A Case Study on Specifying Quality Requirements Using a Quality Model

Conference Paper · December 2012

DOI: 10.1109/APSEC.2012.57

Klaus Lochmann
IBM Deutschland GmbH

Daniel Méndez Fernández
Blekinge Institute of Technology

A Case Study on Specifying Quality Requirements Using a Quality Model

K. Lochmann, D. Méndez Fernández
Technische Universität München, Germany
{lochmann,mendezfe}@in.tum.de

S. Wagner
University of Stuttgart, Germany
stefan.wagner@informatik.uni-stuttgart.de

ABSTRACT

Quality requirements are an often neglected part of requirements engineering. If specified at all, they tend to be either too abstract or very technical and without a rationale. In this paper, we evaluate a quality requirements approach, which makes use of activity-based quality models. To this end, we conduct a comparative case study at Siemens in which we compare the requirements resulting from applying our quality model with the requirements previously used in the same environment. The results indicate an improvement of the requirements regarding, e.g., structuredness and traceability, but also that the productivity perceived by the industry participants could not be increased. The study thus gives first insights into strengths and limitations of using a quality model in an industrial requirements engineering process.

Categories and Subject Descriptors

D.2.1 [**Software Engineering**]: Requirements/Specification; D.2.9 [**Software Engineering**]: Management—*Software Quality Assurance (SQA)*

General Terms

Documentation, experimentation

Keywords

Quality requirements, quality model, industrial case study

1. INTRODUCTION

Quality requirements are part of the *non-functional* requirements of a system, which specify properties of the system that are not its primary functionality. Such properties are typically crucial for making a product attractive, usable or reliable. Although quality requirements are a decisive factor in the success of a system, they are an often neglected issue in the requirements engineering process.

The underlying problem is that quality itself is a complex and multifaceted concept. This is especially true for the intangible product *software*. First, requirements engineers often struggle with specifying quality requirements on a level of abstraction that is suitable for the later phases. Either they remain on a high level of abstraction such as "The system shall be maintainable." or they contain a huge amount of technicalities without a clear connection to stakeholder needs. Second, the elicitation process demands for implicit domain knowledge. One often needs to consider a variety of domain-specific standards and guidelines, whereas it often remains unclear whether, to which extent, and how the contents have to be transformed into useful and appropriate requirements.

In this paper, we evaluate a quality requirements approach that uses a quality model as a means to structure and reuse quality requirements previously inferred from domain-specific standards and guidelines. We investigate in a comparative case study at Siemens the existing specification of a traffic control system and compare it to a new specification produced using the proposed approach. We evaluate to which extent our approach supports the specification of traceable and measurable requirements in direct comparison to the approach preciously used at the same project environment.

Related Work. There exist several approaches considering the elicitation and specification of quality requirements. One type of related approaches attaches quality requirements to functional use-cases and/or misuse-cases [8]. These approaches focus on user-visible characteristics that are directly related to the functionality of the system. Another type of approaches is of goal-oriented nature (see, e.g., [9]). Those approaches offer a methodology for eliciting and refining goals, but give no advice on the structuring and specification of quality requirements beside the general notion of goal refinement. Such guidance is given by a third type of approaches relying on taxonomies (see, e.g., [2]).

To the best of our knowledge, however, there barely exist approaches that make use of guidelines and standards structuring them in an ISO 9126-style quality model, and which have been evaluated in a case study, except for the contribution by Doerr et al. [1] reporting on three industrial case studies. Still, they give only an illustrative description of the specified requirements, without a thorough analysis of the produced specifications.

In this paper, we give such an analysis while the introduced case study has a broader focus and a part of it was already published in [5]. In the following, we exclusively focus on the specification of quality requirements, while in [5] the whole specifications and the requirements engineering process is assessed.

2. FUNDAMENTALS

In this section, we briefly introduce the background of our work and give references for further reading.

Quality Model. Our requirements engineering approach relies on activity-based quality models [3, 10]. The basic idea is to describe quality in form of activities conducted with the system. The activities provide a clear decomposition criterion and are related to the stakeholders concerned with them. For describing detailed requirements, the influence of product characteristics on the activities is made explicit. An excerpt of the quality model used in this case study can be found in Figure 1. It expresses, e.g., that adequate contrast of text elements in a graphical user interface positively influences the effectiveness of perceiving the content.

Quality Requirements Engineering Approach. As the use of quality models seems to be promising in requirements engineering, we developed our own approach hereto. To this end, we make use of an artefact-based requirements engineering approach for business information systems' analysis (BISA) [4, 6]. The BISA approach defines a blueprint of the basic modelling concepts for the requirements engineering artefacts, i.e., it proposes data structures and templates for the artefacts to create and a syntactic model of their contents as well as means to integrate the model into comprehensive software processes while guiding the adoption of the contents in projects ("tailoring mechanisms"). In our case study, we use the BISA approach as a reference model to guide the documentation of the requirements specification with a particular focus on the following document templates:

- *Stakeholder specifications* including a reference for modelling individuals, groups, or organisations with a specific interest in the project expressed by goals.
- *Goal specifications* including a reference for modelling prescriptive statements of intents in relation to responsible stakeholders.
- *Scenario specifications* including a reference for modelling activities performed in interaction with a system in relation to the goals to be satisfied and to the stakeholders that participate in the interactions.
- *Quality requirements specifications* including a reference for modelling system quality requirements (and requirements attributes such as the priority) constraining properties and characteristics of a system in relation to the activities (in the use cases) from which the quality requirements have been inferred.

Finally, we subsequently refer with *Quality Requirements Approach* (QR approach) to these process steps covered by the BISA framework. With *QR spec.*, we refer to the specifications (document templates) created according to the BISA artefacts in which we record the elements inferred from the quality model, i.e., the stakeholders, the goals, the scenarios, and the quality requirements.

3. CASE STUDY DESIGN

The case study is subsequently organised according to the guidelines proposed by Runeson and Höst [7].

Research Questions. The goal of this study is to evaluate the suitability as well as the strengths and weaknesses of the proposed quality requirements approach in an industrial context. We use four research questions to structure the study design. We go from the general suitability for industry to detailed questions on the quality of the produced requirements specifications.

RQ 1 *Is the quality requirements approach suitable for an industrial context?*
This research question focuses on evaluating the feasibility of the quality requirements approach in practice. We analyse whether the approach is clear and understandable to practitioners and whether it supports the requirements engineers to be productive.

RQ 2 *Are the quality requirements in the produced specification sufficiently detailed and traceable to user needs?*
To be useful for discussions with stakeholders and to provide guidance to the developers, quality requirements must be detailed enough and traceable to the stakeholders and their needs. In this research question, we examine these two characteristics.

RQ 3 *Are the quality requirements in the produced specification measurable?*
An important criteria for the quality of a requirements specification is the testability of the requirements. Especially quality requirements are often specified in an abstract and unmeasurable manner. In this research question, we examine the produced quality requirements for their testability.

RQ 4 *Does the produced specification contain only necessary quality requirements?*
Specifying quality requirements using a quality model means to use the quality model as a knowledge repository consisting of a large number of possible requirements. Therefore, the approach has to guide the selection of only those requirements that support the satisfaction of the user needs. Furthermore, the specification of requirements excluded due to external constraints or technical decisions must be avoided.

Case and Subjects Selection. We conduct action research and apply the quality requirements approach to a software development project of a company and specify the requirements for a part of the system under consideration. To select a representative part of the system, we hold a discussion between the industry participants and researchers, made up of two steps: First, a set of use cases is selected, referring to the same business topic and comprising a limited set of actors. This way, the requirements approach can be conducted in its entirety, creating all artefacts starting from goals to detailed measurable requirements. Second, a selection is made regarding the quality requirements to be modelled. Since quality requirements are usually of crosscutting nature, it would be very elaborate to model all quality requirements for the use cases. Therefore, one quality characteristic is chosen and only the corresponding quality requirements are modelled. We define three main groups of participants as study subjects:

1. *Industry participants:* Experts from industry that are familiar with the system. Ideally, they have different viewpoints on the requirements specification, e.g., product managers and developers.
2. *Researchers:* Researchers that are familiar with the quality model approach and the BISA approach. They take the role of requirements analyst and actively support the process.
3. *External reviewer:* In order to achieve an unbiased assessment of the produced specifications an external re-

viewer will be called in.

Data Collection Procedures. The collection of the data for the case study comprises the participation of the researchers in the requirements engineering process as well as an assessment of the specifications by internal and external reviewers. We compare the newly produced specification (called QR spec.) to specifications previously used by the industry partner. The existing specifications are documented in Excel sheets and are therefore called *Excel spec.*

We conduct the *Requirements Engineering Process* by following the steps of the quality requirements approach in a series of workshops. At these workshops, the researchers and the industrial participants are present, whereby the researchers take the role of requirements analysts. For each step of the approach, a separate workshop is organised. After each workshop, the researchers work on the quality model and the specifications. At the last workshop, the specification is jointly reviewed and formally accepted by the industry partners.

For the *assessment of the produced specifications*, we develop a questionnaire covering different assessment criteria. For each criteria we ask an open and a closed question to be answered on a Likert-scale from *1 = I strongly disagree* to *8 = I strongly agree*. The open question is used for additional remarks and explanations regarding the selected grade on the Likert-scale.

Table 1 shows the condensed questionnaire with the statements of the closed questions. Because the external reviewer was not part of the specification process, he can only answer the questions directly relating to the specification documents. The internal assessment is a group interview with the industry participants by the researchers, in which the questionnaire is filled-in. As a preparation, the participants review both the Excel spec. and the QR spec. During the group interview the industry participants discuss each question and agree on one rating for each closed question. The obtained insights of the discussion and the explanations of the rating are recorded in the open question. The external assessment is an interview with the external reviewer. As a preparation, he reviews both the Excel spec. and the QR spec. During this interview the questionnaire is filled in. Additionally to the results of the interviews, we analyse and describe the *quality model* and the *requirements specification* by the number of model elements in the quality model and the number of quality requirements in the specification.

Analysis & Validity Procedures. Due to the low number of participants for the questionnaire, statistical hypothesis testing is not applicable. Therefore, we present the results of the closed questions as a radar chart. The free text answers of the questionnaires are then used as additional input for a discussion.

For RQ 4, we analyse the collected quantitative data on produced artefacts. First, we expect the QR spec. to contain only a fraction of the possible requirements available in the quality model. Second, we judge the modularisation of the QR spec. by analysing the distribution of requirements to categories.

Regarding internal validity, we increase the reliability of the statements of the industrial participants by performing a group interview. The interaction between the group members takes the form of a discussion, producing insights that would be less accessible without this technique. Additionally, researcher triangulation is used: in addition to the internal review, the assessment is done by a researcher not participating in the whole process. To mitigate the threat of a bias toward the QR spec. by the external reviewer, he is not involved in the study prior to the actual assessment. Moreover, methodological triangulation is used, by asking both open and closed questions. Through the open questions the interviewees can express their opinion more freely, while the closed questions force them to agree on one statement.

4. CASE STUDY RESULTS

After describing the cases and subjects, we structure the results according to the research questions.

Case Description. The case study is conducted with a department of Siemens AG developing a traffic control system (TCS). The system is a hybrid of geographically distributed embedded controllers in traffic lights and a central information processing and monitoring system. Typical tasks of the monitoring system are (a) to inform the operators on system events they must react to, (b) planning of routine maintenance tasks, and (c) providing statistical analyses on the availability of traffic lights. The TCS is developed further in releases. For each release, Siemens performs a requirements process, which results in a detailed specification.

Regarding the selection of use cases in the kick-off workshop, all participants agreed to model all requirements that are related to the use cases conducted by the operator of the system. As for the selection of a quality characteristic, we elicit and prioritise tasks performed by the operator while focussing on usability aspects.

In a third step, we built a quality model for usability. As a main source of input, we modeled the *Web Content Accessibility Guidelines*[1]. These guidelines offer a collection of rules for designing web pages to make them accessible to people with disabilities.

The entities of the resulting quality model describe user interface components while the activities describe the steps a human is conducting during interaction with a computer: perceive, understand, operate. In Figure 1, we show a simplified excerpt of the quality model. The entities are denoted with rectangles, the properties with rounded rectangles. The impact between product properties and activity properties are shown in a matrix.

[1] http://www.w3.org/TR/2008/REC-WCAG20-20081211/

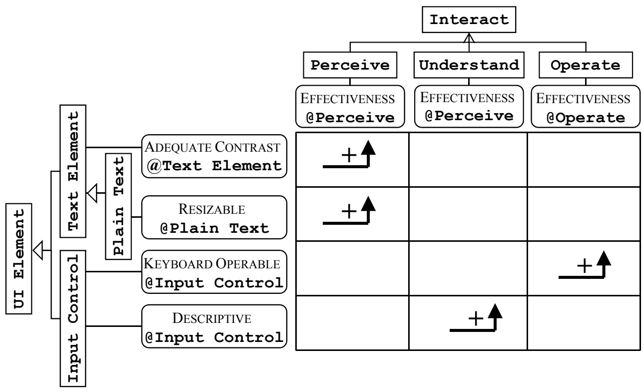


Figure 1: Excerpt of the Quality Model for Usability

Table 1: **Questionnaire for the Assessment (condensed)**

	Criteria	Statement
RQ 1	Ease of use	The process is clear and understandable.
	Productivity	The perceived productivity was high.
	Structuredness	The specification process is systematic.
RQ 2	Syntactic Completeness	All syntactic elements needed to specify the requirements are given.
	Syntactic Minimality	There are no unnecessary syntactic elements in the specifications.
	Traceability	Each requirement has a rationale.
RQ 3	Testability	The fulfillment of each quality requirement is measurable / testable.
	Unambiguity	The quality requirements are stated unambiguously.
	Consistency	There are no contradictory statements in the specification.
RQ 4	Semantic Completeness	All stakeholder needs regarding quality are reflected by the quality requirements.
	Semantic Minimality	There are no needless quality requirements in the specifications.
	Modularity	The specification is organized in modules, separated according to certain topics.

Title	Hotkeys must be complete
Description	Hotykeys are complete if all functions of the system can be accessed via hotkeys.
Constrained Elements	Hotkeys: Hotkeys are an input method to operate a GUI by keyboard.
Id	QR017
Owner	Mr. Anonymous
Priority	High
Rationale	<<*Scenario*>> Operate
Actor	Operator
Explanation	The intention of this requirements is to enable experiences users to faster operate the system.
Quality Attribute	Usability
Source	Quality Model - Product Property F_HqQRcDBQEd-0hqucSf-1pA
State	Accepted

Figure 2: Example of a Quality Requirement

The contents of the resulting specification documents can be summarised as follows. The main stakeholder is the *Operator* using the system. The *Goals* of the operator include to be called on attention if an important system event occurs and to be able to efficiently accomplish his or her tasks with the system. Regarding these goals and the activities of the quality model, 5 scenarios are developed. These scenarios describe the interaction between the operator and the system consisting of three actions: perceiving the output of the system, understanding the perceived output, and operating the system (i.e., providing input to it). The 24 activity properties of the quality model allow to formulate requirements based on the scenarios; for example, (1) operating the system shall be possible by keyboard and (2) operating the system shall prevent unthoughtful actions with lasting consequences. Using the product properties of the quality model, quantitative requirements are derived from the qualitative ones. To prevent unthoughtful actions with lasting consequences, for instance, the quantitative requirement "each transaction commit form must have a prompt for confirmation" is derived. This way, 25 quantitative requirements were derived. These requirements were structured according to the 5 scenarios they belong to. Figure 2 shows an excerpt of the specification: It shows a quality requirement that is documented using a predefined template.

Subject Description. As described in the subject selection, there are three groups of participants. In the group *industry participants* there are two employees of Siemens AG. The *product manager* is responsible for defining the requirements for the control and monitoring system from the customer/user viewpoint. The *project lead* is the head of the development department concerned with the monitoring and control system. Regarding requirements engineering, he is responsible for negotiating the requirements with the product manager. Hence, he has to assess the effort needed for the realisation of the requirements and to assess the requirements' impacts on the existing system. In the further development, he is also concerned with the detailed planning and schedules for the realisation of the requirements.

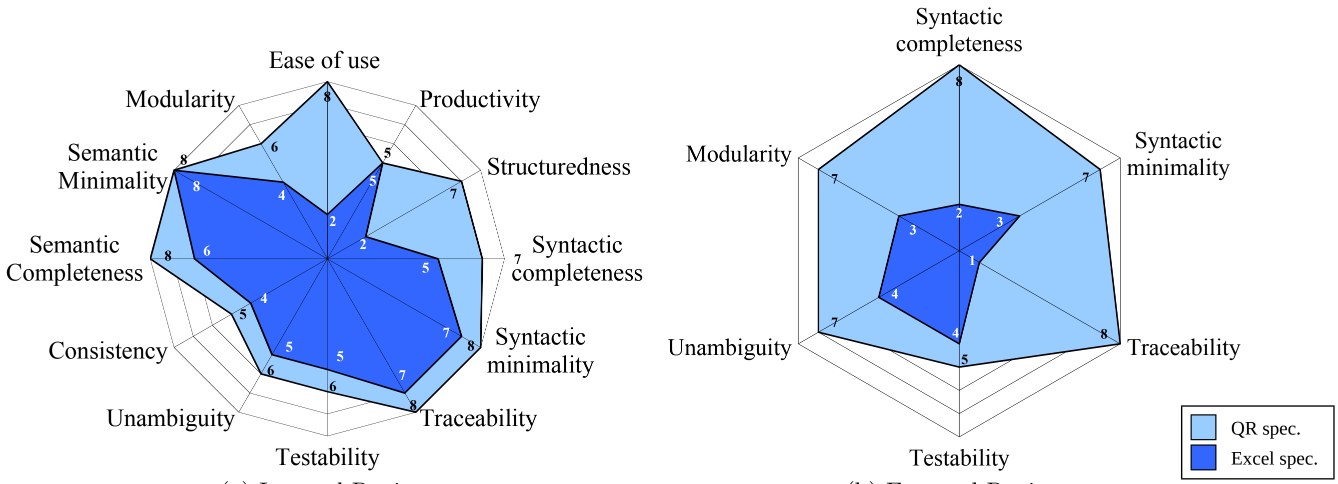
The group of researchers consists of software engineering researchers with a special focus on requirements engineering. K. Lochmann is the main developer of the current version of the quality requirements approach. D. Méndez Fernández is the main developer of the BISA approach and has also a detailed knowledge of the quality requirements approach. As external reviewer acts S. Wagner who was not involved in the earlier steps of the case study. He developed the initial version of the quality requirements approach and has comprehensive knowledge on quality models.

Suitability of the Approach (RQ 1). Figure 3 shows the answers to the questionnaire.

The industry participants judged the QR approach as easier to use. In the interview, they explained that the approach defines a clear process, which defines the actions that have to be conducted. The process to produce the Excel spec. is more ad-hoc and not clearly defined.

As the QR approach gives guidance on elicitation workshops according to logically related requirements clusters, they also saw an increase of the structurednes. Regarding the productivity, they concluded that the heavy-weight process of the QR approach is beneficial if a previously unknown system is specified from scratch. If all participants have already a common understanding of the problem, however, – like in the department where the case study was conducted – then a more lightweight approach is also adequate. Therefore, they judged productivity to be equal in both approaches.

Detailedness and Traceability (RQ 2). Both internal and external reviews assessed the syntactic quality of the specifications. The internal reviewers judged the syntactic completeness to have slightly increased in the QR approach. They explained that in the Excel specification they are able to define columns for all information needed. The use of further description techniques like UML, however, is not possible. The QR approach offers far more syntactic elements and proposes different diagrams for representing requirements, which are better suited for certain kinds of



(a) Internal Review (b) External Review

Figure 3: Questionnaire results as radar plots

information.

The external reviewer judged the QR approach substantially better regarding syntactic completeness. This is because the artefact model and the supported description techniques in the QR approach are more specific and therefore more easy to understand to external people. This assessment is supported by the statement of the internal reviewers that the syntactical elements in Excel are used differently by different people. The meaning of the syntactical elements is often unclear and therefore they are not used consistently.

Both reviews judged that there are less unused syntactic elements in the QR spec.. The external reviewer found out that for example the column *state* in Excel is never used. One possible reason for the syntactic minimality of the QR spec. in contrast to the elements given by the Excel spec. is that the artefact model of the QR approach has been tailored.

The judgment of the traceability is very different by the two types of reviewers. The internal reviewers see a marginal increase in traceability in the QR approach, while the external reviewer assesses the traceability in the Excel spec. with the lowest grade and that of the QR approach with the highest.

The reason for this difference can be found in the explanations the internal reviewers gave in the interview. They acknowledge that there is no rationale for requirements given in Excel. They know, however, that there are other documents in their company where the rationales are implicitly given – for example business proposals. They further acknowledge that background information, like goals, are made explicit in the QR approach.

The difference in the judgment is further explained by the comments of the external reviewer. He could not discover any rationales for requirements in Excel, thus he judged the traceability with the lowest grade. In the QR approach, however, he sees a clear top-down hierarchy given by the refinement notion in the artefact model. Starting from stakeholders and their goals, each requirement serves as a rationale for requirements on a more detailed level of abstraction. Furthermore, the hierarchical structure of the QR spec. simplifies understanding of the specification as a whole.

Measurability of Quality Req. (RQ 3). Both the internal and external reviewers judged the testability of the quality requirements slightly better in the QR approach than in Excel. The internal reviewers stated that in Excel the quality requirements are sometimes very general – like "The topic ABC should be improved". The quality requirements in the QR spec. are better testable. This is because the quality model imposes a rigid structure on them. Furthermore, the quality model defines several attributes that must be filled-in. The external reviewer noticed that in the Excel spec. only for the performance requirements precise test criteria are given. All other types of quality requirements lack them. In the QR approach, detailed test criteria are not given, but the requirements themselves are detailed enough to more easily derive test criteria. Regarding unambiguity of quality requirements, the judgment of the reviewers is very similar. The internal reviewers state that the difference in unambiguity resembles the difference in testability. The external reviewer sees large differences in the Excel spec. regarding unambiguity. Some requirements are high-level while others are detailed and clear. In the QR spec., he sees advantages regarding unambiguity, mainly because the predefined structure gives more guidance. The semantic consistency could be judged only by the internal reviewers, because of their domain knowledge. They rated the semantic consistency for the QR spec. slightly higher than for the Excel spec. Although the difference in the actual specifications is not big, they acknowledge that the structure of the QR spec. is more suitable for helping to find inconsistencies.

Stakeholder-Approp. of Quality Req. (RQ 4). The internal reviewers judged the semantic completeness with the best grade for the QR spec., slightly better than the Excel spec. This is because the integrated approach enforced the discussion and specification of all requirements and their underlying goals. Furthermore, the structuredness and top-down concretisation of requirements strengthens the systematic.

Regarding the semantic minimality, they assessed both specifications with the best possible grade. The reviewers noted that in both specifications they could not find any unnecessary requirements. They added, however, that the Excel spec. contains mostly high-level quality requirements, while the QR spec. has detailed ones. Still, by using the quality model, 31 possible quality requirements were proposed. Through the filtering by entities, 6 requirements were discarded. That leads to 81% of quality requirements from the quality model that were included into the specification. Since the reviewers judged both the completeness and minimality with the best grade, we conclude that the 19% of discarded quality requirements from the quality model were not relevant for the system.

Both the internal and external reviewers rated the modularity of the QR spec. as superior. They noted that the Excel spec. only contains categories of different requirements as means for structuring while the QR approach makes use of the content-related topics for structuring the specification. An example is the grouping of all quality requirements according to the scenarios. The data collected on the specification supports the assumption that scenarios are an adequate means for structuring. The 25 quality requirements are distributed over five categories, with an average of five requirements per category and a standard deviation of 3.74. Hence, the distribution of the requirements over the categories is balanced.

5. CONCLUSIONS AND FUTURE WORK

We proposed a quality requirements approach that is (1) using a quality model as basis for requirements derivation and (2) is integrated into a larger requirements engineering framework ("BISA"). We applied the quality requirements approach in a case study on a traffic control system at Siemens.

The quality requirements approach shows to be suitable for using it in industry. The participants of the study rated it as highly easy to use and very structured, especially in comparison to their current approach. They only did not feel to be more productive, rating the proposed approach as medium. All reviewers also found that the proposed approach has most syntactic elements necessary, but not more. It also provides a high level of traceability in the specification and helps in specifying quality requirements that are moderately easy to measure. The specification still has not a high level of testability and unambiguity, but improves over the current approach and does so more consistently over all requirements. All this is an improvement over the currently used requirements approach as well as over deriving requirements directly from guidelines and standards. It provides a systematic way to structure the contents from guidelines and standards and then derive measurable and complete quality requirements, which are embedded in a requirements engineering process and finally one comprehensive specification. Moreover, the quality model can serve as a requirements repository so that they can be reused in future projects.

These results further confirm evidence from the literature. We can support the indication from our case study in [11] that the requirements are more complete. Furthermore, we confirm Doerr et al. [1] that using a quality model results in more complete and well testable requirements.

Discussion of Validity. Regarding the *construct validity*, we see the threat that the used questionnaire might not adequately represent the research questions. The *internal validity* could be threatened by a bias towards either QR spec. or the Excel spec. from the external and internal reviewers respectively. Another threat could be that different efforts were spent in creating both specifications. However, this threat is seen as minor, because both approaches got the same rating on productivity. Researcher and method triangulation was used to mitigate reliability threats. The assessments of the internal and external reviews have both the same trend and no contradictions in the answers to the closed and open questions have been detected. Regarding the *external validity*, the major concern is the generalisation of the results, because we conducted only one case study in one company.

6. REFERENCES

[1] J. Doerr, D. Kerkow, T. Koenig, T. Olsson, and T. Suzuki. Non-functional requirements in industry - three case studies adopting an experience-based NFR method. In Proc. of the *International Requirements Engineering Conference (RE '05)*. IEEE Computer Society, November 2005.

[2] B. Kitchenham, S. Linkman, A. Pasquini, and V. Nanni. The SQUID approach to defining a quality model. *Software Quality Journal*, 6(3):211–233, 1997.

[3] K. Lochmann and A. Goeb. A Unifying Model for Software Quality. In Proc. of the *International Workshop on Software Quality (WoSQ '11)*. ACM, September 2011.

[4] D. Mendez Fernandez and M. Kuhrmann. *Artefact-based Requirements Engineering and its Integration into a Process Framework: A Customisable Model-based Approach for Business Information Systems' Analysis.* 2009.

[5] D. Mendez Fernandez, K. Lochmann, B. Penzenstadler, and S. Wagner. A Case Study on the Application of an Artefact-Based Requirements Engineering Approach. In Proc. of the *Conference on Evaluation and Assessment in Software Engineering (EASE '11)*. IET, 2011.

[6] D. Méndez Fernández, S. Wagner, K. Lochmann, A. Baumann, and H. d. Carne. Field study on requirements engineering: Investigation of artefacts, project parameters, and execution strategies. *Information and Software Technology*, 54(2):162–178, 2012.

[7] P. Runeson and M. Höst. Guidelines for conducting and reporting case study research in software engineering. *Empirical Software Engineering*, 14(2):131–164, 2009.

[8] G. Sindre and A. L. Opdahl. Eliciting security requirements with misuse cases. *Requirements Engineering Journal*, 10(1):34–44, 2005/01/01/.

[9] A. van Lamsweerde. *Requirements engineering: From system goals to UML models and software specifications.* Wiley, Chichester, 2009.

[10] S. Wagner, K. Lochmann, L. Heinemann, M. Kläs, A. Trendowicz, R. Plösch, A. Seidl, A. Goeb, and J. Streit. The Quamoco Product Quality Modelling and Assessment Approach. In Proc. of the *International Conference on Software Engineering (ICSE '12)*. ACM, June 2012.

[11] S. Wagner, D. Mendez Fernandez, S. Islam, and K. Lochmann. A Security Requirements Approach for Web Systems. In Proc. of the *Workshop Quality Assessment in Web (QAW '09)*. Springer, June 2009.