



UNIVERSITY OF JYVÄSKYLÄ  
INFORMATION TECHNOLOGY  
RESEARCH INSTITUTE

## **Quality Management Activities in Software Architecture Process**

### **AISA Project Report**

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Author: Niina Hämäläinen

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## **Abstract**

Architecture processes are considerably new parts of organisations' processes. These processes have the responsibility to aim at high quality and financially successful architectures. However, the architecture management activities which promote this aim are not clearly defined yet. This study reviews literature and practitioners' experiences on quality management activities that could be suggested to promote the achievement of high quality architectures. These activities are proposed to be taken into account in the software architecture management process design, development and capability assessment.



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# 1 Introduction

Product and process quality management practices as well as process maturity and capability assessment practices are widely adopted and introduced in ICT industry. These practices include, among others, quality standards (e.g. ISO 9000 standards), frameworks for assessment the process maturity of an organization or a project (e.g. CMMI, Software Productivity Research (SPR)) and quality award programs (e.g. Malcolm Baldrige, European Quality Award).

Relatively new parts of organizations' processes are enterprise and software architecture management processes and their quality management. Software architecture management (SAM) consists of the activities of capturing the architectural requirements of software-intensive systems and understanding them. Moreover, the process also includes design, analysis/evaluation, implementation, maintenance, improvement, and certification of the architecture as well as its documentation (Bass et al. 1998; IEEE 2000).

It is quite generally known that software architecture and its management process have an impact on the quality of the system. Academia and practitioners have come to realize that a critical success factor for system design and development is finding a high quality and financial successful architecture. An organisation's architecture management processes has the responsibility to aim at the quality and financial success of architectures. Other processes within an organisation, such as those for investment planning and system development, do not have this responsibility if not this responsibility is clearly included in these processes. This means that the success of architectures is not necessarily considered in decision making in these other processes. Therefore, the status and capability of the architecture management processes in organisations should be considered carefully if the architectural success is the aim of the organisation.

Although the idea of a successful architecture is not clearly defined, practitioners and academia have become increasingly interested in how successful software architecture can be achieved. The aim of this study is to identify and describe such quality management activities relating to software architecture management (SAM) which could be suggested to promote the achievement of a high-quality successful software architecture. In the following, these activities are called SAM-related quality management (QM) activities. By identifying these QM activities, this study aims to help an organisation's processes developers, quality managers and architects to design and develop architecture management processes that aim at high-quality architectures.

Development work and research on SAM related QM practices have already been conducted in the recent years. A variety of methods and best practices, which could be utilized in the quality management of software architectures, are being developed and studied. Process models and approaches for the architectural design have been developed (e.g. by de Bruin and van Vliet (de Bruin and van Vliet 2003) and Chung et al (Chung et al. 1995)). Architecture evaluation methods (e.g. ATAM (Kazman et al.



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1998), ARID (Clements 2000), ALMA (Bengtsson et al. 2004)) and principles (e.g. by Barbacci (Barbacci et al. 1997)) are being developed and studied for the assessment of architectures. Architecture review practices are also discussed, for example, by Maranzano et al. (Maranzano et al. 2005) and Kazman and Bass (Kazman and Bass 2002) and quality assessment criteria and metrics have been investigated, for example, by Hilliard et al. (Hilliard et al. 1996), Losavio et al. (Losavio et al. 2003) (Losavio et al. 2004) and Dias et al (Dias et al. 1999). However, architecture management processes and process activities which promote the achievement of high-quality software architectures have only been briefly discussed or completely ignored in previous research.

This research involved reviewing the quality management literature on QM activities that are relevant for architectural design and development. These activities, presented in sections 3 and 4, were distilled from various quality standards (e.g. ISO standards) and process maturity models (e.g. CMMI) plus articles and books on quality management implementation (e.g. (Juran and Godfrey 2000)). Moreover, in order to collect empirical data for the present study, a group interview was organised for a focus group of practitioners from four ICT service providers and user organizations. As a result, this study presents a number of quality management activities relating to SAM.

This study consists of the following sections. Firstly, section 2 presents the research method used in this study. Secondly, sections 3 and 4 present the results of this study: the quality management activities relating to software architecture management. Section 5 compares the results with the current state of architecture management in ICT service provider and user organisations. Finally, section 6 summarizes the study and presents areas for further examination.



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## 2 Research Method

In order to identify and analyse the quality management activities relating to software architecture management, a series of the following research phases was used in this study.

*Phase 1. The study of quality management literature, standards and maturity models*

Firstly, a list of general product and process quality management activities, mentioned in previous research, standards and process maturity models, was produced. ISO standards and CMMI were especially considered. The list of activities was analysed and the objectives and activities were organised into groups.

*Phase 2. Applying the QM activities to SAM*

The phases of software architecture management were analysed against the identified QM activities. A proposal was produced in which it was described which QM activities could be executed in a certain phase of software architecture management.

*Phase 3. Empirical research: A focus group interview (Krueger and Casey 2000) of practitioners*

A semi-structured group interview for a focus group of practitioners from four ICT user and service provider organisations was organised. The practitioners were specialists of the management of software and enterprise architectures. The goal of the interview was to collect activities from the practitioners. A proposal of SAM-related QM activities was presented in the interview, and the interview was thus structured according to them. The practitioners reviewed the proposal based on their own practical experiences. Moreover, they were also asked to add new activities to the results on the basis of their practical experiences. The interview was tape-recorded and notes were written during the interview session. Based on this data a list of QM activities for software architecture management was produced.

*Phase 4. Consolidation and analysis of results*

The results from the empirical study and previous research were combined. These results are presented in chapters 3 and 4.



### 3 Quality Management of SAM Process

In this study attention was paid to both process and product quality aspects. Moreover, it was established that the quality management activities of software architecture management can be divided as follows:

- 1) *Activities that relate to the quality management of SAM process.* These activities are included in the organization's processes and project management and concentrate on the quality of SAM-process (process quality aspect).

and

- 2) *Activities that relate to the quality management of SA.* These activities are included in the SAM-process phases and concentrate on the achievement of software architecture of good quality (product quality aspect).

In this chapter the QM activities that relate to the quality management of the SAM-process are presented. The QM activities included in the SAM-process are presented in chapter 4.

The quality of architecture is influenced by the process used to acquire, develop, and maintain it. The process capability and quality management activities presented in table 1 were identified as being related to the QM of SAM process.

Table 1. Quality management activities of the software architecture management process.

Activity	Adapted from	Description
<b><i>Organisational Policy</i></b>		
Establishing and maintaining an organisational policy for planning and performing the software architecture management (SAM) process.	(Chrissis et al. 2003), [FGI] = according to focus group interview	
<b><i>Development of SAM Process</i></b>		
Planning and developing a process which is able to produce and manage the software architecture in the operating conditions.	(Chrissis et al. 2003), (Juran and Godfrey 2000), [FGI]	Paying attention especially to: <ul style="list-style-type: none"> <li>• the change management of requirements and architectural designs and</li> <li>• the document management of architectural documents.</li> </ul>



<b>Activity</b>	<b>Adapted from</b>	<b>Description</b>
Proving then that the process can produce, develop and manage software architectures under operating conditions.	(Juran and Godfrey 2000), [FGI]	
Optimizing the process features and goals.	(Juran and Godfrey 2000), [FGI]	
Maintaining the plan for performing the SAM process.	(Chrissis et al. 2003)	
Establishing and maintaining the description of the SAM-process.	(Chrissis et al. 2003)	
Transferring the SAM-process to operations.	(Juran and Godfrey 2000)	Implementing the plan for transfer and validating transfer.
<b><i>Process management</i></b>		
Providing resources (e.g. staff, time, funding) and assigning responsibility and authority for performing the SAM-process, developing the architecture related work products, and providing the services of the SAM-process.	(Chrissis et al. 2003)	
Identifying and involving the relevant stakeholders of the SAM-process as planned.	(Chrissis et al. 2003)	
Training and advising the people performing or supporting the SAM-process as needed.	(Chrissis et al. 2003), [FGI]	
<b><i>Quality Objectives / Goals</i></b>		
Establishing and maintaining quantitative quality objectives for the SAM-process that address quality and process performance based on customer and stakeholder needs and business objectives.	(Chrissis et al. 2003), [FGI]	
Establishing general (no project-specific) optimal quality goals for the SAs that are produced by SAM-process.	(Juran and Godfrey 2000), [FGI]	
<b><i>Quality Measurement and Metrics</i></b>		
Planning process measurements.	(Juran and Godfrey 2000), [FGI]	Deciding what aspects of the SAM-process to measure and choosing the metrics.
Planning software architecture evaluation.	(Juran and Godfrey 2000), [FGI]	Deciding what aspects of the software architectures to evaluate and choosing the metrics.
<b><i>Evaluation of Process Performance</i></b>		
Evaluating the actual performance of the SAM-process, comparing the actual performance of the process with quality goals and acting on difference.	(Chrissis et al. 2003), (Juran and Godfrey 2000)	





Activity	Adapted from	Description
Monitoring and controlling the SAM process against the plan for performing the process and taking appropriate corrective action.	(Chrissis et al. 2003)	
Objectively evaluating adherence of the SAM-process against its process description, standards, and procedures, and addressing non-compliance.	(Chrissis et al. 2003)	
Reviewing the activities, status, and results of the SAM-process with higher level management and resolving issues.	(Chrissis et al. 2003)	
<b>Process Improvement</b>		
Ensuring continuous improvement of the SAM process in fulfilling the relevant business objectives of the organisation.	(Chrissis et al. 2003)	
Collecting work products, measures, measurement results and improvement information derived from planning and performing the SAM process and from architectures produced by the SAM process.	(Chrissis et al. 2003), [FGI]	Information can be used to support the future use and improvement of the organization's processes, process assets and architectures.
Identifying and correcting the root causes of defects and other problems in the SAM process.	(Chrissis et al. 2003)	

## 4 Quality Management of Software Architecture

In this study we identified the following list of quality activities that can be executed and included in the software architecture management process.

### 4.1 Capturing Architectural Requirements and Understanding Them

Architectural requirements capturing related QM activities are as follows.

#### *Requirements Collection*

- Planning the collection of requirements. Planning to collect customer and stakeholder needs (“af = adapted from (Juran and Godfrey 2000)).
- Identifying customers and stakeholders. Identifying both internal and external customers and stakeholders (af (Juran and Godfrey 2000)).
- Identifying what requirements and boundaries organisation's strategy and ICT strategies set for the system [FGI].
- Identifying all relevant standards, regulations, and policies (af (Juran and Godfrey 2000)).



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- Describing the existing environment and identifying boundaries that the existing environment sets for the system [FGI].
  - Identifying the possible change situations. Identifying how the company's environment and the system operation environment may change. [FGI]
  - Identifying also the long term requirements for architecture [FGI].
  - Finally, collecting the requirements. Collecting a list of customers' and stakeholders' needs, expectations, constraints, and interfaces in their language (af (Juran and Godfrey 2000; Chrissis et al. 2003)).

#### *Analysis of Requirements*

- Analyzing, validating and prioritizing customers' and stakeholders' requirements and needs (af (Juran and Godfrey 2000)). Grouping together related requirements and needs (af (Juran and Godfrey 2000)).
- Developing a definition of required functionality and quality attributes for the system (af (Chrissis et al. 2003)).
- Identifying architecturally significant needs/requirements by identifying architecturally significant functionality and architecturally significant quality attributes of the requirements definition [FGI].
- Executing language transfer. Translating architecturally significant needs and requirements into the language of a software architecture development team (af (Juran and Godfrey 2000)).

## **4.2 Designing Architecture**

QM activities related to the architectural design are as follows.

#### *Preparation for architectural design*

- Identifying what is needed so that the architectural designs can be delivered without deficiencies (af (Juran and Godfrey 2000)). Defining design process and other practices.
- Determining methods for identifying architectural features (af (Juran and Godfrey 2000)).

#### *Architectural design*

Designing and developing a software architecture that can respond to the needs and suit the environment (af (Juran and Godfrey 2000)).



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- Firstly, determining which architectural features and goals will provide the optimal benefit for the customer/stakeholders (af (Juran and Godfrey 2000)).
  - Selecting main structures of architecture by selecting high-level architectural features and goals (af (Juran and Godfrey 2000), [FGI]).
  - Selecting and designing detailed structures of architecture. Developing detailed architectural features and goals (af (Juran and Godfrey 2000), [FGI]).
  - Addressing all relevant standards, regulations, and policies (af (Juran and Godfrey 2000)) in the design process.
  - Optimising architectural features and goals. Optimising the software architecture features so as to meet stakeholder needs as well as customer needs (af (Juran and Godfrey 2000)).
  - Finally, setting and publishing the final architectural design.

### **4.3 Analyzing / Evaluating and Certification of Architecture**

QM activities related to architecture evaluation/analysis are as follows.

- Establishing project-specific optimal quality objectives for software architecture (af (Juran and Godfrey 2000), [FGI]).
- Deciding the evaluation criteria and metrics by creating project-specific measurements of quality for software architecture (af (Juran and Godfrey 2000), [FGI]) and identifying the unit of measurement for each customer need (Juran and Godfrey 2000).
- Deciding the explicit criteria to be used in evaluating alternative architectural designs and design features.
- Executing the evaluations. Evaluating and measuring architectural features in the suitable phases of the system life cycle (af (Juran and Godfrey 2000), [FGI]).
- Executing the certification of architecture. Architecture certification can be seen as an act of attesting that the system will meet a certain standard or, generally, as an act of verifying conformance with certain requirements.

### **4.4 Architecture Implementation**

QM activities related to architecture realization / implementation are as follows.

- Before the implementation, proofing and testing the architectural concept by implementing the main structures of the architecture [FGI].



- Producing an implementation plan.
- During the implementation, organising the architecture advisor who gives advices on how to conduct the implementation of the architecture [FGI].
- Collecting feedback from the architecture implementation (e.g. problems occurring in the architecture implementation) [FGI].

## 4.5 Maintaining and Improving Architecture

QM activities related to architecture maintenance and improvement are the following update and evolution activities.

- During the system maintenance, identifying and correcting the causes of defects and other problems in the architecture (af (Chrissis et al. 2003)).
- Making other minor changes for the architecture (e.g. construction of a new interface to the system in the integration situation) [FGI].
- Identifying the development needs of the architecture.
- Proving the development or improvement needs of the architecture (af (Juran and Godfrey 2000)).
- Establishing the infrastructure for improvement (af (Juran and Godfrey 2000)). Identifying the improvement project(s) and establishing project team(s) (af (Juran and Godfrey 2000)). Providing the teams with resources, training, and motivation to 1) diagnose the causes and 2) stimulate remedies (af (Juran and Godfrey 2000)).
- Conducting a diagnostic journey from symptom to cause. This includes analyzing the symptoms, theorizing as to the causes, testing the theories and establishing the causes (af (Juran and Godfrey 2000)).
- Conducting a remedial journey from cause to remedy. This includes developing the remedies, testing and proving the remedies under the operating conditions, dealing with resistance to change, and establishing controls to hold the gains (af (Juran and Godfrey 2000)).
- Finally, implementing remedies and controls (af (Juran and Godfrey 2000)).

## 4.6 Documenting Architecture

QM activities related to architecture documentation are the following.

- Documenting at least the following aspects: 1) input information for architectural design and development, 2) architectural plans including architectural decisions, 3) reviewing results by management, and 4) results



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from architectural evaluations/assessments and the measures taken because of the results (af (Curran 2005)). Taking the users of the documentation into account in documentation process.

- Updating and maintaining architectural documentation [FGI].
- Controlling architectural documents to ascertain that they correspond to the organisation's standards.



## 5 Discussion

Quality management activities relating to software architecture management were identified and analysed. The identified activities were categorised to activities that concentrated on the quality of the SAM-process and to activities that concentrated on the quality of software architecture. These identified quality management activities are suggested to promote the achievement of high-quality software architectures.

During the process of defining these activities, the following observations were made. These observations focus on the current state of architecture management and how the results of this study could be applied in organisations.

### **Architecture management is spread out to many processes in organisations**

As mentioned at the beginning of this paper, software architecture management (SAM) consists of the activities of capturing and understanding the architectural requirements of software-intensive systems. Moreover, it includes designing, analyzing/evaluating, realizing, maintaining, improving, and certifying the architecture as well as documenting it (Bass et al. 1998; IEEE 2000). In this study the more detailed activities were also identified. In the focus group interview the idea was raised that these activities, which aim to drive and control the architecture and architectural quality, may be included in several separate processes in organisations. Parts of these activities may be included in, for example, in investment planning, project management, the organisation's processes management and system development process.

Currently, architecture management processes are not so clearly separate processes in organisations. This situation makes the capability assessment of architecture management difficult. In addition, this situation means that the organisations' different processes and the related tasks currently affect on the organisations' architectures and architectural quality.

### **A need to move from architectures driven by investment planning and system development towards architectures driven by architecture management**

Practitioners in the focus group interview described how investment decisions made in the investment planning process and system development choices affected on the organisation's architectures. It seems that single investments on software or a system (e.g. ERP investments) and single system development projects in organisations may drive the organisations' architectures and architectural quality more than organisations' architectural designs and visions (e.g. enterprise architecture). This means that other processes than architecture management processes drive the architectures. This may affect on the quality of an organisation's architectures. A challenge is to change this situation so that architecture management processes start to drive architectures.



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### **A need of architecture management practices and process models that aim at high-quality architectures**

Currently, it is not clear what activities architecture management process should include, in which order these activities should be executed, and what results should be produced relating to the activities. In addition, it is not entirely clear how the system development and architecture management processes should co-operate. For example, it is not clear in which phases of the system development process architecture evaluations should be executed. This study gives answers to the question what activities should or could be executed in architecture management that would focus on the architectural quality. The development work of process models and of the best practices for architecture management which include these identified activities and describe the execution order should be continued.

### **A need to advance the maturity of architecture management processes**

As mentioned previously, the architecture management activities may be spread out to be parts of many processes in organisations, and other processes may drive architectures more than an architecture management processes. This means that there is a need, firstly, to establish the status of architecture management processes in organisations, and secondly, to increase their maturity. This work is already on-going in many organisations. The results of this study aim to help this work by defining such architecture management activities that promote the achievement of high-quality architectures. The results of this study can be used to support this work of establishing of a SAM-process.

### **A need for agility in architecture management and development**

It came up in the focus group interview that it is hard to execute all these QM activities identified in this study in a very quick-moving industrial environment. Restricted time and quick changes in organisations' structures and operations (e.g. companies' mergers) often change organisations' architectures and architecture management processes. In addition, architecture management processes cannot be too heavy (e.g. require a lot of time and resources) although those processes could produce ideal architectures. However, it was also suggested that the maturity of an organisation's architecture management could be higher when more of these QM activities (identified, for example, in this study) are executed in the organisation's architecture management processes. In summary, agile architecture management should be considered in further research.

### **A need for metrics and metric programs for architectural maturity and quality**

In the focus group interview, it was also mentioned that metrics and metric programs for architectural quality should also be developed. Metric programs have traditionally been primarily developed for the measurement of software and software development quality (e.g. Motorola's, IBM Rochester, and Hewlett-Packard's metrics programs (Kan 2005)). As mentioned at the beginning of this paper, the metrics for the



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assessment of architectures and their management processes have been developed for example, by Hilliard et al. (Hilliard et al. 1996) and Losavio et. al. (Losavio et al. 2003) (Losavio et al. 2004). Research and development work must be continued in order to detail and establish evaluation criteria and metrics for architectural quality. Metric programs for architectural quality can then be developed in organisations.

### **Restrictions and limitations in this study**

There are some limitations in this study. Corresponding quality management activities were combined from different sources. Limited number of quality management activities of software architecture management was considered in this study. However, the results give an image of the QM activities in SAM.





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## 6 Conclusion

Architectural quality is one aim of the architecture management process. Evaluation practices for architectural quality and architectural design patterns that support specific quality attributes have been developed and extensively discussed in the previous research. However, the architecture management process activities aiming at architectural quality have only briefly been discussed so far.

This study identified activities that are suggested to promote the achievement of high-quality architectures. The criticality and execution of these SAM related quality management activities in system development need to be assessed based on surveys directed to ICT service providers and user organisations. This question is being addressed in our on-going research.

In addition, a further research question, raised in this study, is how the existing quality standards (e.g. ISO standards) and maturity models (e.g. CMMI) could be applied to the quality management of software architectures.

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