# Architecting and Coordinating Thousands of Requirements – An Industrial Case Study

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**Abstract.** [**Context & motivation**] When large organizations develop systems for large markets, the size and complexity of the work artefacts of requirements engineering impose critical challenges. **[Problem]** This paper presents an industrial case study with the goal to increase our understanding of large-scale requirements engineering practice. We focus on a senior requirements engineering role at our case company, called requirements architect, responsible for quality and coordination of large requirements repositories. **[Results]** Based on interviews with 7 requirements architects, we present their tasks and views on architecture quality. **[Contribution]** Our results imply further research opportunities in large-scale requirements engineering.

**Keywords:** Large-scale requirements engineering; Empirical study; Requirements repositories; Requirements dependencies; Requirements architect.

## 1 Introduction

Large software companies are often confronted with large and complex requirements repositories. The requirements originate from multiple sources and address multiple customers and market segments. This paper presents an industrial case study of the tasks involved in managing large and complex requirements repositories. The investigated tasks are related to a role called *Requirements Architect* that has recently been introduced at the case company. The requirements architects are responsible for the scope of large platform projects that products are based on [4]. Our motivation to perform this study was to understand current practices in working with large-scale requirements repositories and to find issues for future research. In this study, we have conducted interviews with requirements architects in order to address the following questions: (1) What are the tasks related to working with large-scale complex requirements repositories on multiple products platform projects? (2) How do practitioners perceive the notion of *requirements architecture* and how do they describe good requirements architectures?

The second question is related to sustainable requirements architectures [5]. With the term requirements architecture we mean the underlying structure of requirements, including the data model of requirements with their pre-conceived and emerging

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attributes and relations. By sustainable architectures we mean structures that allow for controlled growth while allowing requirements engineers to keep track of the myriad of issues that continuously emerge. Practitioners facing a transformation to large-scale requirements engineering (RE) may use this research to gain insights in what may come, and researchers may use the results to inform their choices of future research directions.

The paper is organized as follows: Section 2 describes the industrial context at the case company. Section 3 provides the methodology description. Section 4 and 5 highlights the result of interviews. Section 6 concludes the paper.

## 2 Industrial Case Context

The interview study was performed at Sony Ericsson. Due to the technological complexity of the domain, the case company is working in parallel in many advanced system engineering areas such as radio technology, audio and video, and positioning. The complexity of requirements engineering is driven by a large and diverse set of stakeholders, both external to the company and internal. Different stakeholders have different demands on the future functionality of the mobile phone which they express by different types of requirements. Requirements originating from external stakeholders are called *market requirements.* They are mainly supplied by mobile operators, which usually submit specifications with thousands of requirements that require gap analysis. Other sources of requirements are the *Application Planning* and *Product Planning* departments. The platform and market requirements also have to be checked against supplier requirements to ensure that certain functionality can be delivered by a corresponding platform project, including integration of subcontracted parts. Currently, the case company's requirements database contains around 30 000 platform system requirements and a few thousands supplier requirements. The platform system requirements are organized into *features* that represent the smallest units that can be scoped into or out from the platform project [2]. The case company develops products using a product line engineering approach, where one platform project is the basis for many products that reuse the platform project's functionality and qualities [4]. Within the platform project, the case company has defined a number of requirements engineer groups called *Technical Working Groups* (TWGs). They are responsible for elicitation, specification and prioritisation of high-level requirements within a specific sub-domain. Within this industrial context, requirements architects work mainly with platform system requirements and features. Their main responsibility is the management of the scope of platform projects by helping TWGs to specify requirements and project management to see all implications of the scoping decisions. The scoping decisions are made by a *Change Control Board (CCB).*

## 3 Research Methodology

To study individual perceptions of requirements architect role at the case company, we conducted seven semi-structured interviews [6]. Before conducting interviews, a brainstorming and planning meeting was conducted. During this meeting, the scope of

the study was agreed upon and an interview instrument was developed with a set of questions, where the wording could be changed and the order could be modified based upon the interviewer's perception [6]. The third author, acting in his role as manager for requirements architects at the case company, participated in the development of the interview instrument and invited seven interviewees with various experience within the requirements architect role. These persons were chosen from three sub-organizations within the case company, each responsible for products for different market segments. It was sent out via email to all the participants in advance and also discussed at the beginning of each interview to ensure that the scope of the interview was understandable. The interviews were held during the autumn of 2007 and varied in length between 60 and 110 minutes. All interviews were attended by two interviewers and one interviewee. Questions were kept simple and effort was put on avoiding leading or biased questions [6]. All interviews were transcribed. After transcription, each of the interviewees received the transcripts for validation. Interviewees analysed their transcripts in order to ensure that the interviewers heard and understood the recordings and notes correctly. In case of misinterpretations, corrections and comments were sent back to the researchers. The data was then imported to a spreadsheet program to perform a content analysis [3] based on categorisation. The categories such as tasks or notion of requirements architecture quality, were chosen based on the interview instrument topics and other emerging topics in the interviews. Additionally, for each category notes describing problems and improvements were added. Finally, the results were validated by two interviewees that gave independent comments to the proposal of the tasks derived from the interviews.

## 4 Tasks of the Requirements Architect in the Case Company

Based on the analysis of interviews, we have identified six tasks, listed in Table 1, that represent what is considered to be important obligations of the requirements architect role when acting as a senior coordinator in a large-scale setting. Several tasks (T1, T4, and T5) are directly related to change management. In order to cope with the initial definition of the platform projects scope and later incoming change proposals to the platform projects, requirements architects facilitate communication across

**Table 1.** Tasks and goals for requirements architect in the case company

| Task | Goal |
|---|---|
| **T1: Scope management** | Ensure that the platform project scope changes are addressed and that the change proposals are prepared. |
| **T2: Gap analysis** | Ensure that misalignments between market requirements and supplier requirements are addressed. |
| **T3: Enforce requirements quality improvements** | Check the quality of requirements. Alert if requirements quality improvements are needed. |
| **T4: Drive CCB investigations** | Drive change proposal investigations in order to gain understanding of the impact of the scope changes. |
| **T5: Present the scope** | Present the scope of the platform project at milestones. |
| **T6: Request requirements architectures improvements** | Ensure that the requirements structure is maintained according to defined rules. |

different groups of requirements engineers. This may indicate that the complexity in both requirements inter-dependencies and organisational structure in the large-scale case imply hard challenges in communicating decisions about changes. The analysis of gaps between market requirements and what is offered by technology suppliers (T2) is increasingly complicated as the number of stakeholders on the market increases and the number of technical areas that are covered gets larger.

Also, for a basic and common task such as checking the quality of requirements (T3), interviewees express challenges related to the cohesion of complex multilayered requirements structures that originate from multiple sources. In our case, requirements architects have to drive complex changes (T4) that span over many technical areas and may impact many product releases in one platform. Another challenge related to these investigations is the ability to ensure that investigations are made by the right persons with the right competence and that the full impact picture will be ready before CCB decision meetings. Missing some of the aspect may have a great impact on the whole platform project. In a large scale case, the task of presenting the current scope (T5) is especially demanding as the requirements architect must understand both technical aspects as well as the business and market impact of all features in order to conclude them in a way that is meaningful to high-level management and marketing. Finally, we report that in a case like the one we have examined, where several parallel large platform projects coexist, there is an expressed need for a person with a holistic view that has a mandate to request requirements architecture improvements (T6). In this case, the responsibility for ensuring architectural consistency of requirements is not delegated to the projects, but is managed across projects by requirements architects.

## 5 Views on Requirements Architecture and Its Quality

In our interviews with practitioners we have confirm our pre-understanding that the concept of requirements architecture is complex and include many aspects. We have deliberately not imposed a pre-conceived, closed definition of the concept on our interviewees, as we wanted to base our understanding of the requirements architecture on empirical data. We cannot say that a single, generally accepted definition of requirements architecture has emerged, but our findings indicate that all interviewed practitioners included some of the following aspects in their views on requirements architecture: (1) the requirements entities themselves (such as features, system requirements, detailed requirements, functional requirements, quality requirements, etc) and their relationships; (2) the information structure (meta-model) of requirements entities including (a) attribute types of entities, and (b) the relationship types including different types of dependencies to other entities; (3) the evolution of the information structure (a) over time and (b) across abstraction levels as entities are refined both bottom-up and top-down; (4) the implications of organisational structures on requirements structures; (5) the implications of process and methodology on requirements structures; (6) the implementation of tool support and its relation to requirements structures, organisation, process, methodology etc.; (7) the scalability of the requirements structures as the number of entities increase and the interrelated set of entities gets more complex.

In our interviews with requirements architects, we also discussed the notion of quality of requirements architectures. We started the discussion based on the analogy of how system architecture quality supports good design and implementation of systems, and transferred this analogy to how requirements architecture quality supports good requirements engineering. The following quality issues were identified when analysing interview transcripts:

**Understandability and cohesion.** Responders expressed the opinion that a good requirements architecture should be easy to understand and designed to enable a holistic view of different types of modules and abstraction levels in order to enable easy identification of vital information. Furthermore, the way how the structure of requirements information is visualized was also mentioned by our responders as an important factor influencing mentioned quality issues.

**Robustness, integrity and enforcement of policies.** An established process for managing and architecting requirements can result in a consistent, reliable and robust requirements architecture. Lack of clear policies and working rules may result in low reliability of requirements as well as discrepancies in usage of the architectural policies across projects.

**Extensibility, flexibility and efficient traceability.** According to our responders, a good requirements architecture should allow for controlled growth by being extensible and flexible without endangering the previously mentioned qualities of robustness and integrity. Cost-efficient traceability among requirements at different levels of abstraction when continuous growth and refinement occur is important. A good balance between extensibility, flexibility and traceability on one hand and the complexity driven by these qualities on the other hand has to be achieved in order to avoid the risk of ending up with an unmanageable repository.

## 6 Conclusions

This paper presents tasks related to a role called requirements architect, which is working with large and complex requirements repositories at the case company. We also present practitioners views on quality attributes of the artefact called requirements architecture. Efficient management of large sets of information is considered to be crucial in many disciplines. Similar to software architecture, the information model is considered to be not only a technical blueprint for a software-intensive system, but it also includes social, organisational, managerial and business aspects of the software architecture [1]. At our case company, the requirements architecture is an artefact that is managed separately, but in relation to the system architecture, and interviewees express a range of issues that need to be addressed, both soft issues such as organisation and business models as well as technical aspects.

The requirements architect role at our case company is motivated by a perceived need of special attention to cross-cutting issues, and inter-disciplinary communication across sub-domains and technical areas. We found several tasks of normal requirements engineering practice, such as change management, scoping and specification quality enforcement that is viewed as particularly challenging in the studied large-scale setting, and therefore included in the responsibilities of requirements architects acting as senior coordinators of the requirements engineering process. We also found

expressions for specific quality aspects of the requirements architecture itself that are viewed as important to support an effective and efficient management of an increasingly large and complex repository.

In relation to the concept of requirements architecture, we highlight the following areas to be considered in further research:

- Continued conceptual and empirical investigation of the notion of requirements architecture.
- Investigations on features of computer-aided tools for managing requirements architectures.
- Studies of the organisational and process aspects in relation to requirements architectures.
- Development of assessment instruments for requirements architecture quality and competence certification of requirements architects.
- Analysis methodology and visualisation models for requirements architectures in large-scale product line engineering.

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