

Fraunhofer Institut
Experimentelles
Software Engineering

Non-Functional Requirements in Industry – Three Case Studies Adopting the ASPIRE™ NFR Method

Authors:
Joerg Doerr
Daniel Kerkow
Tom Koenig
Thomas Olsson
Takeshi Suzuki

IESE-Report No. 025.05/E
Version 1.0
April 2005

A publication by Fraunhofer IESE

Fraunhofer IESE is an institute of the Fraunhofer Gesellschaft.
The institute transfers innovative software development techniques, methods and tools into industrial practice, assists companies in building software competencies customized to their needs, and helps them to establish a competitive market position.

Fraunhofer IESE is directed by
Prof. Dr. Dieter Rombach (Executive Director)
Prof. Dr. Peter Liggesmeyer (Director)
Sauerwiesen 6
67661 Kaiserslautern

Abstract

Non-functional characteristics of products can be essential for business success and are a key differentiator between a company and its competitors. This paper presents the application of a systematic, experience-based method to elicit, document, and analyze non-functional requirements called ASPIRE NFR. The objective of the method is to achieve a minimal and sufficient set of measurable and traceable non-functional requirements. The method gives clear guidance for the requirements elicitation, using workshops for capturing the important quality aspects and eliciting the non-functional requirements. This paper shows its application in three different settings, reporting the experience and lessons learned from industrial case studies that applied ASPIRE NFR. As the case studies were applied in different domains and performed with companies of various maturity, and since different quality attributes were considered, a set of interesting results has emerged. Therefore, each case study tells its own story about how the elicitation of NFR in industry can work. The paper discusses the different settings and gives a comparison of the different lessons we learned from the case studies.

Copyright © Fraunhofer IESE 2005

Table of Contents

1	**Introduction**	**1**
2	**The ASPIRE NFR method**	**3**
3	**The Wireless Plant Control Case Study**	**5**
3.1	Setting	5
3.2	Applying the ASPIRE NFR method	6
3.3	Experience	8
4	**The MFP Case Study**	**11**
4.1	Setting	11
4.2	Applying the method	11
4.3	Experience	15
5	**The Geographical Information System Case Study**	**17**
5.1	Setting	17
5.2	Applying the method	17
5.3	Experience	20
6	**Discussion**	**22**
7	**Conclusion**	**24**
References		**25**

Copyright © Fraunhofer IESE 2005

1 Introduction

Requirements Engineering (RE) aims at building the basis of a product that satisfies the customers. In today's life, customers demand a lot. In addition to pure functionality, customers demand non-functional characteristics. They want products to be secure, stable, usable, and showing high performance. Recent developments show that non-functional characteristics can be essential for business success. Well-known examples for quality problems are the moose-test of the Mercedes Benz A Class [1] or the Siemens mobile phone 65 series, where an unintended combination of events might have led to hearing damage [2]. Non-functional characteristics are therefore a key differentiator between a company and its competitors, in particular for systems empowered by software.

During system and software development, non-functional characteristics are important for deciding on the architecture and planning quality assurance. To successfully address non-functional characteristics in these phases, it is essential to elicit and capture the non-functional requirements (NFR) during the requirements engineering phase.

Few approaches for NFR are currently being applied in industry. The first comprehensive method for specifying NFR was developed by [3] in the 1990s. This NFR framework, provides detailed guidance on how to refine NFR and how to denote relationships between the NFR. As the focus is on refinement, no detailed elicitation support or support for documenting NFR as part of a requirements document is given. In addition, it provides no assistance in relating NFR with functional requirements and architecture. [4] shows one approach on how to combine NFR and use cases. Use cases and NFR are elicited separately and are then combined to make sure that the use cases satisfy the NFR. However, in practice, the elicitation of NFR, FR and architecture has to be intertwined. Sometimes a refinement of non-functional aspects is not possible without detailing the functionality or architecture. Furthermore, there are approaches that address one specific quality attribute (QA), e.g., for usability or security like [5] or [6]. These approaches allow detailed examination of this one characteristic, but they are limited to one QA. A complete survey on NFR approaches can be found in [7].

At the Fraunhofer Institute for Experimental Software Engineering (IESE), we experienced that these methods have their advantages, but they tend to lack systematic guidance on how to use them and how to end up with measurable NFR. In general, one can say that current approaches for dealing with NFR provide frameworks for thinking about NFR, but they do not work for many practical problems emerging during software development. Therefore, we developed

Copyright © Fraunhofer IESE 2005

a systematic, experience-based method to elicit, document, and analyze NFR called ASPIRE NFR[1]. The goal of the method is to achieve a minimal and sufficient set of measurable and traceable NFR. To capture a sufficient set means that only the essential NFR are captured, and that the set is complete on a certain level of abstraction.

This paper is intended to report on experience gathered with the ASPIRE NFR method. Details on this method have already been described in [8], [9], [10], and [11]. Three industrial projects served as case studies. The method was successfully applied in

- a project in the field of wireless plant control with a large anonymized company in Germany,
- in the field of multi-functional office equipment with Ricoh in Japan,
- in the field of geographical information systems with the state of Rhineland Palatinate, Germany.

In Section 2, we will give an overview of the method, its core components, its benefits and how it works. Sections 3, 4 and 5 describe the case studies. The differences between the case studies and the experience gathered are discussed in Section 6 and finally, in Section 7, we conclude.

[1] The method is now called ASPIRE NFR. In the references, the method is often called EMPRESS method, referring to the ITEA-EMPRESS project, funded by the German Ministry of Education and Research (BMBF).

Copyright © Fraunhofer IESE 2005

2 The ASPIRE NFR method

In this section, we give an overview on the method, as it is necessary to understand its application in the case studies. The main features of the ASPIRE NFR method are:

- a process for common treatment of the various high level QA (ISO 9126, see [12]) e.g., maintainability, efficiency, portability, usability, security, and reliability
- experience-based quality models that capture experience with general characteristics of QA, metrics to measure these QA, and means to achieve them
- distinction between different types of QA, which gives guidance on how to elicit and where to document the NFR
- detailed elicitation guidance in terms of checklists and a prioritization questionnaire. The former are derived from the quality model and the types of QA and help to elicit efficiency NFR in concert with use cases and a high-level architecture. The latter helps to focus the effort spent on NFR elicitation on the most important QA.
- documentation guidance by providing document structure and templates
- the use of rationales to justify each NFR. Using rationales supports minimality of the set of NFR.
- treatment of NFR together with functional requirements and the system architecture
- requirements management support including a dependencies-analysis on the elicited set of requirements.

We distinguish between quality attributes (QA) which are captured in quality models (QM), and non-functional requirements (NFR) that are captured in documents based on templates. A QA is a non-functional characteristic of a system, user task, system task, or organization. Organizational QA include development process specific aspects. A NFR describes a certain value (or value domain) of a QA that should be achieved in a specific project. The NFR constrains a QA by determining a value for a metric associated with the QA. For example, the NFR "The database of our new system shall handle 1000 queries per second" constrains the QA "workload of database". The value is determined based on an associated metric "Number of jobs per time unit". Similar to approaches such as [13] and [14], we use a notation based on goal graphs for dependencies and refinement. We use this notation for capturing the relationships between the QA such as efficiency and maintainability in reference QM.

Copyright © Fraunhofer IESE 2005

The actual NFR are captured in documents intertwined with FR and architectural decisions. With this approach, complicated dependencies are captured in reference QM, and do not have to be captured for each project.

Figure 1 shows the main artifacts used and produced in our method. In a first step, the priorization questionnaire is used to focus the elicitation and documentation process. This is performed to prioritize the high-level QA (i.e., maintainability, efficiency, reliability, usability). For the highest ranked QA, the reference QM get tailored in a workshop. In this tailoring process, experts from the company tailor each QM to the needs of the project. Based on the tailored QM, the reference checklists and templates are tailored to specific project contexts. The tailored checklists and templates are then used in a second workshop for the actual NFR elicitation.

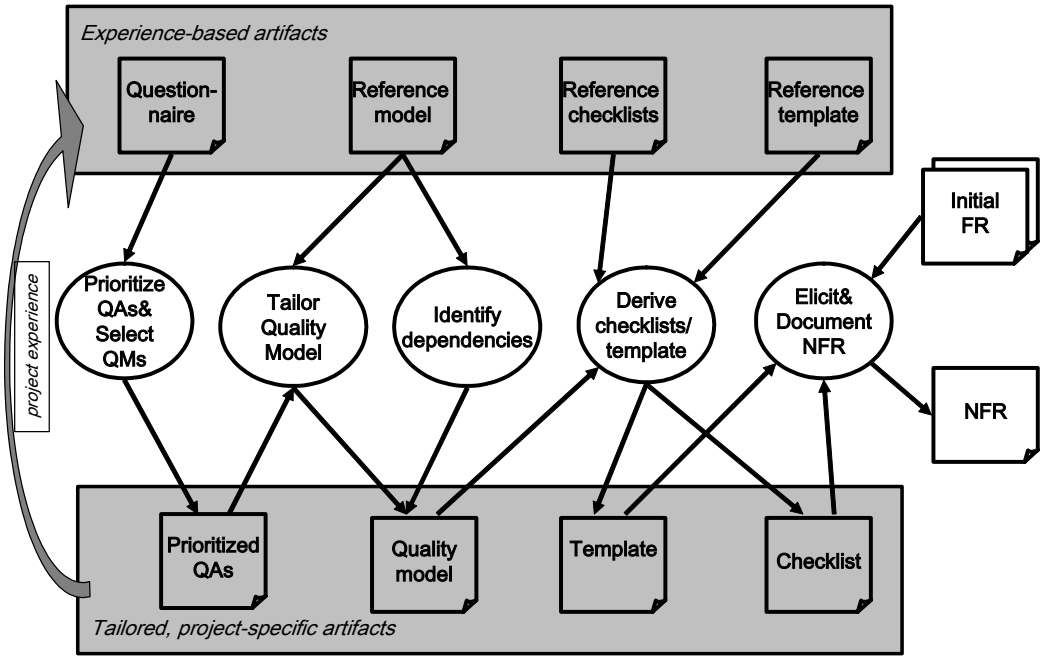


Figure 1: Overview on ASPIRE NFR method

The experience-based artifacts were initially developed from literature. In each project, new experience was incorporated into the reference QM. Therefore, each application in a project resulted and will result in more mature reference QM.

Copyright © Fraunhofer IESE 2005

3 The Wireless Plant Control Case Study

The first of the three case studies presented is on a distributed, embedded system. The case study was performed together with a large German company that mainly develops embedded systems.

3.1 Setting

In the case study, the requirements for a distributed and embedded system were elicited and documented. The case is a wireless control system for controlling and monitoring a manufacturing plant. The purpose of the developed system is to be able to control, through handheld computers and cell phones, a manufacturing plant. This means reading data from the machines in the plant, receiving alarms, and controlling aspects of the machines. An alarm might be caused by a jam in one of the machines, which might stop production. An employee should be able to acknowledge the alarm on a handheld device and then move to fix the problem.

The focus of the system was on reliability, efficiency, and maintainability. Reliability, as loss of production will mean a loss of money, especially if alarms of a critical nature are missed. Maintainability, as it is expected by the development side that the system will be extended and maintained over a period of time. Finally, efficiency was also important, because the application needs to run on handheld devices communicating through a wireless network.

The system in the case study is a fictional one for non-disclosure reasons. However, the general structures and problems are representative of those normally developed by the company in question.

As this was the first case study where the QM were applied in a larger context, the models were based on theoretical studies. The original QM were mainly a refinement of the ISO 9126 [12] standard, refined by using literature for each quality attribute (QA). Hence, as there had been no project experience, see Figure 1, the QM and checklists had not been complemented with experience. As would be expected, the first experience collected applying the ASPIRE NFR method led to more significant rework than in later applications.

The artifacts used for the elicitation were the original requirements documents, including a nonsystematic set of NFR.

Copyright © Fraunhofer IESE 2005

3.2 Applying the ASPIRE NFR method

The ASPIRE NFR method was applied together with the company and mainly consisted of filling out the prioritization questionnaire and of holding two workshops. Based on the prioritization, efficiency, reliability, and maintainability were chosen for further elaboration. Before the workshops took place, the requirements documents were transformed into a use case notation. The original requirements were not in use cases. This only required a small effort. In the first workshop, efficiency and maintainability were elaborated. The models were tailored and then used to elicit NFR. An excerpt from the tailored efficiency QM can be seen in Figure 2.

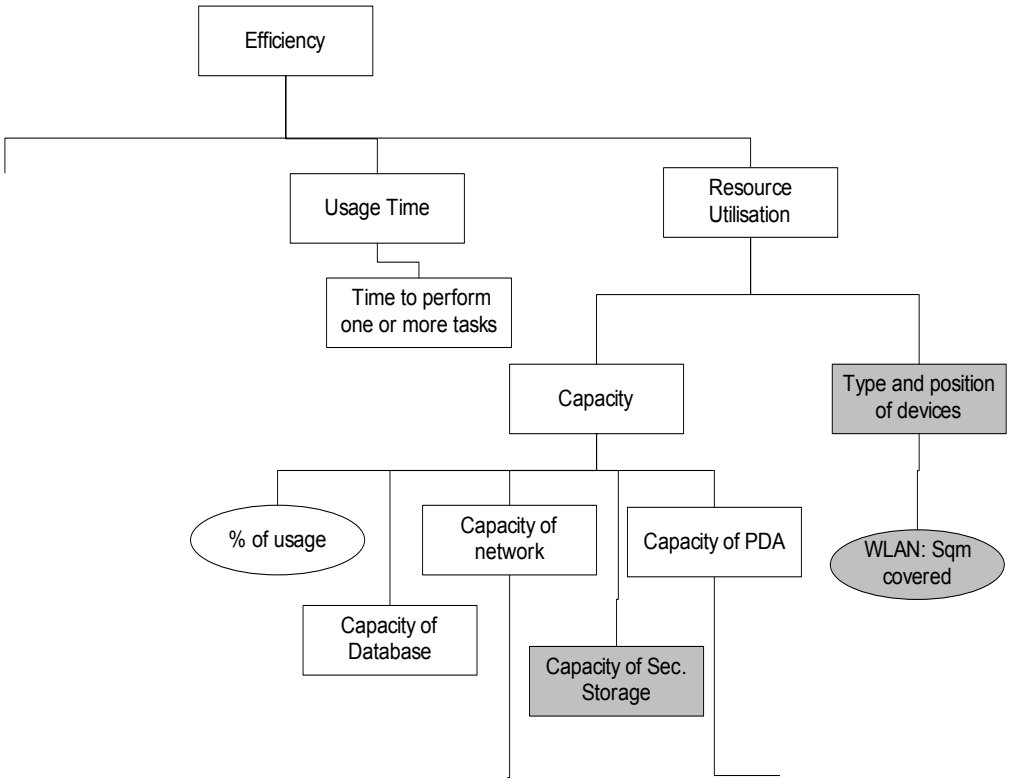


Figure 2: Excerpt from tailored efficiency model

Wireless access from handheld devices was important in the case study. This is reflected in the QM, on the right-hand side, by the coverage metric. This is a typical example of how the tailoring can proceed. In the reference QM for efficiency, the QA is not specific for wireless access, but reflects any type of network. Due to the importance in this case, it was deemed relevant to reflect the wireless aspect in the QM.

Copyright © Fraunhofer IESE 2005

After the tailoring, elicitation of the efficiency requirements was performed, supported by the QM and the checklist. The checklist complements the QM with additional experience and information, see Figure 3. In the checklists, a reference to where the elicited information should be documented is given. This is seen in italics and in parenthesis in the checklist after the name of the checklist step, e.g. "*(quality attribute -> efficiency -> responsetime -> high level)*", see Figure 3. The checklists also guide the workshop participants on which artifacts a QA is relevant for. For example, step 2 in the checklist states "For each system…", indicating that this particular QA should be elicited on a system basis, not on a task basis.

2. Elicitation of boot / start-up time requirements
For each system that has to be booted / started, specify the boot time / startup time of the HW and SW.
3. Elicitation of response time / usage time NFR *(quality attributes->efficiency ->response time ->high level)*
a. Create high level UC descriptions
b. Specify response time or usage time NFR (depending on the UC type) on the level of the UC names (e.g., if the UC name is "warn user", the NFR can be "In case machine A is running out of resources, the user has to be warned within 1 minute.")

Figure 3: Excerpt from efficiency checklist

In Figure 4, examples of requirements elicited are presented. Due to time constraints, it was not possible to elicit maintainability requirements at this first workshop. Therefore, the efficiency QM was tailored and the requirements were elicited, while for maintainability the tailoring was not finished.

Machine->Database2 (Network):
Throughput: Normally: with 16 machines: 2 alarms every 10 minutes (but with normal monitoring activity)
Throughput: Worst case: 60 alarms at the same time

Database2:
Boot time: 1 min
Capacity: 70 GB is more than enough
512MB for the server second HD of 70 GB to mirror data.
Workload polling: normally: 2 * sum of complete data of the machines per second
Workload server download: maximum: downloading 8 files at the same time

Database2->PDA (Network):
Throughput: Normally: with 16 machines: 2 alarms every 10 minutes (but with normal monitoring activity)
Throughput: Worst case: 8(1/PDA) * 60 alarms (count again) at the same time
Throughput: worst case: 8 people shall be able to download 1 doc (size of 8 docs constrained to: <55MBit) /person within 5-10 secs

Figure 4: Example of efficiency requirements

Copyright © Fraunhofer IESE 2005

For the second workshop, maintainability and reliability were tailored. The maintainability QM tailoring was finished and the requirements were elicited. Most of the time was spent on eliciting the maintainability NFR, as the tailoring had already started. For the reliability QM, however, more tailoring was necessary. An excerpt from the original reliability model can be seen in Figure 5 and an excerpt from the checklist in Figure 6.

As this was the first time the method and the QM were applied to a real case, more focus was put on analyzing and documenting the experience made and updating QM and checklists.

3.3 Experience

The experience from the case study is that the approach as such was shown to be promising and that the effort seems reasonable. Especially the prioritization of the QA was perceived as helpful. The tailoring does, however, take some time, as not only tailoring is done, but there is also unification of the terminology to ensure a common understanding.

Furthermore, it can be concluded that new and important NFR were found using the method. Hence, there is an indication that the method is effective, meaning that we do, in fact, discover requirements otherwise overlooked.

Based on the tailoring performed for the three QM, the models themselves were updated and improved. Many of the issues that surfaced in the tailoring were, in fact, improvements of the QM rather than tailoring. This was expected, as this was the first time we applied the mentioned models and checklists.

Copyright © Fraunhofer IESE 2005

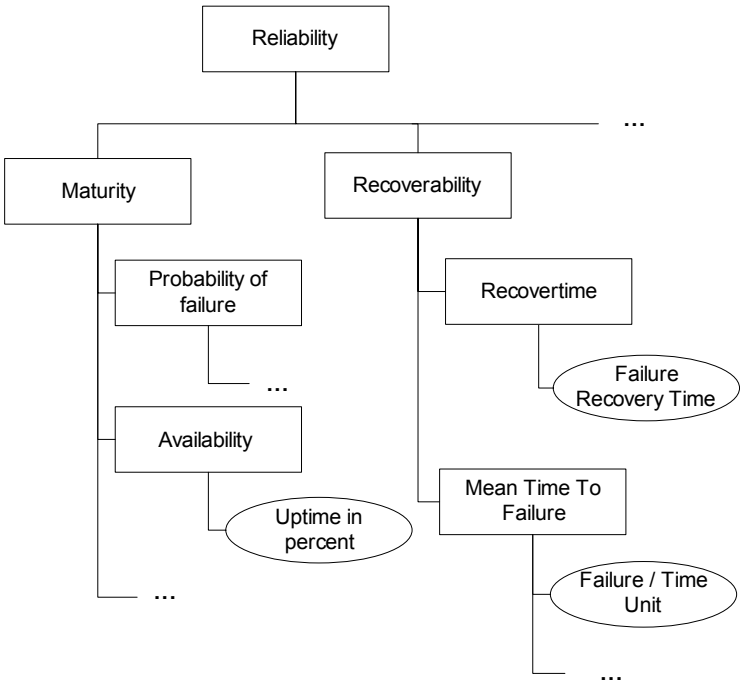


Figure 5: Excerpt from the original and untailored reliability quality model

For example, in the reliability model, availability is a part of maturity in the ISO standard, seen in Figure 5. The understanding developed was that maturity has to do with how long system and components have been used, number of users so far, etc. Hence, availability was moved to be a direct sub-attribute of reliability and maturity was changed to reflect the time-in-use aspect.

Another aspect realized for the reliability part was that certain aspects of the checklist might be of a more general nature, applicable to more than one project. For example, failure classification, see Figure 6, is most likely something that will not change in every project. Hence, here a default classification can be provided, which is tailored for a company or business division rather than for each project. This was also an experience from the maintainability workshop, regarding which relevant artifacts to involve in the maintainability requirements.

In this first case study only 5 out of 54 elicited NFR were not measurable. That is, we did achieve a high degree of measurable NFR, but there are still some that we were not able to formulate in a quantifiable manner. Still, having more than 90% of the NFR measurable is a significant improvement over current industry practice and previous methods.

Copyright © Fraunhofer IESE 2005

In this step NFR are collected for one type of UC. Thus, consequences from concurrently active instances of the same UC are reflected.

1. **Determine the failure classes**
   The types of failures should be classified in degree of severity (e.g. minor (cosmetic), major (part of use case cannot be performed), severe (complete failure of the system)).
2. **Elicitation of reliability compliance requirements** (*NFRs-> Project issues-->Process||Documentation*)
   Check the specific certification required by the user organization of the system. Check, for example:

- …

Figure 6: Excerpt from reliability checklist

Furthermore, we did elicit and document many NFR missed before, as we could see when we compared them with the original specification. Additionally, when the case was applied in another setting, but without using the ASPIRE NFR method, several important NFR were missed, which were elicited by us when applying the method, leading to an architecture that did not fulfill the customer's expectation. It was estimated that the cost of changing the architecture would be twice the cost of having applied the ASPIRE NFR method from the beginning.

One important finding was the benefit of the dependency analysis activity of the method, since a set of conflicting requirements could be identified and resolved in an early phase, which otherwise would probably only have been discovered in test activities, at the earliest.

Copyright © Fraunhofer IESE 2005

4 The MFP Case Study

The Japanese company Ricoh is a provider of digital office equipment including copiers, printers, and multi-functional products. From 2003, Ricoh has been an industrial partner of the competence center "Virtual Office of the Future" [16], [17] founded by Fraunhofer IESE and the German Research Centre for Artificial Intelligence (DFKI) in Kaiserslautern, Germany. This case study was done as part of this collaboration.

4.1 Setting

Multi-functional Printer systems (MFP) are integrated office equipment consisting of printer, scanner, and facsimile functionalities. As usual in the domain of embedded systems, MFP software and hardware are highly interconnected to achieve the required performance. In addition, due to its wide range of functionalities, the requirement analysis for the MFP products is complicated. Especially handling of performance requirements considering the corresponding functionalities and architectural constraints is difficult.

In addition, since some of the existing functionalities are widely accepted and used in the office environment, users' intentions tend to focus on non-functional aspects, e.g., image quality, productivity of copying, and integrity of the system with the office environment. Furthermore, some of these non-functional aspects are hardly measurable.

In this case study, we report on the efficiency aspect of MFP requirements, since it has been regarded as one of the most important aspects of the office equipment in general. We applied the ASPIRE NFR method to a middle range color MFP product with an automatic document feeder (ADF), shift sort tray for output paper handling, and network interfaces. The setting is typical for a normal office environment. We used use cases previously defined and other product-related artifacts as input for the NFR elicitation process. In the use cases, the NFR had been specified partially, however, the analysis of interdependency between NFR was not sufficient.

4.2 Applying the method

As described in the previous section, the ASPIRE NFR method focuses on facilitating the NFR elicitation process through stakeholder workshops. We conducted two workshops; each of them integrated essential processes of the

Copyright © Fraunhofer IESE 2005

method, namely a workshop for customizing the QM and a workshop for NFR elicitation. See also [11] for detailed procedures.

During an introductory part of the first workshop, the requirements engineer tried to find the priority of QA by interviewing the developers.

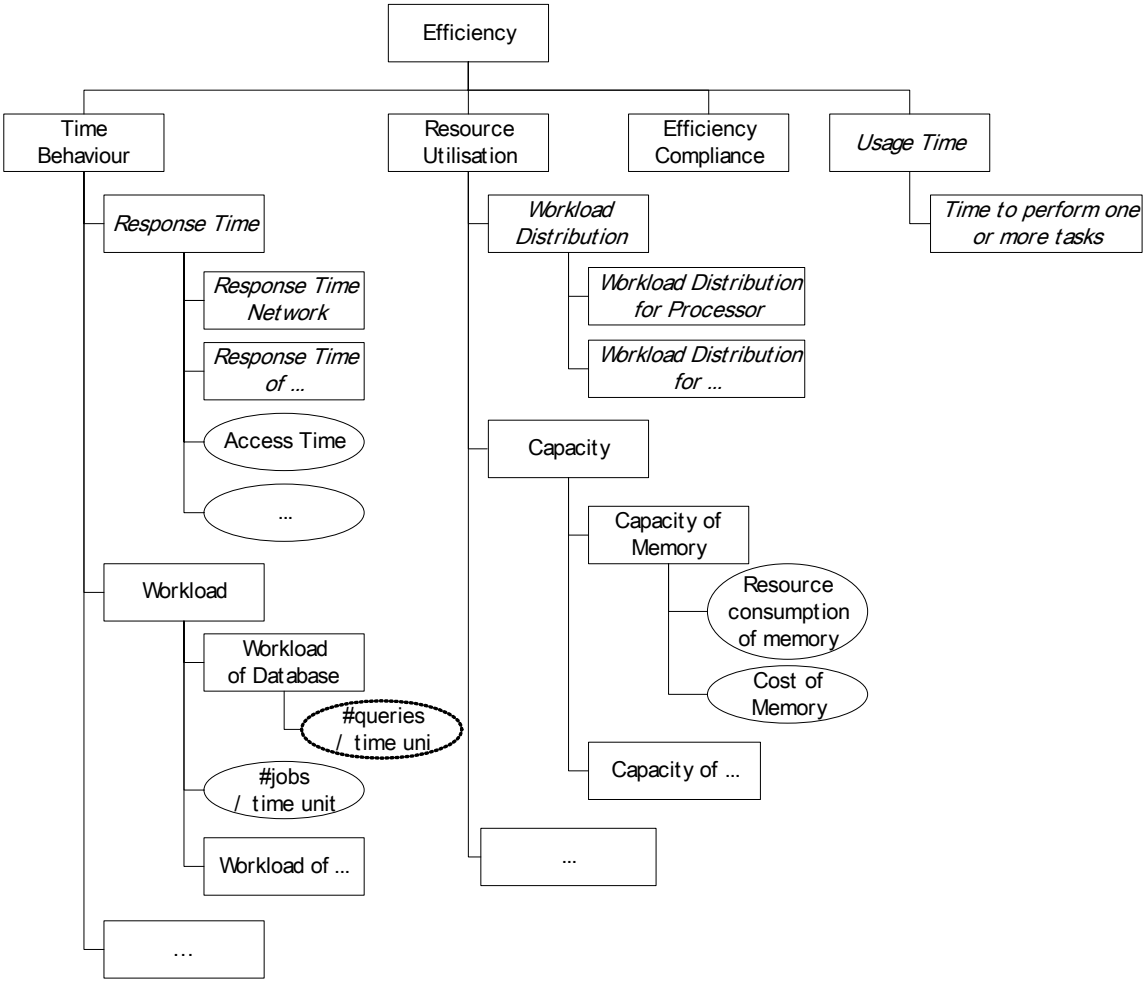


Figure 7: Excerpt of the reference quality model

Judging from the current interest of Ricoh, and from a general office environment viewpoint, we decided to investigate efficiency first. In this process, we referred also to the ISO 9126 framework and the IEEE standard 830-1998. In succession, we customized the reference QM (Figure 7) according to Ricoh's specific interests and constraints. The reference model gives the general viewpoint of QA categorization. For this customization, we first formed an initial sketch of the QM for the efficiency QA in a hierarchical representation (Figure

Copyright © Fraunhofer IESE 2005

8) by interviewing the Ricoh developer based on the reference QM (see Figure 7).

Due to the many interrelationships within the productivity category and between other categories, it was revealed that the productivity of the product, i.e., scanning, printing, and copying documents, has central importance over the efficiency attribute in this case. This result is consistent with the developer's understanding, provided by a separate feature- and variability- analysis on the MFP products.

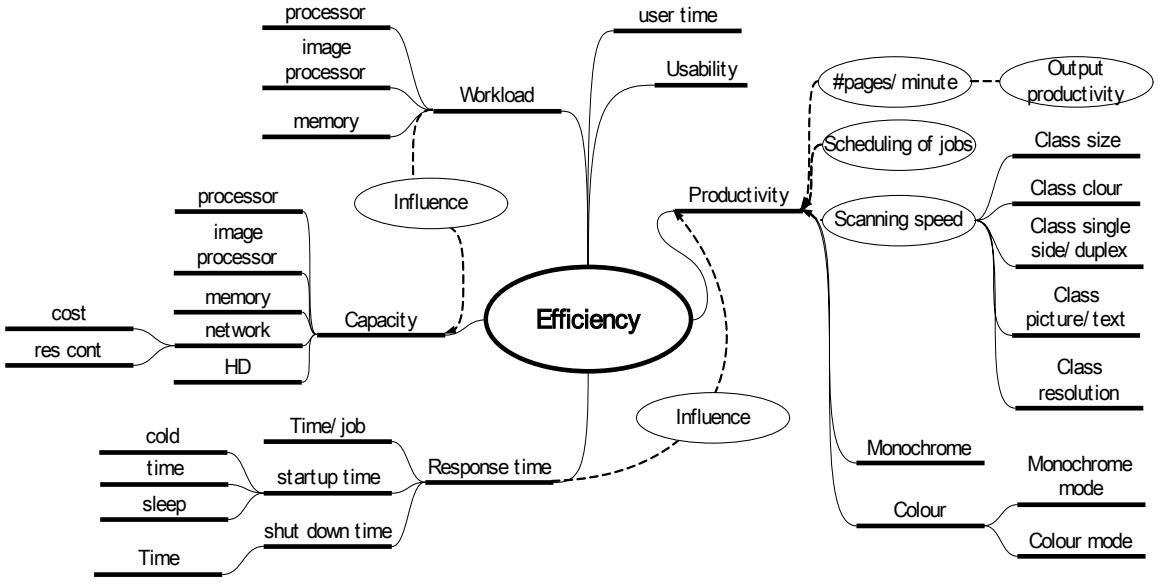


Figure 8: Excerpt of the initial sketch of the tailored quality model

We also clarified and listed metrics and constraints based on use cases and other product-related artifacts in the first workshop. Therefore, at this point of time, we had neither organized nor categorized the metrics. The tailored checklist was also derived from the experience-based reference checklist. A way to define the experience feedback loop and to tailor the reference QM and checklist is given in [11].

The second workshop was for the NFR elicitation. The requirements engineer presented the tailored QM (Figure 9) and explained the analysis of the QM, and gave the tailored checklist (Figure 10) to elicit the NFR. It shows metrics that support each NFR. If we have many conditions or options to be considered, the checklist can become large. Actually, a part of the checklist could not be covered by the workshop because of time constraints. Consequentially, the developer group needed to complete the checklist and the QM separately after the workshop. Even in this case, the well-defined and organized checklist was self-

Copyright © Fraunhofer IESE 2005

explanatory for the developer. Through this analysis, we found 16 NFR in addition to the original NFR in the use cases. All of them are categorized and each has supporting metrics. As shown in Figure 11, NFR are normally supported by several metrics; some of them represent the functionality- or constraints-specific metrics.

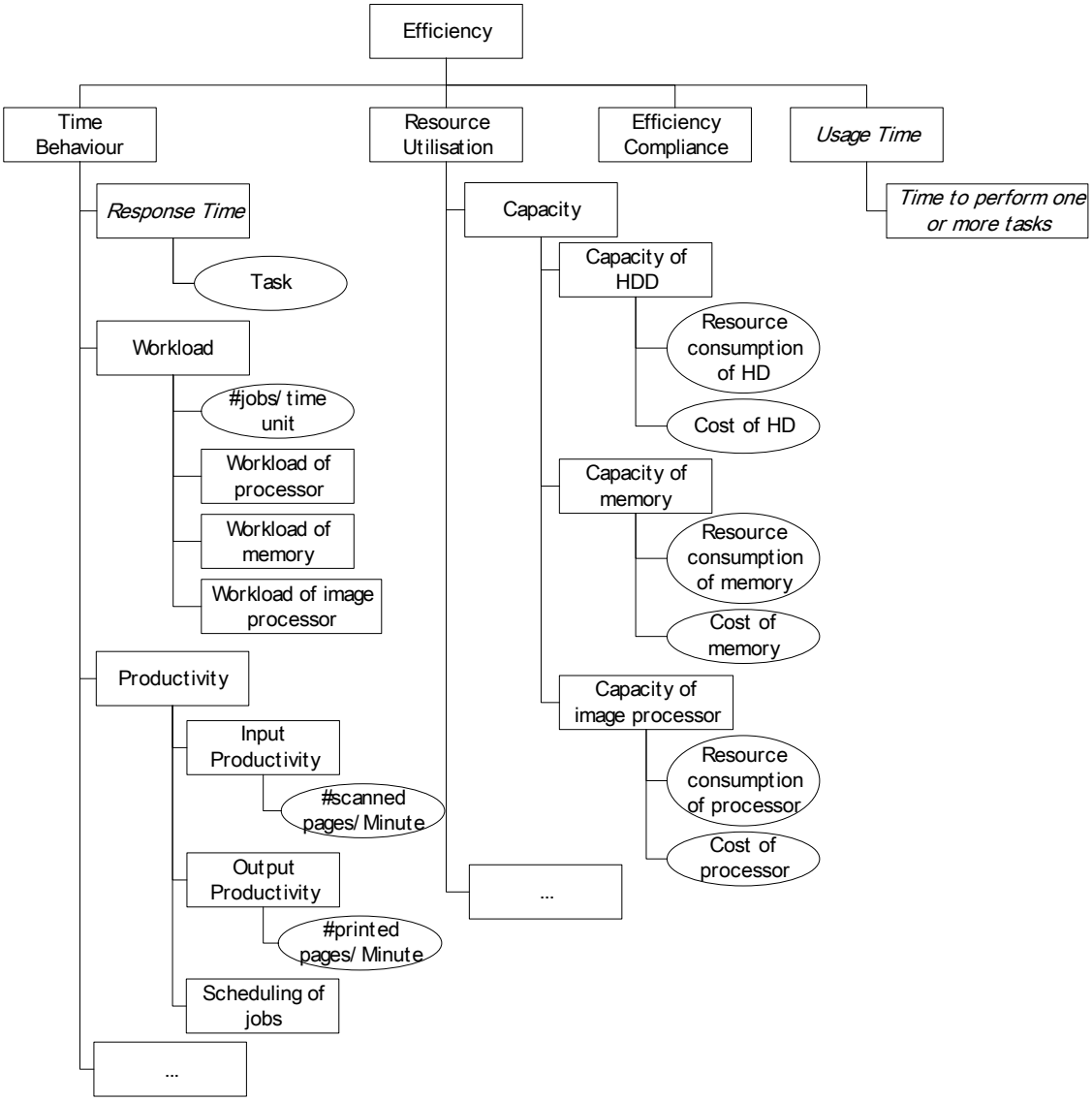


Figure 9: Excerpt of the tailored quality model

For example, in the copy mode of MFP, we need to specify input productivity NFR in two ways, i.e., using either the ADF or the contact glass, with the ADF being an optional function.

Copyright © Fraunhofer IESE 2005

Elicitation of Productivity NFR
Go through each high- & medium- level Use Case: For each classification dimension (Color mode/Monochrome mode, Paper Size, Single Sided/Double Sided, Picture Mode/Text Mode, Resolution):

- Specify the input productivity in terms of #scanned pages per minute
- Specify the output productivity in terms of #printed pages per minute
- …

Figure 10: Excerpt of the NFR elicitation checklist

4.3 Experience

The consequence of the ASPIRE NFR method is that NFR are elicited collaboratively through the workshops. In this case study, we found the reference QM and checklist encourage NFR elicitation in the workshops. In order to elicit and manage NFR systematically, consensus on a requirements granularity between requirements engineer and developer is needed. The combination of the reference QM and checklist and collaborative analysis through workshops gave the rationale and criteria for the requirements granularity.

Productivity
Input productivity: pages inside the Automatic Document Feeder
→ average, monochrome A4, single sided, 200 dpi, mixed mode

- Normal default usage (average) [40 pages per minute is the highest]
- Lowest input
  - A3 → 20 pages
  - A4 double sided → 10 or 15 pages
  - …

Figure 11: Example NFR of MFP

As usual in the case of embedded system, MFPs are also highly integrated systems of hardware and software. Accordingly, it is difficult to clarify all requirements in advance of the specification. Requirements management in iterations is essentially needed for MFP development. Therefore, the NFR specified through workshops must be detailed while the development is proceeding. In this regard, requirements traceability is of crucial importance. This case study was mainly for NFR elicitation, however, the hierarchy in the QM, the reference templates (giving a document structure), and explicit correspondence between NFR and metrics could support this traceability throughout the development. Furthermore, basic requirements management support for the ASPIRE NFR method is available. Unambiguous NFR tagging and a basic change process that integrates a dependency analysis are part of ASPIRE NFR. As the NFR elicitation

Copyright © Fraunhofer IESE 2005

was performed in solely one increment, the requirements management support was not utilized in this case study.

The difficulty we found in this case study is that the quality of the NFR derived with the method depends on the quality of the functional requirements definition, and the fact that the method requires the functional requirements specification as input. In this case, the functional requirements were represented in use cases. Because of their interdependencies, functional and non-functional requirements should be investigated intertwined, and high effort for iterations is needed. Investigation into an evolution of NFR through iteration and its cost are still open.

Copyright © Fraunhofer IESE 2005

5 The Geographical Information System Case Study

In order to grant farmers access to the same information resources as administration, the Rhineland-Palatinate Ministry of Economy, Transportation, Agriculture, and Viniculture (MWVLW) has initiated a project within the context of implementing the Integrated Administrative and Monitoring System (InVeKoS).

5.1 Setting

The goal of this project is to develop a web-based geographical information system (GIS) for farmers. The farmer will thus be given the opportunity to access maps and data related to his areas via the Internet, using a standard browser. In an initial step, the MWVLW contracted Fraunhofer IESE to conduct a case study with the objective to design, implement, and evaluate a web-based GIS prototype to support subsidy applications. Furthermore, a concept for the future development of the system was to be generated.

A requirements document containing functional requirements, as well as some initial security requirements were input to the method.

5.2 Applying the method

The initial prioritization regarding the QA (see Figure 1) showed that security was the most important QA in the context. This was due to the fact that important parts of the information accessible to a user of the system are company-related and thus subject to privacy policy security requirements. As in the second project phase, the farmer will not only be able to access certain information, but also apply for the subsidies via the system, the security aspect will be of even higher importance.

Copyright © Fraunhofer IESE 2005

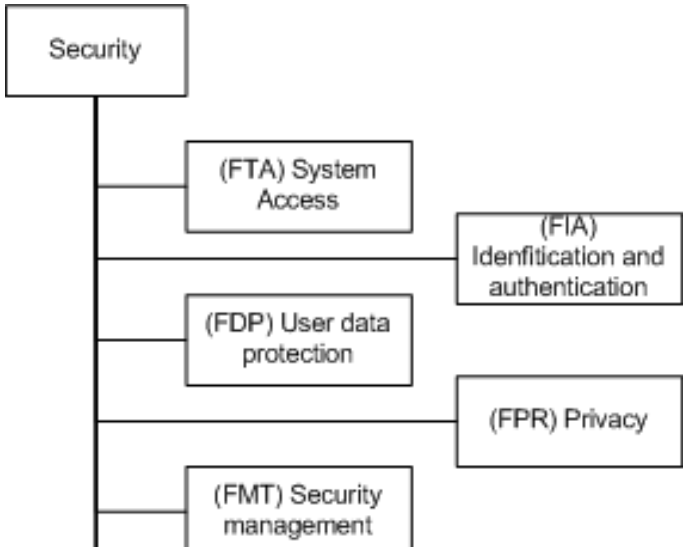


Figure 12: Security model first level

A requirement voiced by the partners during the prioritization step was to adhere to a standard regarding security. As the initial QM was based on the ISO standard 9126, focusing broadly on security aspects, we adapted the initial security QM in cooperation with security domain experts. Based on the Common Criteria (CC) [15], a de facto standard in security, security characteristics were integrated into the QM.

The integrated QM was then in the next step tailored to the project context, as seen in Figure 12, to meet the specific project needs. The abbreviations contained are references to CC elements ensuring the traceability of each element of the model to the respective CC element, providing a general description of the different attributes independent of the project context.

Each attribute (e.g., identification and authentication, etc.) is further refined into a set of sub-attributes that sum up to the abstract parent attribute. Figure 13 shows this refinement, exemplary for the abstract attribute identification and authentication.

Copyright © Fraunhofer IESE 2005

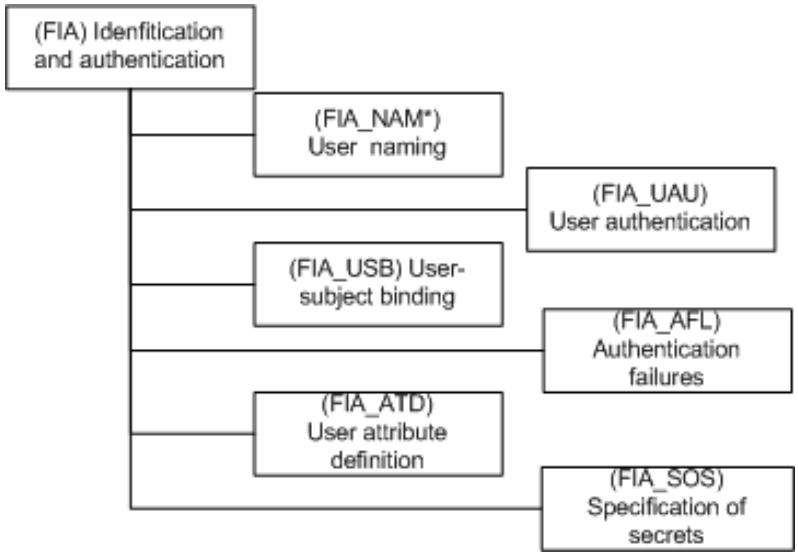


Figure 13: Identification and authentication QA

Based on this QM a checklist was derived that served as a basis for the elicitation activity. The checklist contained detailed questions that help to determine requirements regarding the specific attributes. Figure 14 and Figure 15 show the checklist questions for the attributes User naming and Authentication failures, respectively.

How are users of the secure parts of the system identified?
Examples:
- by account names within the system
- by user names within an external authentication server
- by presenting a public key certificate

Figure 14: Checklist question(s) for User Naming

How should failed authentication attempts be handled?
Examples:
- After failing to provide the correct password 3 times in a row, the system disables this user account. On contrary, disabling user accounts may lead to a Denial of Service (DoS).
- After a failed login attempt, further authentication attempts are only allowed after an (exponentially) increasing period of temporary lock-out

Figure 15: Checklist question(s) for Authentication failures

Copyright © Fraunhofer IESE 2005

Based on the checklist and the initial requirements document, a workshop was conducted that determined the different security requirements for the project. Figure 16 and Figure 17 specify two requirements that were elicited during the workshop:

NFR.S1 Users are identified by username (company id) and password – the account names are stored on an external authentication server.

Figure 16: User naming security requirement

The structured set of requirements was integrated into the requirements document that served as the basis for the further development.

NFR.S2 If the user fails to provide the correct password 3 times in a row, his account is disabled for 10 minutes.

Figure 17: Authentication failures security requirement

5.3 Experience

During earlier stages of the project, security requirements arose at different points. This led to a highly unstructured set of requirements especially with regard to security. The workshop conducted afterwards helped to elicit a set of security requirements in a systematic and structured way. On the one hand, the requirements that were already in place were confirmed. Several of these requirements were further refined, as the checklist questions pointed out different aspects that should be considered. For example, NFR.S1 specified in Figure 16 had already been brought up in parts at an earlier stage. The basis of the authentication step, namely company-id and password, had already been specified. During the workshop, the requirement was further elaborated to also include that the authentication data is held within an external system. Furthermore, the workshop also helped to identify requirements that had not been considered at all, but were of high importance for the project. Thus, the resulting requirements were very structured and the completeness of the security requirements was further improved by applying the method.

With the help of the checklist, the workshop was straightforward. The examples in the checklist checklist were used to clarify the meaning of each question and were perceived as being very helpful.

In a later phase of the project, test cases had to be derived based on these requirements. This process was also rather straightforward, since almost all of the resulting requirements were testable, even though the QM mainly did not include metrics for the different QA (as this was not possible for most of the at-

Copyright © Fraunhofer IESE 2005

tributes). Basically, this is a result of the incorporation of security experts while deriving the checklist questions from the QM.

The elicitation process also showed that the intertwined consideration of functional, architectural, and NFR is very important, as a significant architecture rework was necessary to integrate the security NFR.

Generally, the security QM and especially the derived checklist were an important help in the elicitation process. Due to the fact that both artifacts include certain domain know-how, domain experts are not necessarily needed during the actual workshop. As the checklist contains fully specified questions in combination with examples that help to clarify problems, little domain knowledge is needed to conduct the workshop.

Copyright © Fraunhofer IESE 2005

6 Discussion

In the case studies, there were some common but also some unique observations.

The first setting, the wireless control of a manufacturing plant, was the only one in which NFR for more than one quality attribute were elicited and documented. With our approach, important NFR that were not elicited before became apparent. Experts judged that these NFR have an impact on the architecture, leading to major rework. The method showed that a high percentage of the NFR were measurable.

In the second setting, the one of multi-functional printer systems, efficiency requirements were elicited. The refinement of efficiency differed in several aspects to the refinement in the first case study. The case study emphasized the need for requirements management support. Our method provides basic requirements management support, based on an unambiguous NFR tagging and a change process with integrated dependency analysis.

In the third setting, the geographical information system, the focus was on security. The method resulted in a structured set of security NFR. Due to the need of the setting, a security expert enriched the reference security QM before the actual method started. In the case of security, it is hard to attach metrics to the QA. Nevertheless, we achieved a set of testable NFR due to the well-formulated checklist for security.

In all three case studies, NFR had never been elicited so exhaustively. On the one hand, the experts had to spend more time for NFR than before. On the other hand, all experts agreed that there was a positive return on the invested time and the systematic approach providing templates and checklists enabled the participants to continue the elicitation process after the workshops. The experience-based QM, capturing past results and domain expertise led to confidence among the stakeholders about the completeness and correctness of the elicited NFR.

The case studies also showed that all industrial applications had different priorities for QA. The QM and their subordinated QA also differed. It seems obvious that project-specific variation influences the QA, but more than this, the workshop participant's individual definitions for each QA differ, too (e.g., defining "availability" once in the context of "maturity" and once in the broader context of "reliability"). An important lesson learned, is that a general, absolute QM that fits in every context does not exist.

Copyright © Fraunhofer IESE 2005

One major benefit of the ASPIRE NFR method is the enhancement of communication and the definition of a common ground as basis for high quality requirements engineering.

Copyright © Fraunhofer IESE 2005

7 Conclusion

The different settings and the flexibility of the ASPIRE NFR method led to a slightly heterogeneous experience in its application. In all case studies presented, the application of the method led to more complete NFR, and therefore, to results that matched the customer's expectations more than before.

In the case studies, we presented several excerpts from QM for various QA (efficiency, reliability, and security), some of them before the tailoring, some of them after the tailoring. Some checklist questions and the resulting NFR were presented. We discussed the lessons learned and experience gathered for each case study.

The case studies showed that the method gave sufficient guidance in the task to elicit and document NFR. The reference QM were always considered helpful, as they capture experience and are a means of communication. A priorization of the QA and tailoring of the QM were an essential step to focus the effort on the relevant QA. In the first case study, where quantitative data was available, over 90% of the elicited NFR were measurable and all of them were traceable. In each case study, no irrelevant NFR were elicited, but new, important NFR were elicited in a structured way. To conclude, the experience supports the impression that the method achieved its goal to elicit and document a minimal and sufficient set of measurable and traceable NFR.

In future projects, the method will be applied in new industrial projects. By gathering this new experience, the reference QM, checklists, and templates will be further improved.

Acknowledgements

We want to thank all workshop participants during the case studies, especially Mr. Yamauchi from Ricoh, Mr. Eisenbarth and Mr. Schwenkler from Fraunhofer IESE, and Mr. Jimenez.

Copyright © Fraunhofer IESE 2005

References

[1] „Mercedes: Wie sicher ist die A-Klasse?“, German news magazine: "Der Spiegel", ISSN 0038-7452, Oct. 27th 1997, p. 120; english translation: http://www.geocities.com/MotorCity/downs/9323/aclacap.htm, last visited on Feb. 11th, 2005

[2] „Siemens Warns of Possible Hearing Damage in Some Cell Phones”, consumeraffairs.com, http://www.consumeraffairs.com/news04/siemens_mobile.html, last visited on Feb. 11th, 2005

[3] Chung, L., Nixon, B.A., Yu, E., Mylopoulos, J.,“*NFR in Software Engineering*”, Kluwer Academic Publishers, 2000

[4] Cysneiros, L.N., Leite, J.C.S.P, “*Driving NFR to Use Cases and Scenarios*”, XV Brazilian Symposium on Software Engineering, 2001

[5] Dzida et al., “Gebrauchstauglichkeit von Software: ErgoNorm. Ein Verfahren zur Konformitätsprüfung von Software auf der Grundlage“ DIN EN ISO 9241 parts 10 and 11. Bremerhaven: Wirtschaftverlag, 2001

[6] Russel, D, Gangemi, G.T., “*Computer Security Basics”*, O’Reilly, 1991.

[7] Paech, B. & Kerkow, D., *”Non-functional requirements engineering – quality is essential”*, 10th International Workshop on Requirments Engineering – Foundation for Software Quality, 2004, pp. 237-250.

[8] Paech, B. et al. ., “*An experience based approach for integrating architecture and requirements engineering*“, From Software Requirements to Architectures (STRAW), Workshop held at ICSE 2003

[9] Doerr, J., Kerkow, D., von Knethen, A., Paech, B., „*Eliciting Efficiency Requirements with Use Cases*”, 9th International Workshop on Requirments Engineering – Foundation for Software Quality, Workshop held at CaiSE’03, June 2003, pp. 23-32.

[10] Kerkow, D., Kohler, K., Doerr, J., “*Usability and Other Quality Aspects Derived from Use Cases*” Performance by Design. Proceedings of forUSE 2003, Second International Conference on Usage-Centered… (2003), pp. 135-154.

Copyright © Fraunhofer IESE 2005

[11] Kerkow, D., Doerr, J., Paech, B., Olsson, T., Koenig, T., "*Elicitation and Documentation of Non-functional Requirements for Sociotechnical Systems*" in José Luis Maté, Andrés Silva, "Requirements Engineering for Sociotechnical Systems", Idea Group, Inc., 2004

[12] ISO/IEC 9126-1:2001(E), "Software Engineering - Product Quality - Part 1: Quality Model", 2001

[13] Gross, F., Yu, E., "Evolving system architecture to meet changing business goals: an agent and goal-oriented approach", ICSE-Workshop, STRAW 2001

[14] Liu, L., Yu, E., "From requirements to architectural design – using goals and scenarios", ICSE-Workshop, STRAW 2001

[15] Common Criteria Version 2.1, http://csrc.nist.gov/cc/CC-v2.1.html

[16] Denger, C. et al., "*Product Line Analysis for Applications in the Virtual Office of the Future*", 17th International Conference on Software & System Engineering and their Applications, November 2004

[17] Virtual Office of the Future: www.ricoh.rlp-labs.de/

Copyright © Fraunhofer IESE 2005

Document Information

Title:	Non-Functional Requirements in Industry – Three Case Studies Adopting the ASPIRE™ NFR Method
Date:	April 2005
Report:	IESE-025.05/E
Status:	Final
Distribution:	Public

Copyright 2005, Fraunhofer IESE.
All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means including, without limitation, photocopying, recording, or otherwise, without the prior written permission of the publisher. Written permission is not needed if this publication is distributed for non-commercial purposes.