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# QUALITY MANAGEMENT ACTIVITIES FOR SOFTWARE ARCHITECTURE AND SOFTWARE ARCHITECTURE PROCESS

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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 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 software architectures and a good quality software architecture process. These activities are proposed to be taken into account in the software architecture process design, development and capability assessment.

**KEY WORDS**
Software architectures, software architecture process, software engineering, quality assurance, and quality

## 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).

Enterprise and software architecture management processes and their quality management are relatively new parts of organisations' processes. 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 [1, 2].

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. 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 [3] and Chung et al [4]). Architecture evaluation methods (e.g. ATAM [5], ARID [6], ALMA [7]) and principles (e.g. by Barbacci [8]) are being developed and studied for the assessment of architectures. Architecture review practices are also discussed, for example, by Maranzano et al. [9] and Kazman and Bass [10] and quality assessment criteria and metrics have been investigated, for example, by Hilliard et al. [11], Losavio et al. [12, 13] and Dias et al [14]. 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 ISO quality standard, CMMI and Juran's Quality handbook [15]. 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.

## 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 CMMI, ISO standards and Juran's Quality handbook ([15]) was produced. 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** [16] **of practitioners:** A semi-structured group interview for a focus group of practitioners from four ICT user and service provider organisations was organised. The goal of the interview was to collect activities from the practitioners. Practitioners were specialists of the management of software and enterprise architectures. The companies and interviewees are described in the table 1.

The participants from these companies were interviewed as one group in order for group members to influence each other by responding to ideas and comments of others [16]. This group influence came up and new aspects were brought out. However, some aspects may not have been brought out by interviewees due to confidentiality reasons. We presented a proposal of SAM-related QM activities in the interview and in turn structured the interview 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.

Table 1. Interviewees in the focus group interview.

| *Companies* | *Number of interviewees* | *Viewpoints of interviewees* |
|---|---|---|
| Architecture consultation company<br>Number of personnel 10 (year 2005) | 2 | system and software architecture consultation |
| Banking, finance and insurance company<br>Number of personnel 11 974 (year 2005) | 2 | enterprise architecture, management |
| Telecommunication company<br>Number of personnel 4989 (year 2005) | 2 | enterprise architecture, management |
| Business & IT consulting and development organization<br>A part of a large international company having 329 373 employees (year 2005) in total | 1 | software architecture, management, marketing |

*Data collection:* 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. In the results, the factors identified in the literature review are marked with the literature reference. The factors identified purely from the interview data are marked with the marking [FGI] and these factors are without literature reference. The factors recognized both from the interview data and from literature are marked both the literature reference and [FGI].

## 3. Quality Management of SAM Process

In this study attention was paid to both process and product quality aspects. 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 concentrate on the quality of SAM-process (process quality aspect).
2) *Activities that relate to the quality management of SA*. These activities 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 2 were identified as being related to the QM of SAM process.

Table 2. Quality management activities of the software architecture management process.

| Activity | Adapted from |
|---|---|
| ***Organisational Policy*** | |
| Establishing and maintaining an organisational policy for planning and performing the software architecture management (SAM) process. | [17], [FGI] = according to focus group interview |
| ***Development of SAM Process*** | |
| Planning and developing a process which is able to produce and manage the software architecture in the operating conditions. | [17], [15], [FGI] |
| Proving then that the process can produce, develop and manage software architectures under operating conditions. | [15], [FGI] |
| Optimizing the process features and goals. | [15], [FGI] |
| Maintaining the plan for performing the SAM process. | [17] |
| Establishing and maintaining the description of the SAM-process. | [17] |
| Transferring the SAM-process to operations. | [15] |
| ***Process management*** | |
| 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. | [17] |
| Identifying and involving the relevant stakeholders of the SAM-process as planned. | [17] |
| Training and advising the people performing or supporting the SAM-process as needed. | [17], [FGI] |
| ***Quality Objectives / Goals*** | |
| 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. | [17], [FGI] |
| Establishing general (no project-specific) optimal quality goals for the SAs that are produced by SAM-process. | [15], [FGI] |
| ***Quality Measurement and Metrics*** | |
| Planning process measurements. | [15], [FGI] |
| Planning software architecture evaluation. | [15], [FGI] |
| ***Evaluation of Process Performance*** | |
| Evaluating the actual performance of the SAM-process, comparing the actual performance of the process with quality goals and acting on deviations. | [17], [15] |
| Monitoring and controlling the SAM process against the plan for performing the process and taking appropriate corrective action. | [17] |
| Objectively evaluating adherence of the SAM-process against its process description, standards, and procedures, and addressing non-compliance. | [17] |
| Reviewing the activities, status, and results of the SAM-process with higher level management and resolving issues. | [17] |
| ***Process Improvement*** | |
| Ensuring continuous improvement of the SAM process in fulfilling the relevant business objectives of the organisation. | [17] |
| 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. | [17], [FGI] |
| Identifying and correcting the root causes of defects and other problems in the SAM process. | [17] |

## 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.

QM activities related to **architectural requirements capturing and understanding** are as follows.

Requirements Collection

- Planning the collection of requirements. Planning to collect customer and stakeholder needs ("af = adapted from [15]).
- Identifying customers and stakeholders. Identifying both internal and external customers and stakeholders (af [15]).
- Identifying what requirements and boundaries organisation's strategy and ICT strategies set for the system [FGI].
- Identifying all relevant standards, regulations, and policies (af [15]).
- 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 [15, 17]).

Analysis of Requirement*s*

- Analyzing, validating and prioritizing customers' and stakeholders' requirements and needs (af [15]). Grouping together related requirements and needs (af [15]).
- Developing a definition of required functionality and quality attributes for the system (af [17]).
- 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 [15]).

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 [15]). Defining design process and other practices.
- Determining methods for identifying architectural features (af [15]).

*Architectural design*

Designing and developing a software architecture that can respond to the needs and suit the environment (af [15]).

- Firstly, determining which architectural features and goals will provide the optimal benefit for the customer/stakeholders (af [15]).
- Selecting main structures of architecture by selecting high-level architectural features and goals (af [15], [FGI]).
- Selecting and designing detailed structures of architecture. Developing detailed architectural features and goals (af [15], [FGI]).
- Addressing all relevant standards, regulations, and policies (af [15]) 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 [15]).
- Finally, setting and publishing the final architectural design.

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

- Establishing project-specific optimal quality objectives for software architecture (af [15], [FGI]).
- Deciding the evaluation criteria and metrics by creating project-specific measurements of quality for software architecture (af [15], [FGI]) and identifying the unit of measurement for each customer need [15].
- 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 [15], [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.

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].

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 [17]).
- 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 [15]).
- Establishing the infrastructure for improvement (af [15]). Identifying the improvement project(s) and establishing project team(s) (af [15]). Providing the teams with resources, training, and motivation to 1) diagnose the causes and 2) stimulate remedies (af [15]).
- 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 [15]).
- 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 [15]).
- Finally, implementing remedies and controls (af [15]).

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 from architectural evaluations/assessments and the measures taken because of the results (af [18]). 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 and a good quality software architecture process. 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 [1, 2]. 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.

**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 [19]). As mentioned at the beginning of this paper, the metrics for the assessment of architectures and their management processes have been developed for example, by Hilliard et al. [11] and Losavio et. al. [12, 13]. 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. In addition limited number of sources was studied. 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.

## 6. Conclusion

Architectural quality is one aim of the architecture management process. Evaluation practices for architectural quality 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 and a good quality software architecture process. The criticality and execution of these architecture management related quality management activities in system development need to be assessed based on surveys directed to ICT service providers and user organisations.

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## References

[1] IEEE, IEEE recommended practice for architectural description of software-intensive systems, 2000.
[2] L. Bass, P. Clements, & R. Kazman, *Software architecture in practice* (Boston, MA, USA: Addison-Wesley, 1998).
[3] H. de Bruin, & H. van Vliet, Quality-driven software architecture composition, *Journal of Systems and Software*, *66*(3), 2003, 269-284.
[4] L. Chung, B. A. Nixon, & E. Yu, An approach to building quality into software architecture, *Proc. The 1995 Conference of the Centre for Advanced Studies on Collaborative research*, Toronto, Ontario, Canada, 1995, 13
[5] R. Kazman, M. Klein, M. Barbacci, T. Longstaff, H. Lipson, & J. Carriere, The architecture tradeoff analysis method, *Proc. The Fourth IEEE International Conference on Engineering of Complex Computer Systems, ICECCS '98*, Monterey, CA, 1998, 68-78.
[6] P. C. Clements, Active reviews for intermediate designs, cmu/sei-2000-tn-009, 2000.
[7] P. Bengtsson, N. Lassing, J. Bosch, & H. van Vliet, Architecture-level modifiability analysis (alma), *Journal of Systems and Software*, *69*(1-2), 2004, 129-147.
[8] M. R. Barbacci, M. H. Klein, & C. B. Weinstock, Principles for evaluating the quality attributes of a software architecture, technical report cmu/sei-96-tr-036, 1997.
[9] J. F. Maranzano, S. A. Rozsypal, G. H. Zimmerman, G. W. Warnken, P. E. Wirth, & D. M. Weiss, Architecture reviews: Practice and experience, *IEEE Software*, *22*(2), 2005, 34-43.
[10] R. Kazman, & L. Bass, Making architecture reviews work in the real world, *IEEE Software*, *19*(1), 2002, 67-73.
[11] R. Hilliard, M. Kurland, J., S. Litvintchouk, D., T. Rice, & S. Schwarm, Architecture quality assessment, version 2.0, 1996.
[12] F. Losavio, L. Chirinos, N. Lévy, & A. Ramdane-Cherif, Quality characteristics for software architecture, *Journal of Object Technology*, *2*(2), 2003, 133-150.
[13] F. Losavio, L. Chirinos, A. Matteo, N. Lévy, & A. Ramdane-Cherif, Iso quality standards for measuring architectures, *The Journal of Systems and Software*, *72*(2), 2004, 209-223.
[14] O. P. Dias, I. C. Teixeira, & J. P. Teixeira, Metrics and criteria for quality assessment of testable hw/sw systems architectures, *Journal of Electronic Testing: Theory and Applications*, *14*(1-2), 1999, 149-158.
[15] J. M. Juran, & A. B. Godfrey, *Juran's quality handbook* (McGraw-Hill Publishing Co, 2000).
[16] R. A. Krueger, & M. A. Casey, *Focus groups: A practical guide for applied research* (Sage Publications, Inc., 2000).

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[17] M. B. Chrissis, M. Konrad, & S. Shrum, *Cmmi: Guidelines for process integration and product improvement* (Addison-Wesley Professional, 2003).
[18] ISO 9001:2001 standard
[19] S. H. Kan, *Metrics and models in software quality engineering* (Boston: Addison-Wesley, 2005).