathering, analysis and reporting results (2 case companies) Jarmo Ahonen • Research planning • Commenting on article Markku Sakkinen and Tommi Kärkkäinen • Commenting on article Tanja Ylimäki • Writing article
Article II	• Research planning • Data gathering • Data analysis • Writing article	Tanja Ylimäki • Data gathering • Commenting on article Jouni Markkula and Markku Sakkinen • Commenting on article

(Continues)

TABLE 7 (Continues)

Article III	• Research planning • Data gathering • Data analysis • Writing article	Jarmo Ahonen and Tommi Kärkkäinen • Commenting on article Ari Andersin • Commenting on article
Article IV	• Research planning • Data gathering • Data analysis • Writing article	Tanja Ylimäki and Eetu Niemi • Data gathering (focus group interview) • Commenting article
Article V	• Research planning • Data gathering • Development of construction • Writing article	Tommi Kärkkäinen and Jouni Markkula • Commenting on article Tanja Ylimäki • Participation in evaluation of construction (focus group interview)
Article VI	• Research planning • Development of construction • Validation • Writing article	Tanja Ylimäki and Eetu Niemi • Participation in evaluation of construction (focus group interview) Jouni Markkula • Development of construction • Writing article
Article VII	• Research planning • Data gathering • Data analysis • Development of construction • Evaluation of construction (2 case studies) • Writing article	Tanja Ylimäki and Eetu Niemi • Data gathering (focus group interview) Tanja Ylimäki and Eetu Niemi • Participation in evaluation of construction (2 case studies) Tommi Kärkkäinen • Giving significant comments affecting the research planning • Commenting on article

7 CONCLUSIONS

This section concludes the dissertation by presenting the summary of the results, the evaluation of reliability, validity and applicability of results, and outlining the future research. The future research section draws out future research opportunities to complement and to continue the work carried out in this dissertation.

7.1 Conclusions

Measurement and evaluation capabilities and skills are seen as essential for architecture work and its adaptation. Development of these capabilities and skills is a current concern of many architecture groups and architects in companies. In this dissertation, purposes of evaluation in architecture management are studied and practices for them are developed. The key aims behind carrying out this dissertation were especially the following: 1) to support architecture management practitioners in companies to recognize the significance and use possibilities of evaluation, 2) to support them to focus their evaluation practices development in the architecture management area and 3) to support them in the development of practices and processes for evaluation and measurement. The following sections present answers to the research questions studied and conclusions that can be reached based on the results of this dissertation.

7.1.1 Conclusions: context of evaluation and measurement in architecture management

The first objectives of this dissertation were to describe some of the context in which architecture work-related evaluations and measurement are carried out and to ensure the appropriateness of the research problem and to ensure if it is useful to focus on this area. In addition, the objective was to identify what areas

are essential to study and develop practices for. The questions studied relating to these objectives and answers for these questions were the following.

What challenges exist in architecture management in companies?

Features of architecture management challenges in companies were identified. In addition, architecture management areas which need methods and tools to be developed, improved and/or introduced from a practice point of view were identified. The results are described in the section 6.1.1 and in Article I.

What factors affect the success of architecture?

System development areas affecting the success of software architecture were identified. A model of main factors affecting the success of software architecture was developed. These are presented in Section 6.1.2 and in Article II.

The results of this study support the view that evaluation and metrics are essential parts of both enterprise and software architecture capabilities and execution of those are success factors for architecture. Thus these need to be taken into account in the development of architecture practices and processes in companies. In addition, this study supports the view that a lack of architecture capability related evaluation practices are challenges in companies. Based on the results, the evaluation of architecture before its implementation was identified to be a success factor for the software architecture. Conversely, skipping the architecture related evaluations was identified to be a failure factor for software architecture.

7.1.2 Conclusions: purposes of evaluation and measurement in architecture management

Evaluations and measurements are means. However, "*Means for what?*" is currently a central question in the area of architecture management. The objectives of this dissertation were to describe purposes of evaluations in architecture management and to define and categorize companies' triggers for evaluations and evaluation areas supported by evaluation methods. In addition, an objective was to define evaluation/measurement aspects in which evaluations could be carried out relating to a company's architecture capabilities. The questions studied relating to these objectives and answers for these questions were the following.

What evaluation purposes and possibilities do existing architecture evaluation methods support?

Existing architecture evaluation methods were examined and a categorization of application areas of architecture evaluations was produced (Section 6.2.1 and Article III).

What are triggers (information needs) for architecture evaluations in companies?

Practitioners' from companies were interviewed and a categorization of companies' triggers for architecture evaluations was produced (Section 6.2.2 and Article IV).

In which aspects could evaluation and measurement be carried out relating to a company's architecture capabilities?

In this study, a group of measurement aspects for enterprise architecture program was identified (Section 6.3.3 and Article VII).

The results of this study show that evaluation is a multifaceted instrument in the area of architecture management. Architecture evaluations can be used in very different situations to support the management and planning work carried out in companies as well to support the development of company's information systems. In summary, based on the results of this study, purposes of evaluation and metrics in architecture management are especially:

1) To support the management of architecture work,
2) To improve and assure quality of architecture management processes, practices and deliverables,
3) To identify impacts, use and benefits of architecture work and to drive architecture activities towards achieving business and IT benefits, and
4) To produce information for architecture planning and decision making.

Enterprise architecture evaluation can be utilized in different stages of enterprise and software architecture planning and development work. It can be executed, for example, in EA planning, transformation as well as in EA governance. Similarly, software architecture evaluation can be utilized in the different phases of the system life cycle: for example in designing, realizing, maintaining as well as in improving the system.

The results of this study show that application areas of both enterprise and software architecture evaluation should be understood to offer more extensive possibilities than have been used until now.

7.1.3 Conclusions: practices development

The last objective of this dissertation was to develop evaluation and measurement practices to the architecture management domain. In this dissertation, practices for quality management in an architecture management context, quality evaluation of architecture documentation, and metrics definition for EA program were developed. Open questions were identified to relate to these areas and these areas were seen as essential to support through practices development. More precisely, the following questions were studied and answered.

How can quality management be carried out as a part of architecture management? What activities should be carried out to achieve architecture of good quality?

Architectural quality is one aim of the architecture management process. The quality aspect should be taken into account in the development of architecture processes and practices as well as in the development of architectures themselves. In this dissertation, an application of general quality management activities to the context of software architecture management was carried out. As a result, a group of activities that should or could be taken into account in the development of software architecture processes and practices is presented (Section 6.3.1 and Article V). The results can be seen as the quality model for a software architecture process and as the quality model for the software architecture. The evaluation of a company's software architecture definition process against these models is suggested.

How to carry out the quality evaluation of architecture documentation?

Architecture documentation is another crucial issue in architecture work. In this dissertation, a group of evaluation questions, criteria and metrics for the quality assessment of architectural documentation and models is developed. Based on these, a framework for the quality evaluation of architecture documentation is presented. These are presented in Section 6.3.2 and Article VI.

The understanding of architecture can be seen as a prerequisite for following and applying architecture. It can be seen as a prerequisite for the realization of architecture. The quality of architecture documents may thus even have an effect on the realization of architectures.

The quality of architecture documentation should be a concern of the architects, as well as of the whole company. Enterprise and software architects should ensure the quality of architecture documents during the production of them. The production of documents is, therefore, the first situation when quality can be ensured. It is suggested that checking of the quality of architecture documents in architecture reviews be included. Quality evaluation checklists should be also developed in companies. The results of this study can be used in the production of these checklists. These checklists are suggested to be used in architecture design by architects and in architecture reviews by reviewers.

How to define metrics for an architecture program?

This dissertation introduces an iterative and goal-oriented measurement planning process for enterprise architecture program. In addition, it identifies information that should or could be gathered, used and produced in the definition of metrics for an EA program. These are introduced in Section 6.3.3 and Article VII.

These were developed and tested in the development of metric proposals for enterprise architecture groups of two case companies. An iterative approach and feedback session was found essential in the development of metrics. This

experience proved that although the defining metrics for EA program is challenging, it is possible. Therefore, the author of this dissertation sees that metrics definition for an EA program should not be avoided in companies even if it is felt that it is challenging. Naturally, several iterations may be needed to get good metrics, but these iterations are useful because during this process EA team views a company's business and IT goals from the EA team viewpoint and learns more about these goals and further clarifies the EA team's own goals. Therefore, other benefits are also achieved from the metrics definition, in addition to the direct information produced through metrics.

7.1.4 Summary of conclusions

Evaluations and metrics are key means to support the management, development and improvement of company's architecture capabilities; to ensure achievement of the benefits of architecture capabilities, and to support the architecture related decision making in a company. Although, developing evaluation methods and metrics for a company's architecture capabilities may not always be easy, it is recommendable.

The significance of architecture capabilities for companies is continuously increasing in this complex and changing world. Therefore, the author of this dissertation thinks that each company having or developing architecture capabilities should plan and act on architecture management related evaluations and metrics. The results of this dissertation aim to support this work.

7.2 Recommendations

The following recommendations for companies can be presented based on the results of this study.

Grounds for evaluations and metrics

- Ensure and identify the basis for evaluations and metrics
    - What are a company's business and IT goals? Which of those are relevant from an architecture work point of view?
    - What are the rationale and needs for architecture capabilities in a company?
    - What information needs exist relating to architecture capabilities and architectures?
    - What possibilities exist in a company to carry out measurement and evaluations relating to architecture work (effort available, information sources available)?
- Co-operation with other stakeholders: in architecture work, investigate and listen to stakeholder's needs and concerns relating to evaluation and measurement. Pay special attention to their information needs and descriptions of evaluation possibilities in the company.

Skills, resources, and practices for evaluation and measurement

- Skills: Develop and ensure a company's enterprise architecture group's and architects' skills and knowledge in the measurement and evaluation (both in evaluation and metric definition principles and architecture management related evaluations)
- Resources: Define staff who have the main responsibility for the development of evaluation practices and carrying out evaluations. Give them time and other resources to develop practices for evaluations and to implement them.
- Practices: Define focus areas for your company's architecture management related evaluations. Measurement aspects produced in this study can be used to support the definition of focus areas. Develop and/or choose needed practices and metrics for these areas for your company.

Metrics planning for enterprise architecture program

- Do not avoid metrics definition for enterprise architecture program because of the belief that it is too difficult. Accept that metrics definition needs iterations. Do not thus rush to use metrics and widely gather measurement information. However, testing metrics and evaluation practices (for example, with a small amount of information or cases) is useful for the metrics and evaluation practices development.
- Start from goals, not from metrics. If you decide to choose a metric or metrics used in other companies or found from somewhere else, evaluate them against your own company's goals. Are these metrics suitable for your company (business, IT, EA team) goals and for your company's context?
- Do not believe everything that is said about metrics. Make your own choices. It seems that some black-and-white conceptions about EA metrics exist. These conceptions may drive the metrics definition work in companies. For example, it is highlighted quite often in the architecture management area that one should not use activity-level metrics to measure the performance of an enterprise team producing so called "history-data" (e.g. how many projects have been served by an architecture team, how many hours are used for different tasks). The author of this dissertation agrees with that an EA team should not *only* use these kinds of metrics and history-data may not be useful as such. However, new needed information can be produced (i.e. derived) based on this "history-data". Information produced with these metrics may thus be needed to plan and manage *future* architecture work (e.g. for resource planning of architecture work, to identify if the work is directed to right places/aspects and to drive the work to new directions).

7.3 Reliability, validity and applicability

This dissertation study draws on the research carried out in three research projects. These projects were described in the introduction section. These projects were carried out in co-operation with companies. Therefore, the surrounding context formed by these research projects' and by industrial co-operation has had an effect on this study. This context has given special opportunities to understand companies' reality and real problems in the architecture management area. However, this context has also given some limitations.

The main limitations of this dissertation study are the following. A limited number of literature and other data sources were analyzed during the study although the aim was to identify all relevant sources. In particular, a limited number of focus group interviews were carried out in each study. In addition, the participants in the focus group interviews were mainly or completely enterprise and software architecture management specialists. Other perspectives and concerns were not analyzed and identified. A limited validation of the developed practices during this study can be also seen as a limitation for the results. In the following, the relevance, validity, reliability, and applicability of the results of this study are evaluated and considered in more detail.

Firstly, *the relevance of this dissertation's results* is evaluated. In the framing of research targets and activities that this dissertation's studies would address, the identified business needs were used to assure research relevance (such as Hevner et al. suggest (Hevner et al., 2004)). The needs to solve and study relevant questions for the research projects' research areas and consortiums (e.g. co-operation companies) have, therefore, driven the choice of the questions studied in the research projects in which this dissertation was carried out, and in turn, driven the definition of research problems studied in this dissertation. The author of this dissertation sees this context effect as wanted, useful, and important. The needs and questions presented by practitioners from companies have been of special assistance in focusing the studies. They have assisted in identifying relevant research areas and questions from a practical point of view. The author of this dissertation sees that this has increased and ensured the relevance of these studies.

Secondly, *the validity and reliability of results achieved in case studies and grounded theory studies* are evaluated. By attempting to connect the grounded theory with aspects of existing formal theory, a more general substantive theory can result (Glaser & Strauss, 1967), p. 34. Eisenhardt also advocates this approach, noting "Overall, tying the emergent theory to existing literature enhances the internal validity, generalizability, and theoretical level of theory building from case study research" (Eisenhardt, 1989), p. 545. The existing literature and knowledge of existing terms and theories was used when choosing used terms and categories in the creation of: features of architecture management challenges in companies, a model of main factors affecting the success of software architecture, a categorization of application areas of architecture

evaluations, a categorization of organisations' triggers for architecture evaluations, and measurement aspects for enterprise architecture program. While more empirical work is necessary to elaborate and verify these categories, model and measurement aspects, this provides a useful starting point. These theoretical categories were generated by examining a limited number of empirical and non-empirical data, albeit in depth. More empirical grounding and comparison will sharpen and enrich concepts developed here and yield more complex understanding of the phenomenon of evaluation in architecture management. Empirical validation and elaboration of these categories, measurement aspects, and a model in other settings are also clearly needed.

Thirdly, the *effect of focus group interviews on the validity of results* is evaluated. In this study, focus group interviews were used as a central data gathering technique. More focus groups would have given more information for as a basis for the study. The decision of the author of this dissertation was not to carry out more focus groups relating to each study because participants in each focus group interview were experienced specialists in the architecture management area. The value of this focus group method is thus very sensitive to the experience and insight of the participants (Kontio et al., 2004). Depending on the type of research question, participants may be people that do not have much experience in the topic of the focus group – or may be seasoned experts that can rely on their years of experience when interacting in the group (Kontio et al., 2004). In this study, companies independently chose their participants for the focus group interviews. The participants chosen were experienced enterprise or software architecture specialists, working in central positions concerning architecture management in their companies. Therefore, these participants were well able to discuss and present their views about the topics of the focus groups.

Finally, *applicability of developed practices* is evaluated. The developed practices for quality management of software architecture and quality evaluation of architecture documentation were evaluated through a focus group interview. Furthermore, the measurement process for enterprise architecture process was tested in two company cases. More practical testing of these practices is obviously needed. In addition, one limitation in the practices' evaluations carried out in this study was that the predefined evaluation criteria and metrics, such as recommended by Hevner et al. (relating, for example, to usability and completeness of practice), were mainly not used in these evaluations (Hevner et al., 2004). Rather, open feedback was gathered about practices. Only, in the evaluation of the quality evaluation framework for the architecture documentation was evaluation criteria used (significance of each document evaluation criteria and question was evaluated).

These practices were developed in the enterprise and software architecture management area. These practices are also at least somewhat applicable in other architecture approaches (e.g. service-oriented architecture). However, these practices may need some changes or additions when these are applied in other architecture domains. Application of these practices in relation to other architecture approaches still needs more research.

7.4 Further Research

As described in the beginning of this dissertation, companies currently need, and will need in the near future, knowledge and practices to develop evaluation practices and metrics for their architecture capabilities. Therefore, the author of this dissertation thinks that open questions which impede or may impede this development work should be identified and research should be focused especially on solving these questions. In addition, the author of this dissertation thinks that in current situation research approaches and methods should be used which produce knowledge and practices efficiently and at a sufficient quality level that new knowledge and practices are available for companies when companies need to make their own choices and decisions about their evaluation practices. Very long term studies may produce high quality results; however results of these studies may be available too late from a companies' point of view in this rapidly developing area. In addition, basic research is also needed, for example, to stabilize the definitions for evaluation and metric concepts in enterprise and software architecture domains.

More precisely, based on this study, the areas and questions that need to be studied more are the following. This study focused on the identification of challenges met in IT service provider organisations' architecture management. ICT user organisations' architecture management challenges and their improvement needs for the architecture methods and practices should be studied as well. In addition, success and failure factors for software architecture need to be studied more. For example, a developed model of the main factors affecting the success of software architecture should be evaluated in the real software architecture development projects and situations in order to validate the identified factors. In addition, it should be identified how these factors should or could be taken into account in the development of software architecture management practices in companies. It would also be interesting to know how well existing software architecture management methods and practices take into account these factors. The significance of identified architecture evaluation purposes should be identified and evaluated in the different kinds of organizations. In addition, more knowledge and practices are needed, especially for the definition of the metrics for organisations' architecture capabilities. In this study, the developed practices for the quality management of software architecture, the quality evaluation of architecture documentation and the metrics definition process for enterprise architecture program should also be further evaluated and tested in real architecture management situations.

In summary, there exists a wide range of research opportunities relating to evaluation and measurement in the enterprise and software architecture management area. There also exist practical needs for the knowledge and practices resulting from this research.

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YHTEENVETO (FINNISH SUMMARY)

Nykyinen liiketoimintaympäristö edellyttää yrityksiltä kykyä nopeasti kehittää uusia palveluja sekä vastata muutostilanteisiin ja -tarpeisiin (esim. ulkoistukset, yritysfuusiot ja -hankinnat). Näiden kykyjen kehittämisen pohjana voivat olla kokonais- ja ohjelmistoarkkitehtuurit (engl. enterprise architecture, software architecture), jotka ovat yrityksen rakenteellisia hahmotustapoja. Ne sisältävät liiketoimintaprosessien, tietojärjestelmien, liiketoiminnassa tarvittavien tietojen sekä teknisen infrastruktuurin näkökulmat. Arkkitehtuurien avulla tuetaan yrityksen kykyä kehittää nopeammin ja kustannustehokkaammin sen liiketoimintaa tukevia tietojärjestelmiä sekä kykyä reagoida muutostarpeisiin.

Nykyisin yritykset kehittävät aktiivisesti kykyjään toteuttaa arkkitehtuurien suunnittelua ja kehittämistä. Tässä kehittämistyössä ovat nousseet yhä tärkeämmäksi arviointikäytänteiden ja mittarien kehittäminen osaksi yrityksen arkkitehtuurityötä. Kuitenkaan tähän mennessä ei ole vielä selkeästi muodostunut yhtenäistä näkemystä siitä, millaisia erilaisia arviointeja tulisi tai olisi hyvä toteuttaa yrityksen arkkitehtuurien hallintaan liittyen. Lisäksi niiden kehittämiseen ja toteuttamiseen puuttuu käytänteitä.

Tämä väitöskirja pyrkii omalta osaltaan selkeyttämään vallitsevaa tilannetta tuottamalla tietämystä siitä missä eri merkityksissä arviointeja ja mittaamista voidaan toteuttaa yrityksen arkkitehtuurien hallintaan liittyen. Lisäksi tämä väitöskirja kehittää käytänteitä arviointien ja mittarien kehittämiseen ja toteuttamiseen. Tulosten pohjalta esitetään suosituksia yrityksille miten niiden olisi hyvä edetä arkkitehtuurien kehittämiseen liittyvien arviointien ja mittareiden kehittämisessä.

Tämän väitöskirjan tutkimuksen pohjaksi on kartoitettu Suomessa toimivien kansallisten ja kansainvälisten yritysten arkkitehtuurityötä tekevien työntekijöiden näkemyksiä ja kuunneltu heidän kokemuksiaan arkkitehtuurityöhön liittyvistä arvioinneista. Lisäksi tutkimuksen pohjaksi on kartoitettu ja tunnistettu arviointeihin liittyvää olemassa olevaa tietämystä aikaisemmista tutkimuksista ja arviointimenetelmistä. Väitöskirjassa on tutkittu yritysten arkkitehtuurien hallinnassa kohdattavia haasteita ja ohjelmistoarkkitehtuurien menestystekijöitä. Arviointien merkityksiä on tunnistettu tutkimalla yritysten arkkitehtuureihin liittyviin arviointeihin johtavia syitä ja olemassa olevien arviointimenetelmien tarjoamia mahdollisuuksia. Käytänteitä on kehitetty ohjelmistoarkkitehtuurien laadunhallintaan, arkkitehtuuridokumenttien laadun arviointiin ja mittarien kehittämiseen yrityksen kokonaisarkkitehtuurityöhön liittyen.

Yritykset kaipaavat ja tarvitsevat tietoa ja käytänteitä yhä enemmässä määrin arkkitehtuurien alueen arviointikäytänteiden ja mittarien kehittämiseen. Tämä väitöskirja vastaa osaltaan näihin tiedon tarpeisiin. Tämä väitöskirjatutkimus tuottaa uutta tietoa arvioinneista ja mittaamisesta yritysten arkkitehtuurien suunnittelun ja kehittämisen alueelle sekä käytänteitä arviointien toteuttamiseen.