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Capturing, Eliciting, and Prioritizing (CEP) Non-Functional Requirements Metadata during the Early Stages of Agile Software Development

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We hereby certify that this dissertation, submitted by Richard Maiti, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirements for the degree of Doctor of Philosophy.

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An Abstract of a Dissertation Submitted to Nova Southeastern University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

Capturing, Eliciting, and Predicting (CEP) Non-Functional Requirements Metadata during the Early Stages of Agile Software Development

By
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Agile software engineering has been a popular methodology to develop software rapidly and efficiently. However, the Agile methodology often favors Functional Requirements (FRs) due to the nature of agile software development, and strongly neglects Non-Functional Requirements (NFRs). Neglecting NFRs has negative impacts on software products that have resulted in poor quality and higher cost to fix problems in later stages of software development.

This research developed the CEP "Capture Elicit Prioritize" methodology to effectively gather NFRs metadata from software requirement artifacts such as documents and images. Artifact included the Optical Character Recognition (OCR) artifact which gathered metadata from images. The other artifacts included: Database Artifact, NFR Locator Plus, NFR Priority Artifact, and Visualization Artifact. The NFRs metadata gathered reduced false positives to include NFRs in the early stages of software requirements gathering along with FRs. Furthermore, NFRs were prioritized using existing FRs methodologies which are important to stakeholders as well as software engineers in delivering quality software. This research built on prior studies by specifically focusing on NFRs during the early stages of agile software development.

Validation of the CEP methodology was accomplished by using the 26 requirements of the European Union (EU) eProcurement System. The NORMAP methodology was used as a baseline. In addition, the NERV methodology baseline results were used for comparison. The research results show that the CEP methodology successfully identified NFRs in 56 out of 57 requirement sentences that contained NFRs compared to 50 of the baseline and 55 of the NERV methodology. The results showed that the CEP methodology was successful in eliciting 98.24% of the baseline compared to the NORMAP methodology of 87.71%. This represents an improvement of 10.53% compared to the baseline results. of The NERV methodology result was 96.49% which represents an improvement of 1.75% for CEP. The CEP methodology successfully elicited 86 out of 88 NFR compared to the baseline NORMAP methodology of 75 and NERV methodology of 82. The NFR count elicitation success for the CEP methodology was 97.73 % compared to NORMAP methodology of 85.24 %which is an improvement of 12.49%. Comparison to the NERV methodology of 93.18%, CEP has an improvement of 4.55%. CEP methodology utilized the associated NFR Metadata (NFRM)/Figures/images and linked them to the related requirements to improve over the NORMAP and NERV methodologies. There were 29 baseline NFRs that were found in

the associated Figures/images (NFRM) and 129 NFRs were both in the requirement sentence and the associated Figure/images (NFRM).

Another goal of this study was to improve the prioritization of NFRs compared to prior studies. This research provided effective techniques to prioritize NFRs during the early stages of agile software development and the impacts that NFRs have on the software development process. The CEP methodology effectively prioritized NFRs by utilizing the αβγ-framework in a similarly way to FRs. The sub-process of the αβγ-framework was modified in a way that provided a very attractive feature to agile team members. Modification allowed the replacement of parts of the αβγ-framework to suit the team's specific needs in prioritizing NFRs. The top five requirements based on NFR prioritization were the following: 12.3, 24.5, 15.3, 7.5, and 7.1. The prioritization of NFRs fit the agile software development cycle and allows agile developers and members to plan accordingly to accommodate time and budget constraints.

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Chapter 1

Introduction

Background

In Software Engineering, Functional Requirements (FRs) have taken precedence and Non-Functional Requirements (NFRs) are overlooked until the later stages of software development. Software developers pay more attention to the functional needs of a software that fulfill the business needs and NFRs such as performance, usability, reliability, security, and scalability are usually handled later in an ad-hoc manner during the system testing phase (Nguyen, 2009). In order to have a better understanding of NFRs the following needs to be examined: what are NFRs, why NFRs so important and why do NFRs need to be considered during the early phase of agile software development.

NFRs refer to both observable qualities and available qualities of a system where observable qualities are system performance, availability and dependability whereas available qualities refer to maintainability and portability (Ameller, Ayala, Cabot, & Franch, 2012). FRs states what a system is supposed to do, whereas NFRs states how the system is supposed to achieve the behavior (Danylenko & Lowe, 2012).

The success of a system depends both on both FRs and NFRs (Slankas & Williams, 2013). An agreement made between customers and suppliers in regards to NFRs is important to the success of the Information Technology (IT) projects (Poort, Key, With, & Vilet, 2012). The complexity of software has been increasing and it becomes more important not just on the FRs of software but also NFRs which needs to be taken into consideration (Yin & Jin, 2012). Some NFRs such as load, security and

usability are detrimental to a software system if not handled properly (Yin & Jin, 2012). Software Architecture (SA) takes into account both FRs and NFRs where NFRs play a critical role in the overall system (Fabio, Lucena, & Lucena, 2013). When NFRs are missed significant cost issues become a problem. A cost issue example is the U.S. Army intelligence sharing application, which cost 2.7 billion dollars (USD) to develop and the application has been found to be useless (Slakas & Williams, 2013). In another example, electronic health records (EHRs) have been found to be not very user friendly requiring major rework of the application (Slakas & Williams, 2013). In software development projects where NFRs are not considered, a failure rate of 60% or higher has been observed (Bajapi & Gorthi, 2012).

NFRs have been gaining more attention lately and the mishandling of NFRs has been identified as the source for many project failures (Saadatmand, Cicchetti, & Sjodinm, 2012). NFRs are still not taken seriously and are often an afterthought towards the end of the development phase (Saadatmand et al., 2012). NFRs are stated in an informal way in with a high level of abstraction; therefore it is necessary to develop tools and methodologies to include NFRs along with FRs in the early phase of development (Saadatmand et al., 2012). The handling of NFRs was especially important in embedded and real-time systems due to the limitations on these systems (Saadatmand et al., 2012).

The methodologies for FRs have been in existence for many years whereas NFRs are starting to take precedence lately (Affleck, Krishna, & Achuthan, 2013). In modern and often-preferred agile software development such as SCRUM and Extreme Programming (XP) is designed for delivering quality FRs quickly. However, these agile software development methods do not take NFRs into consideration (Farid &

Mitropoulos, 2012). It has been noted that incomplete requirements have caused software projects to go over time, over budget and have caused the failure of software projects (Affleck et al., 2013). Many researchers have been trying to determine in which phase of software development to integrate NFRs (Jung & Lee, 2010). Taking NFRs into consideration during the early phases of the agile software engineering processes has improved the quality and agility of software (Farid & Mitropoulos, 2012). There has been increased research to deal with NFRs in a systematic way in the early stages of software development (Liu, Zhivi, Qiu, Chen & Shao, 2012).

There have been several studies that focused on evaluating Requests for Proposals (RFPs) in the early stages of development in order to reduce ambiguity of user requirements and to involve all stakeholders (Saito, Matsumoto, & Moden, 2012). The stakeholders are entities that have an interest in the project which maybe inside or outside of the organization (Karlsen, 2002). Examples of key stakeholders are customers, user groups, project manager and the development and the test teams. Stakeholders are actively involved in the project and have an influence on the project's objectives and outcomes (Karlsen, 2002). The project management team identifies the stakeholders in order to determine their requirements and expectations (Karlsen, 2002). The stakeholders' influences are managed in relation to the requirements in order to determine the success of a project (Karlsen, 2002). The research conducted by Saito et al. (2012), focuses on early evaluation of NFR before a contract is signed with the stakeholder. An early detection of NFRs is useful because it enabled system level constraints and incorporates early architectural design rather than being included towards the later phase of software development (Bajapi & Gorthi, 2012). Integrating NFRs in the early phase of

software development has lead to high customer satisfaction and profit maximization (Bajapi & Gorthi, 2012).

It is hypothesized that including and giving equal importance to NFRs in the early stages of software development can be effective in developing software which will improve stability and versatility (Farid, 2010; Domah, 2013). NFRs can be found in documents, images, and other artifacts during the early stages of software development. These include informal meetings with the architect and software engineers during the preliminary stages of software development. Research has been gathering NFRs from texts. However, there is a lack of research to gather NFRs from images and other documents. There are limitations to the NFR Locator, it worked well with texts but it did not extract information from tables and images (Slankas & Williams, 2013). NFRs need to be captured accurately and precisely not only from text but also from images. Furthermore, based on existing FRs, historical trending needs to be incorporated to predict other NFRs, which may not be transparent, based on the gathered FRs and NFRs. Historical trending is beneficial in using past data to predict an outcome in the future. In the medical field it was found that using interpretations by providing qualitative summaries of data can be beneficial when considering a given time in the past in deciding what measures are needed for patients (Salatian, Adepoju & Odinma, 2009). Applying similar concepts toward NFRs in examining past NFRs to predict accurate NFRs. In addition, similar to the prioritization of FRs there needs to be similar methodologies apply to prioritizing NFRs.

Problem Statement

Although intensive research in NFRs has been gaining attention, there needs to be further research to capture and elicit NFRs from images in agile software engineering during the early stages of agile software development. As mentioned by Slankas and Williams (2013), the NFR Locator was not able to extract NFRs from images within documents. The research conducted by Farid (2011) extracting NFRs from text based documents developed the NORMAP methodology focused on gathering NFRs and FRs and linking them with FRs from W^8 User Story Card. The study conducted by Domah (2013) extended the NORMAP methodology further by including two cards to gather FRs and NFRs called the NFRusCOM. Slankas and Williams (2013) developed the NFR Locator tool which worked well when capturing NFRs from text based documents, but the tool did not capture NFRs from images. NFRs can be located outside of text files where important NFRs could potentially be overlooked and ignored.

NFRs have been mostly ignored in software engineering and have often been considered during later stages of software development in an ad-hoc manner. Software developers pay more attention to the FRs of software that fulfills the business needs, and NFRs are usually handled later in an ad-hoc manner during the system testing phase (Nguyen, 2009). This has resulted in poor quality of software and high costs to fix the problems during later stages of software development. The methodologies that do exist cannot accurately gather NFRs metadata from images. This has resulted in software engineers having to go back and fix the problems in an ad-hoc manner, which results in higher unexpected costs.

Improving the accuracy of capturing NFRs from multiple sources during the early stages of software development involved the use of optical character recognition (OCR). OCR is aggressively used in digital preservation and has the ability to search through images to gather NFRs. There has been research and development over a decade that has resulted in OCR systems including both commercial and open source that can recognize printed as well as well-constrained hand written documents with accuracy (Peng, Cao, Setlur, Govindaraju & Natarjan, 2013). Using existing FRs methodology to prioritize NFRs may be overlooked during the early stages of software development

Dissertation Goal

The goal of this research was to develop a methodology to accurately capture and elicit NFRs from non text-based images. In order to accomplish this goal, OCR was used to capture and elicit NFRs from images and other digitized documents which was designated as a metric known as NFR metadata. These NFR metadata are often overlooked and NFRs have been mostly captured from user stories in agile process which is a 3 x 5 index card that are text based. NFRs have become as important as FRs and needs to be incorporated along with FRs in the early stages of software development. It was important to look at the impacts NFRs have in software architecture. The impacts resulted in better software and quality that is easy to maintain during the life cycle of the software which leads to cost savings and better quality of software. In addition, this study serves to build upon prior studies conducted by Farid (2011) and Domah (2013) in understanding the impacts of NFRs during the early stages of agile software development.

Research Questions and Hypotheses

The research study answered the following questions:

RQ1: How effective is the CEP methodology in identifying and linking metadata with NFRs such as images with other FRs and NFRs in the early stages of agile software engineering?

RQ2: To what degree can the additional NFRs gathered combined significantly improve gathering of NFRs and reduce the number of false positives from the NORMAP and NERV methodology?

Relevance and Significance

In agile software development, FRs has taken precedence and NFRs have been handled in an ad-hoc manner in the system-testing phase. Software developers pay more attention to functional needs of a software that fulfill the business needs and NFRs such as performance, usability, reliability, security, and scalability are usually handled later in an ad-hoc manner during the system testing phase (Nguyen, 2009). The research conducted by Fabio et al. (2013) extends the Strategy for Transition between Requirements models and Architectural Models (STREAM) process which reduced the gaps between architectural development and requirements where NFRs were considered in an ad-hoc manner, the architectural pattern (AP) was used to extend the STREAM process to STREAM-AP to include NFRs where the gap of refining and selection of an architecture is addressed.

Umar and Khan (2011) state that NFRs are important to address in the beginning stages of software development otherwise if they are identified later it will become costly and complex. When NFRs are missed significant cost issues have been a problem

(Slankas & Williams, 2013). Some examples of cost issues are the U.S. Army intelligence sharing application which cost 2.7 billion dollars (USD) and the application has been found to be useless (Slakas & Williams, 2013). Other examples, such as Electronic health record (EHR) have been found not to be very user friendly that requires major rework of the application (Slakas & Williams, 2013). In software development where NFRs are not considered come up with a failure rate of 60% or higher (Bajapi & Gorthi, 2012).

There is no known previous research study that examined the elicitation and capturing of NFRs metadata from images and used those NFRs metadata to link to other NFRs and FRs metadata. Most of the focus has been gathering NFRs from text documents where user stories reside. It is important to capture NFRs from other media that can be linked to other NFRs and FRs in improving the quality of software. In addition, the NFRs metadata gathered from images can help in reducing the number of false positives.

Barriers and Issues

This section presents the barriers and issues for the study. The key for success of this study is to effectively gather NFRs from images using optical character recognition (OCR). There are barriers in an organization that involves the use of multi-media to gather requirements. Some organizations may use traditional methods such as text based user story cards to gather requirements in an agile process and may not record metadata which take place in conferences and on white boards since agile methodologies such as Extreme Programming (XP) and SCRUM capture requirements in a simple 3 x 5 cards. Customers define their valuable features in a story which represents the smallest possible

increment in XP (Qasaimeh, Mehrfard, & Hamou-Lhadj, 2008). Furthermore, key activities in SCRUM consist of product and spring backlog list where sprint goals are set every 30 days (Qasaimeh et al., 2008). The Crystal Methodology has Crystal Light and Crystal Orange where Crystal Light is for small projects and Crystal Orange is for bigger projects (Oasaimeh et al., 2008). The Crystal Clear requirements are very light expressed in UML such as use case, class diagram and object diagram whereas Crystal Orange has more documentation and natural language for requirements (Oasaimeh et al., 2008). In FDD the detailed model is built which captures the requirements of the stakeholder and shares similarities to Crystal Methodology (Oasaimeh et al., 2008). In ASD the requirements start out as unclear and with each iteration the requirements become clear (Oasaimeh et al., 2008). The agile process is reduced to informal documentation, face-to-face communication, and on-site customer visits (Oasaimeh, 2008). There are important preliminary requirements gathering and discussion meetings that take place between software engineers, stakeholders and architects prior to software design where devices such as tablets and smart phones are used to gather requirements. These important metadata may not be recorded systematically in traditional agile requirement gathering methodology. Therefore, this methodology is geared for organizations that utilize technologies such as smart white boards, tablets, smart phones and the wikis in the requirements gathering process of software development.

Other barriers that may exist are organizations that take only FRs into consideration while ignoring NFRs. In agile software engineering most organizations take FRs into consideration where NFRs are often not considered until later stages of development. Software developers pay more attention to functional needs of a software

that fulfill the business needs and NFRs such as performance, usability, reliability, security, and scalability are usually handled later during the system testing phase in a ad-hoc manner (Nguyen, 2009). There is a lot of neglect for NFRs where FRs requirements are taken into consideration thorough out the software development process and NFRs are considered in the later phase of software development (Bajapi & Gorthi, 2012). Furthermore, agile has very short iteration periods which last between one to four weeks (Domah, 2013). Therefore, it is necessary to elicit and capture NFRs during this short period of time which may be difficult due to the nature of agile software development.

The use of optical character recognition (OCR) may not be compatible with different media types where NFRs are located and could pose a barrier due to compatibility. Furthermore, there was not a way to test the NFR captured by OCR in order to verify the quality of the NFR. It was important to look at images and other media where potential NFRs may exist along with FRs. This was the first use of OCR technology to gather NFRs where potential barriers of OCR may exist in the technique of gathering NFRs metadata.

Assumptions

The following assumptions were made within the study. The data used in the study from the United States and European Union requirements document was representative of a requirements document used in a business or organization for agile software development. Furthermore, the NFRs gathered were a representation of a business or organization requirements in agile software development.

Limitations

The study was restricted to requirement documents from the United States and European Union. The study may differ in different organizations around the world. The other restriction was that the limitation of using a few sets of requirement documents and the study may differ with an aggregate of requirement documents.

Delimitations

The study was limited to software requirement documents in Europe and the United States. In addition, the study was restricted to requirement documents for agile software engineering. Furthermore, the images gathered from these documents were restricted to documents from corporate organizations.

Definition of Terms

Functional Requirements (FR) - FRs states what a system is supposed to do whereas NFRs states how the system is supposed to achieve the behavior (Danylenko & Lowe, 2012).

Non-Functional Requirements (NFR) - refers to both observable qualities and available qualities of a system where observable qualities are system performance, availability and dependability whereas available qualities refer to maintainability and portability (Ameller et al., 2012).

NFRs metadata (NFRM) - refers to Non-Functional Requirements and its associated metadata.

Optical Character Recognition (OCR) - is used for converting text from scanned documents into digital versions that can be editable and managed (Peng et al., 2013).

Predicted NFRs - refers to Non-Functional Requirements that are predicted from past metadata.

Summary

The objective of this chapter is to give an introduction to the study, present the research problem and cover the dissertation goals. The research problem emphasized the need for further research to capture and elicit NFRs from images in agile software engineering during the early stages of agile software development. To accomplish this goal, OCR was used to capture and elicit NFRs from images and other digitized documents that was designated as a metric known as NFR metadata. NFRs have become as important as FRs in agile software development. There is a need to examine the impacts NFRs have on software architecture. These impact results in better software quality that is easy to maintain during the life cycle of the software.

Furthermore, the research questions and hypotheses are presented in this section. The relevance and significance of the study is presented in order to provide a theoretical basis for the study. The remainder of the research is organized as follows: review of literature of NFRs, methodology, results, and conclusion, implication, recommendations, and summary.

Chapter 2

Review of the Literature

Introduction

The current approach has given more emphasis on FRs in the initial stages of software development where NFRs are not considered until the final stages of software development although at this stage it may not address the user's requirements (Ullah, Iqbal, & Khan, 2011). There have been a number of studies conducted to incorporate NFRs with FRs during the early stages of software development. The literature survey examines the NFRs approaches in the following categories: goal driven approach and Chung's NFR framework, pattern based approach, Unified Modeling Language (UML) approach, visualization approach, other approaches and studies that were conducted to show importance of NFRs over FRs. Furthermore, a section for Optical Character Recognition (OCR) and historical trending is added. Some of the approach in literature may overlap with each other therefore it is difficult to put them in a concise category.

Goal Driven Approach and Chung's NFR Framework

The goal driven and Chung's NFR framework approach has been used by many researchers as a methodology to incorporate NFRs. The goal driven and Chung's NFR framework approach is simplistic and can be extended to include other goals as needed. Software developers pay more attention to functional needs of a software that fulfill the business needs and NFRs such as performance, usability, reliability, security, and scalability are usually handled later in an ad-hoc manner during the system testing phase (Nguyen, 2009). NFRs may be needed in all aspects of Software Product Line (SPL) where a requirement maybe common across all product lines and the variation exists in

the requirement; this is where the parameterized or alternative feature is applied (Nguyen, 2009). The strategy was to develop a requirement engineer that models both NFRs and FRs, a framework to analyze NFR that takes the interdependencies of both FR and NFR, and application engineering that selects and characterizes product configuration for both FR and NFR.

The modeling being considered here is goal based modeling where all requirements are considered to be goals (Nguyen, 2009). NFRs are considered to be softgoals and two AND/OR trees can be built to visualize goals where one is for NFRs and the other is for FRs (Nguyen, 2009). The correlation can be shown as a direct graph where the nodes are goals, the target nodes are softgoals and the edges are represented by the + or – characters (Nguyen, 2009). The requirements are organized in hierarchy which is a logical AND tree where each node is the following: feature or an NFR, priority of the requirement is contained within the node, if a feature does not have an impact on NFR its priority is equal to zero and the priority of a child cannot exceed its parent (Nguyen, 2009). The extended approach based on UML where the PLUS extends to include performance requirements in different modeling phases by the SPL (Nguyen, 2009).

Nguyen (2009) recommended extending the PLUS approach above to include other NFRs since the focus is currently on the performance NFRs only. Also to include discrete values to express degree of satisfice-ability for rating purposes to rate NFRs as high, medium or low (Nguyen, 2009). In the same manner the security NFRs can be enhanced to provide the levels of protection by acknowledging the level of data protection as outlined in the NIST standard (Nguyen, 2009). Nguyen (2009) also proposed to add new stereotypes to support NFR as follows: common, optional,

alternative, and parameterize NFRs. The weakness of this approach is that it only focuses on a particular NFR and not all NFRs can be used in the same methodology since NFRs can drastically differ from each other. Furthermore, one NFR may have impacts on another NFR or even FR. The strength of this methodology was that it uses existing design tools such as UML to incorporate NFRs. The developers and software architects are familiar with these tools and incorporating NFRs with FRs is perhaps easier if similar tools are utilized. Umar and Khan (2011) found that the limitations of the Extended PLUS approach included only a single NFR and that NFR being performance. There is gap in this research that it does not incorporate all the NFRs since not all NFRs share the same attributes. Next, similar research studies are examined.

Software system requirements fall into two categories, FRs and NFRs, where FRs are clearly defined in IEEE and NFRs are not clearly defined (Burgess, Krishna, & Jiang, 2009). The managing of NFRs has been a challenge and is often considered to be conflicting where one NFR may help satisfy functionality and another NFR may hinder the functionality (Burgess et al., 2009). NFR's are subjective in nature where system developers may consider efficiency of a system to have responses between 1-2 seconds and the users may not agree with the performance of the system; due to this subjective nature of NFRs it becomes apparent to use tools and methodologies to manage NFRs (Burgess et al., 2009).

Chung's NFR framework is based on goal-based Artificial Intelligence which is a process driven approach to managing NFRs (Burgess et al., 2009). In Chung's NFR framework, NFRs are represented as softgoals as opposed to goals that are defined (Burgess et al., 2009). The basic structure of Chung's NFR framework is represented

with softgoals that are to be satisfied and operationalizing softgoals that represent system functionalities which is displayed in a graph like structure with the relationships of interdependencies between NFRs and system functionalities (Burgess et al., 2009). The Softgoal Interdependency Graph (SIG) is where system functionalities are assigned and satisfied labels on operationalizing softgoals (Burgess et al., 2009). The NFR softgoals are labeled as the following: Satisficed (S), Weakly Satisficed (W+), Unknown (U), Conflict (C), Weakly Denied (W-), or Denied (D) (Burgess et al., 2009).

The methodology presented by Burgess et al. (2009), showed an adaptation of Chung's NFR framework that is process-driven which automatically determines the optimal set of system functionalities which meets a given set of NFRs. Softgoal Interdependency Rule set Graphs (SIRGs) is a newly developed methodology that represents NFR system functionalities and the relationships for automatic optimization (Burgess et al., 2009).

There are additional features that could be added to SIRGs such as Top-level NFR's assigned priority levels, the total volume *v* having a weight according to NFRs priority level (Burgess et al., 2009). The operationalizing softgoals can have costs assigned which represent a wide range of resource factors as follows: development time and cost, maintenance cost and risks in terms of development difficulties (Burgess et al., 2009). The weakness is that all NFRs are treated equally and in essence there is a gap where NFRs are not equal and can differ from one NFR to another. However, the strength of the approach was to assign cost, priority and weight given to NFRs. This is taking risk into consideration to discretely classify NFRs. Next, the approach that is examined is the uses of the Chung's NFR framework.

The leading cause of many project failures is due to improper management of NFRs (Affleck & Krishna, 2012). The Chung's NFR framework was developed to address this issue where NFRs were applied in late requirements or early design phase (Affleck & Krishna, 2012). The Chung's NFR framework bridged the gap between requirements and design in terms of NFRs (Affleck & Krishna, 2012). However, the Chung's NFR framework did not have any quantitative support and the research conducted by Affleck and Krishna (2012) extends the Chung's NFR framework. The steps to extend the Chung's NFR framework include the following: identify softgoals, decompose softgoals, assign leaf-softgoals weights, identify operationalization, calculate operationalization scores, calculate leaf-softgoal scores, calculate softgoal scores and calculate attainment. The discrepancies that were found in the extended Chung's NFR framework during the simulation were due to satisfying the rules of the simulation or the decisions that were made by the developers during the simulation (Affleck & Krishna, 2012). It was found that the extended framework can be applied to any system but it may not be necessary to do so, one-on-one mapping of softgoals and operationalization did not have any use of the extension in decision making and the higher number of trade-off present in SIG was useful for the developers (Affleck & Krishna, 2012). The operationalization selection process can be modified to optimize the leaf-sofgoal, softgoal and attainment scores which can have an impact in the improvement of effort, time, cost which are success factors for a software project (Affleck & Krishna, 2012). The strength can be observed from the extended Chung's NFR framework which can be applied to any system as observed by Affleck and Krishna (2012). The research study does not discuss any of the other or specific NFRs as examined in the previous studies that not all NFRs

are alike and cannot be treated equally. The weakness in the research lies in identifying and classifying specific NFRs which seems to be a trend with many of the research studies. Next, additional studies that are similar to this study are reviewed and examined.

The importance of NFRs such as security, reliability and performance play an important role in determining the success or failure of a system (Uznov, Falkner, & Fernandez, 2013). The research conducted by Uznov et al. (2013), developed a three-level conceptual framework decomposing distributed software architecture that incorporates NFRs in an early stage by offering additional structure and provides a basis of new design level NFRs. The decomposition approach starts at the any level of architectural element in the earliest stages of development to detailed design (Uznov et al., 2013). The levels of decomposition framework include the following: high-level modeling abstraction, functionality decomposition layers and technical realization abstractions (Uznov et al., 2013). At the top of the framework contains a set of modeling abstractions which are used to develop architectural models and to set a common vocabulary on distributed systems, the middle or second framework level contains the functionality of the distributed system, and the third framework level consists of low-level abstractions that are attached to functionality in the decomposed layers (Uznov et al., 2013). The research demonstrated the use of the framework with the use of incorporating security requirements along with simple security analysis process (Uznov et al., 2013). The framework can be used to process other NFRs such as reliability and performance (Uznov et al., 2013). The framework does have the capability to support reliability and performance. These were not incorporated in the demonstration of the framework. The security scope that is available is limited and should include pre-defined

attack list to support the framework, this would be more helpful for developers that do not have an extensive experience in security (Uznov et al., 2013).

The weakness as discussed is that the Chung's NFR framework did not test for reliability and performance although there is support within the framework for reliability and performance. As mentioned earlier not all NFRs should be treated alike since they many differ from each other and one NFR may depend on one or the other NFR. There also could be conflicts with NFRs and FRs therefore accurate classification of NFRs is required. Also, security is becoming more main-stream where attacks here are pre-defined. There needs to be more extensive NFR research done to incorporate different types of NFRs such as security.

The trends of these approaches use the Chung's NFR framework that is goal based where each author has extended each of these approaches from Chung's NFR framework. The trend with each of these approaches as mentioned earlier was identifying and classifying each of the individual NFRs where NFRs seems to be broad or selective NFRs in each of the methodologies presented. Next, NFRs using a pattern based approach is examined.

Pattern Based Approach

Dealing with NFRs requires a large body of knowledge in regards to NFRs where such knowledge can be used to capture NFR patterns to be reused (Supakkul & Chung, 2010). However, there can be complexity and rules to reuse NFRs when they are only represented in a textual manner (Supakkul & Chung, 2010). The research conducted by Supakkul and Chung (2010) examines NFR visualization patterns, objective patterns that capture definition of NFR, problem patterns that capture obstacles to achieve an NFR,

alternative patterns that capture options to achieve NFR, and selection patterns for the most alternative acceptable compromise.

Security and trustworthiness are treated as softgoals (Supakkul & Chung, 2010). Four kinds of patterns as follows: objective pattern, problem pattern, alternative pattern and selection pattern (Supakkul & Chung, 2010). A NFR pattern is captured in a visual model that represents a NFR knowledge that is common (Supakkul & Chung, 2010). An NFR pattern can be subjective in nature depending on the stakeholder's definition therefore objective patterns can be used to visually and explicitly capture different definitions of NFR where the stakeholder can reuse the NFR with the specific softgoal (Supakkul & Chung, 2010). The problem pattern is used in capturing the knowledge of soft-problems (Supakkul & Chung, 2010). In order to deal with the subjective and conflicting NFRs that are different from achieving a softgoal, a soft-problem can be captured in an alternative pattern (Supakkul & Chung, 2010). The selection pattern can be used to capture selection schemes which help make decisions more automatic and systematic (Supakkul & Chung, 2010). The patterns are organized as follows: Specialization-of Relationship, Part-of Relationship and Occurrence-of Relationship (Supakkul & Chung, 2010). The Specialization-of Relationship captures situations that are specialized for a specific situation, part-of relationship is used to put together smaller patterns into larger chunks of knowledge (Supakkul & Chung, 2010). The pattern operation takes one or more softgoal or soft-problem and references them into one softgoal or soft-problem (Supakkul & Chung, 2010). In the apply operation a NFR model references a softgoal or soft-problem to be refined to a specific pattern (Supakkul & Chung, 2010). The specialized operation supports extensions of visual model in a

model-based tool environment (Supakkul & Chung, 2010). The compose operation takes one or more patterns in order to produce a new composite pattern (Supakkul & Chung, 2010). The instantiate operation takes a pattern that serves as a template to reference the model for binding specifications (Supakkul & Chung, 2010).

The tool developed by Supakkul and Chung (2010) is an extension of StarUML to visualize NFR patterns, objective pattern that captures definition of NFR as a goal to be achieved, problem pattern that captures obstacles that need to be avoided, alternative patterns for capturing solutions, and selection patterns to choose alternatives (Supakkul & Chung, 2010). The tool is also supportive of visualization of inter-pattern relationships which includes the following: specialization, composition, and instantiation. A framework for supporting visualization for NFR patterns is used to capture refinement rules and is applied to a target model during reuse where refinement rules are used in enforcing integrity constraints for relationships of patterns (Supakkul & Chung, 2010). The weakness lies in the number of patterns that are available and the more NFR patterns that exist the more refined the NFR pattern may become in the future. There is a dependence on other NFRs patterns. The strength is in the reuse of patterns which is in support of reusing in the software development and design process. The visualization of NFRs patterns is an advantage in communicating the NFRs requirements between stakeholders and developers. The limitation of the Chung model as explained by Umar and Khan (2011) is that the model does not take other software development phases such as architecture and design into consideration. To take the other software development phase into consideration would strengthen this methodology. Next, similar research is examined.

The complexity of software has been increasing and it becomes more important not just on the FRs of software but also the NFRs which need to be taken into consideration (Yin & Jin, 2012). Some NFRs such as load, security and usability are critical to a software system (Yin & Jin, 2012). The Problem Frame (PF) is an approach that is used for classifying, analyzing and structuring software problems but it does not capture NFRs (Yin & Jin, 2012). The research conducted by Yin and Jin (2012) integrates NFRs into the PF approach. The PF approach is to capture commonly found problems into sub-problems where it deals with FRs, and the approach by Yin and Jin (2012) integrated NFRs and follows a similar approach. The condition of the NFRs must be specified and therefore a proposed meta-model of NFRs elicitation process is developed called NFR Enhanced Problem Model (NfrEPM) (Yin & Jin, 2012). The process is a step-by-step approach to capture NFRs by PF approach which includes selecting the approach of each problem, capturing the NFRs and identifying the conditions (Yin & Jin, 2012). This is another approach where an existing approach is taken that is used to capture FRs using PF and is integrated to capture NFRs. The weakness is that NFRs can vary; Therefore, not one model that fits all approached can be taken into consideration as has seen from previous research. Just as the complexity of software is increasing, the complexity of NFRs is also increasing; Therefore, specialization of dealing with different NFRs is required (Yin & Jin, 2012). Also, advanced methodologies need to incorporate the changing NFRs to deal with complex systems.

UML approach

In this section, NFRs that are integrated with Unified Modeling Language are examined. The use of UML is simplistic since it is well known by most software engineers and stakeholders. SysML is an extension to UML which is used for complex systems engineering where it could be extended into requirements modeling (Gnaho, Semmak, & Laleau, 2011). This research extended the SysML requirements meta-model to incorporate NFRs and the emphasis is given on the impacts of NFRs to FRs (Gnaho et al., 2011). The meta-class Non Functional Goal gathers information in regards to non functional goals which is a subclass of meta-class goals followed by a subclass of SysML (Gnaho et al., 2011). The non-functional goals are either elementary NFG that cannot be extended further or abstract NFG which is broken into smaller sub-goals (Gnaho et al., 2011). Towards the end of the refinement process it will be necessary to identify and come up with a possible solution for the NFG since unlike FG, NFG can be subjective therefore the concept of contribution is to come up with a solution to satisfy the elementary NFG (Gnaho et al., 2011). The contribution characteristics are captured by the association Contribution-Feature which has the following two properties: Contribution-Nature where the contribution is explicit or induced and Contribution-Type where the contribution is either positive or negative (Gnaho et al., 2011).

The approach by Gnaho et al. (2011) was to take functional goals and non functional goals in the same level of abstraction because non functional goals may have impacts when making decision in regards to functional goals. The concept of Impact is contributed by two main properties which are Impact-Type and Impact-Argument (Gnaho et al., 2011). The negative and positive are impacts that are associated with the

contribution towards the achievement goal (Gnaho et al., 2011). The strength of the approach is that it treats NFRs and FRs equally as goals and determines their impacts equally. However, the weakness is that is satisfied an elementary NFG which is simplistic; as know from previous literature NFRs are not simplistic and can differ drastically therefore the research needs to be refined to capture complex NFG.

There has been increased research in the area of NFRs to provide software that meets user compliance (Liu et al., 2012). There has been an increased research to deal with NFRs in a systematic way in the early stages of software development (Liu et al., 2012). There is a gap between requirement analysis and software design in terms of NFRs (Liu et al., 2012). Most of the approaches in dealing with NFRs are coarse-gained framework that lack in detailed and operational procedures (Liu et al., 2012). In order to systematically deal with NFRs in software development there needs to be more processing based analysis on existing NFRs (Liu et al., 2012). The approach proposed by Liu et al. (2012), transitioned NFRs into UML design models. NFR specific patterns are used as a knowledge base where the NFRs are refined and aspect-oriented mechanism was used to integrate the instantiation into an existing design model (Liu et al., 2012). The approach takes the Chung's NFR framework from Supakkul and Chung (2010) and initial design model incorporating traditional approaches (Liu et al., 2012). The approach is as follows: the NFR is identified using the Chung's NFR framework where the Softgoal Interdependency Graph (SIG) will be produced, NFR tactic models are built based on the SIGs, and for each tactic in the tactic model corresponding implementation pattern is selected from the NFR-pattern repository (Liu et al., 2012). In order to incorporate NFR tactics a responsibility-driven and annotation-based mechanism is used

to instantiate selected pattern which are based on system functionality (Liu et al., 2012). The integration of models is used with aspect-oriented techniques which are automatically generated from existing models (Liu et al., 2012).

Designing NFRs and integrating them into design model in the key to integrate them into the software development process (Liu et al., 2012). The pattern-based approach is to design NFR tactics and to integrate them with the UML design models (Liu et al., 2012). The use of SIGs is incorporated to model NFR tactics, designed on NFR patterns and incorporating them to existing UML models with the use of aspect-oriented mechanism (Liu et al., 2012). A pattern library would be useful for frequently used NFRs (Liu et al., 2012). Also, basic or common pattern of NFRs would be useful patterns as well. The approach was not validated in a real project which the author intends to do in future studies (Liu et al., 2012). The weakness of the methodology as stated by the author is that the approach has not been validated. However, this is an approach that considered NFRs to be complex and needs to be dealt with in a systematic order. The use of UML is a familiar design tool among developers and designers alike and incorporating NFRs in an existing tool that is used for FRs can be useful and simplistic to adapt. Also, the author acknowledged that the early design to incorporate NFRs is useful in the design phase. Next, another approach that incorporated the use of UML is reviewed.

NFRs have been gaining more attention and the mishandling of NFRs has been identified as the source for project failure (Saadatmand et al., 2012). NFRs are still not taken seriously and are often thought of as an after thought towards the end of the software development phase (Saadatmand et al., 2012). NFRs are stated in an informal

way in a high level of abstraction therefore it is necessary to develop tools and methodology to include NFRs along with FRs in the early phase of software development (Saadatmand et al., 2012). The handling of NFRs is important in embedded and real-time systems due to the limitations on these systems (Saadatmand et al., 2012). There are several reasons to incorporate NFRs in the development process especially in real-time embedded systems where NFRs play a critical role (Saadatmand et al., 2012). Model Based Development (MBD) would be appropriate to integrate with NFRs since both provide a high level of abstraction (Saadatmand et al., 2012). Implementing NFRs through UML has multitude of benefits since UML is already an accepted standard modeling tool where the learning curve will be less that includes cost and saving benefits for organizations.

The following characteristics of NFRs were developed by Saadatmand et al (2012): traceability of design decisions since NFRs crosscut different parts of the system, traceability among NFRs where higher level of NFRs are broken down into concrete ones, the satisfaction level of NFR to compare current design with system specific design and customer requirements, the impacts of NFRs on other NFRs, the priority of NFRs to compare the importance of each NFRs, coherent terms for NFRs and coherent measures of NFRs (Saaadatmand et al., 2012). There are templates that describe abstractions which captures different aspects of non-function properties (Saadatmand et al., 2012).

The above research introduced Q-Softgoal Interdependency Graph (SIG) which is a quantified version of SIG to apply this in the form of UML which provides a tooling solution for evaluation analysis and evaluation of NFRs modeling (Saadatmand et al., 2012). Saadatmand et al. (2012) introduced UML profile for modeling NFRs and their

dependencies. The comparison showed different design models to determine which ones achieved a higher level of satisfaction for NFRs (Saadtmand et al., 2012). This approach is not very applicable in large systems due to the issue of scalability and applicable to large complex systems (Saadtmand et al., 2012). This section ends by showing two different approaches that use UML. The use of UML to incorporate NFRs is a familiar tool to both stakeholders and developers alike. As the author pointed out the learning curve for UML is much shorter than an unfamiliar tool. Also, the above research stated the drawbacks for using UML for NFRs is for simplistic systems and may not be adequate for larger and complex systems. Therefore, the gap exists that there is not an NFR modeling tool for capturing NFRs for large and complex systems. This seems to be an underlying problem with many of the methodologies and tools that were evaluated. Another growing area of dealing with NFRs which is visualization of NFRs is examined next.

Visual Tool approach

In this section different methodologies that incorporate visualization of NFRs are examined. The advantage of the visualization framework allows software architects and designers to view the interactions of NFRs (Umar & Khan, 2011). Several studies have incorporated the visualization framework with other known frameworks such as Chung's NFR framework. The visualization framework and methodologies are examined in the sections to follow.

The research conducted by Rohleder (2012) looks in NFRs in the area of services rather than a specific behavior. These services are qualities that the service must show such as a service of confidentiality (Rohleder, 2012). The approach conducted by

Rohleder (2012) is based on the International Service Model (ISM). Rohleder (2012) demonstrates a graphical and textual representation of NFR as shown in Figure 1.

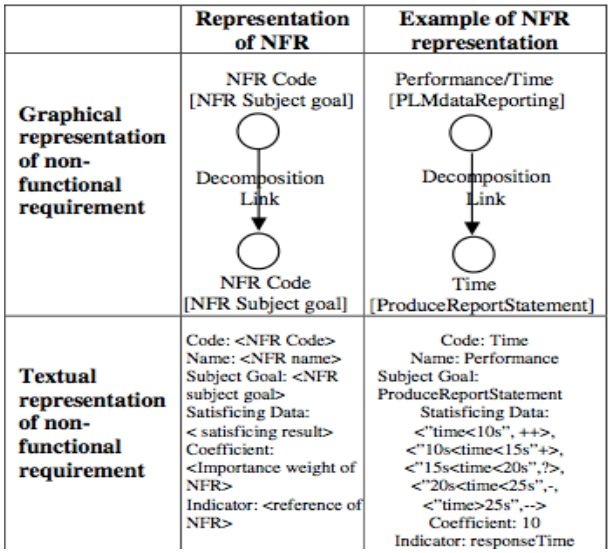


Figure 1. Graphical and Textual representation of NFR (Rohleder, 2012).

In Figure 1 above shows, a NFR is represented by a circle and is used to decompose the NFR (Rohleder, 2012). The textual representation of NFR goals shows the NFR NAME, subject goal, satisficing data, coefficient and indicator (Rohleder, 2012).

The ISM model was used to include NFRs in the area of Quality of Service (QoS) (Rohleder, 2012). This type of model is easy to understand for business stakeholder due to the strategic and tactical thinking (Rohleder, 2012). The model represents the service as well as the NFR impacts in an easy to understand graphical representation (Rohleder, 2012). This also provides a communication tool between the user and other stakeholder which may include designers and developers (Rohleder, 2012). The graphical representation is helpful in communicating between stakeholders and developers. The graphical approach is simplistic as explained by the author. These are the strengths of the

methodology. The weakness lies that it looks into an area of service rather than specific NFRs where all NFRs are treated alike. This is a trend that has been seen with many of the methodologies dealing with NFRs. This is a significant gap in research where NFRs need to be distinctly classified.

Software development methodologies have not linked NFRs with FR (Farid & Mitropoulos, 2012). It has been shown that NFRs are not well defined in conventional requirements of engineering and are often ignored in agile development methodologies (Farid & Mitropoulos, 2012). The study conducted by Farid and Mitropoulos (2012), developed a tool called Non-Functional Requirements Modeling for Agile Automatic (NORMATIC) which is a Java based tool that supports general NFRs modeling. The research conducted used the NORMAP methodology to identify, link and model NFRs with FRs to improve software quality in an agile development process (Farid & Mitropoulos, 2012). Previous studies have shown that there is a lack of NFRs identification, modeling and linking FRs in an agile environment where agile development methodologies lack NFRs (Farid & Mitropoulos, 2012). The objective of NORMATIC was to develop a NFRs modeling tool which supports agile development process (Farid & Mitropoulos, 2012). The building block of NORMATIC which incorporated the NORMAP framework is as follows: Agile Use Case (AUC), Agile Loose Case (ALC) and Agile Choose Case (ACC) (Farid & Mitropoulos, 2012). AUC includes the requirement quality attributes and additional information such as requested start/end dates; release and sprint of requirement, and risk score (Farid & Mitropoulos, 2012). Where as the ALC identifies to address NFR as a story where the term “Loose” is derived from Chung’s NFR framework of “Soft” goals referring that these goals are

difficult to identify (Farid & Mitropoulos, 2012). ACC is used as the potential solution for identifying the ALC and additionally contains basic project management data such as size, estimate, risk and business priority (Farid & Mitropoulos, 2012).

The objective of NORMATIC was to integrate FRs and NFRs modeling in one agile tool, improve agility by parsing user stories automatically, improve agility by classifying NFRs, improve story card model to capture NRFs or FRs, and classifying NFRs into the following types: source code, architecture and design, and organizational policies (Farid & Mitropoulos, 2012). Additionally, NORMATIC objectives were to improve visualization of NFRs and their potential solutions and provide extensions through project management and requirement quality metrics (Farid & Mitropoulos, 2012). The strength of this approach was that it takes a well-know agile software development methodology and project management methodology to come up with an innovative tool that can be used by software developers, architects and project managers. The weakness may lie that it takes a general NFR model as mentioned by the authors.

The research gap that exists is combining Agile Project Management methodologies with Agile NFRs (Farid & Mitropoulos, 2013). The Non-functional Requirements Plan (NORPLAN) develops a new project management metric, risk quality metrics, and risk driven algorithm that can be used by project managers and SCRUM team for better prioritizing and integrating NFRs (Farid & Mitropoulos, 2013). The NORMAP methodology takes additional metrics into account: technical and project risks (Farid & Mitropoulos, 2013). The requirement quality metrics in NORMAP are equally important in calculating risks which is important in agile planning (Fardi & Mitropoulos, 2013). The case study was limited to the European Union (EU) procurement system

(Farid & Mitropoulos, 2013). The analysis showed that the riskiest requirements are more expensive to mitigate later in the phase of development than requirements addressed in the early phases of software development (Farid & Mitropoulos, 2013). One case study was used to validate NORPLAN with the use of the NORMAP methodology (Farid & Mitropoulos, 2013). There needs to be further research done to include more requirement quality metrics to further validate NORPLAN (Farid & Mitropoulos, 2013). There needs to be more case studies conducted in other industries to further validate the NORMAP methodology in industries other than the EU. The risk is taken into consideration but cost was not taken into consideration which is perhaps a weakness in the study.

In regards to the NORMAP methodology, Agile Loose Case (ALC) has a possibility of having impacts on other ALCs (Farid & Mitropoulos, 2013). Using Chung's NFR framework the ALCs can impact one another in the following four modes: MAKE, HELP, HURT or BREAK (Farid & Mitropoulos, 2013). The research conducted by Farid and Mitropoulos (2013) further expanded the NORMAP methodology to assigned numeric impact values as follows: 0-25% for BREAK, 26-49% for HURT, 50-80% for HELP and 81-100% for HURT. The limitation of Chung's model is that it does not take other software development phases such as architecture and design into consideration (Amar & Khan, 2011).

The Non-Functional Requirements Elicitation, Reasoning and Validation NERV methodology addressed NFRs in the early stages of the agile process (Domah, 2013). It is a light weight methodology to help agile team member in handling NFRs (Domah, 2013). The agile metrics developed in the NERV methodology were based on the 12

principles of Agile Manifesto to develop the NERV agility index (NAI) (Domah, 2013). The NERV methodology incorporated previous research studies in NFRs to form a blended approach by also using the Chung's NFR framework and Zachman's framework to develop the NFR trigger card (Domah, 2013). The NERV methodology is an improvement upon the NORMAP methodology.

FRs has taken more precedence and NFRs are not taken seriously until later in the software development stages. The emphasis has been to fulfill the business needs where NFRs are neglected and handled in an ad-hoc manner. Nyguyen (2009) states NFRs can be performance, usability, reliability, security, and scalability. Per literature reviewed NFRs can have a tremendous impact on a software system. Furthermore, taking action early can be beneficial to incorporate NFRs into the early stages of software development.

NFRs along with FRs are the most important requirements combined in software developments (Umar & Khan, 2011). Furthermore, Umar and Khan (2011) state that NFRs are important to address in the beginning stages of software development; otherwise if NFRs are identified later it will become costlier and complex. This is a view shared by many of the literature that was evaluated. Requirements Engineering (RE) is the most important part of the software development life cycle (Umar & Khan, 2011). The expectations of customers and stakeholders are to get quality functional software which takes NFRs into consideration (Umar & Khan, 2011). However, NFRs are considered to be one of the most difficult areas to deal with and have been ignored by the software industry until the start of this decade where considering both FRs and NFRs increased the rate of success for software (Umar & Khan, 2011).

Optical Character Recognition

Optical Character Recognition (OCR) which is used for converting text from scanned documents into digital versions that can be editable and managed (Peng et al., 2013). There has been decades of research and development that has resulted in OCR systems that include both commercial and open source that can recognize printed as well as well-constrained hand written documents with accuracy (Peng et. al., 2013). The rise of affordable cameras and mobile smart phones has resulted in significant interest in location and recognition of scene text for a variety of mobile applications thus becoming a hot area for research (Peng et al., 2013).

The first step of an OCR system is preprocessing which is to identify the text within the document, segment them into text lines and generation of a noise-free, normalization of line or word image leading to further processing (Peng et al., 2013). Most OCR systems are designed to work with binarized images where good binarization is crucial for performance leading to instance research in binarization (Peng et al., 2013). The next step is page segmentation where regions of the text of a document image is identified and separated into meaningful components where the information is fed into a line finding and recognition system (Peng et al., 2013). The line finding algorithm is applied to extract lines of text from the document image where machine printed language is easier to extract than hand written text which requires the use of graph based methods (Peng et al., 2013). Bukhari, Shafait and Breuel (2009) propose a script independent text line segmentation approach that is based on contour lines for multilingual OCR system. The OCR system further divides the text lines into small units such as word, characters or sub-characters for identification (Peng et al., 2013). In most OCR the script and language

is assumed to be known beforehand thus improving performance for identification (Peng et al., 2013). There have been advances made in OCR in the multilingual handwritten scripts (Peng et al. 2013). However, a multilingual OCR system that can recognize any script by re-training on data is not easy to achieve and this is the underlying weakness of multilingual OCR (Peng et al., 2013).

OCR technology has existed for years and the accuracy has improved where many regard the commercially available OCR to be perfectly accurate (Kluzner, Tzadok, Chevion & Walach, 2011). However, this is not accurate since more OCR engines have an error rate between 1% and 10% (Kluzner et al., 2011). There is a need to improve methods for whole-book recognition and the popular approach is adaptive OCR which is the system using an adaptive mechanism that adapts itself to the text book being processed (Kluzner et al., 2011). Klunzner et al. (2009), introduced a new word-recognition technique based on adaptive OCR assuming that the existence of non-linear distortion in the words. The Omin-font OCR approach is used at the beginning of the process followed by the recognition process with the adaptive process (Klunzner et al., 2011). The main goal of the training process is to develop a font resource for recognition (Klunzner et al., 2011). Klunzer et al. (2011) developed a unique recognition system that uses two gray-level images along with the character being processed and the accepted character referred to as the super symbol. The adaptive OCR performed better than traditional OCR with a recognition rate of 88.2% whereas Adaptive OCR has a recognition rate of 91.5% (Klunzer et al., 2011). The use of the new algorithm proved to be effective in recognizing characters that were highly distorted (Klunzer et al., 2011).

The underlying weakness of this study was that it did not take system performance into consideration (Klunzer et al., 2011).

There have been advances made in reducing the OCR error rate by combining outputs from different scans to generate a composite version which has fewer errors (Wemhoener, Yalniz & Manmatha, 2013). The output of OCR is noisy with error that range in alternation of a single letter to an entire page (Wemhoener et al., 2013). There are different versions of the same book where they differ in introduction, footnotes, notes, pagination and formatting but the main texts of the book remain the same (Wemhoener et al., 2013). Therefore, making the OCR error uncorrelated and combining them will reduce the errors (Wemhoener et al., 2013). The process begins by aligning and combining three OCR outputs with the following three stages: the first stage is the pairwise alignment of the three texts, the second stage takes the pairwise alignment and builds alignment of the tree texts, the third stages builds a corrected composite text by taking the multiple sequence alignment (Wemhoener et al., 2013). It was also shown that the composite OCR has a greater accuracy of 4% compared to highest OCR accuracy among the book editions that were chosen (Wemhoener et al., 2013). The composite text for the document selected had an accuracy of 95.39% compared to the most accurate OCR that was 91.25% (Wemhoener et al., 2013). It was shown that composite OCR has a higher accuracy rate compared to the highest OCR accuracy (Wemhoener et al., 2013). The weakness is that the accuracy is dependent on the versions of the documents that are available. Furthermore, in the experiment punctuation marks were removed because they are frequently misrecognized (Wemhoener et al., 2013). Overall, it was found that the underlying weakness of different OCR systems is the accuracy to interpret the characters.

There have been advances that have been made in research of OCR to improve the accuracy of the data gathered.

Historical Trending

Medical staff members are confronted with large amounts of data that are noisy (Salatian et. al. 2009). Therefore, using interpretations by providing qualitative summaries of data can be beneficial when considering a given time in the past in deciding what measures are needed for patients (Salatian et al., 2009). The research proposed by Salatian et al. (2009), developed an algorithm for deriving intervals in historical data where the attributes are possible value increasing, decreasing or steady holds which are trends of data over the interval. The Wavelet algorithm process was used to look at data at different scales and resolutions (Salatian et al., 2009). The strength of the research shows that having ample amount of data and being able to look at snap shots can be advantageous in predicting the next step. However, the weakness of this research lies on the amount of historical data that is available at a given time which could be critical in this type of environment.

The research conducted by Koomey, Berard, Sanchez and Wong (2011), showed that the performance of computers have grown steadily over the past 65 years. The performance of personal computers has doubled in performance every 1.5 years which corresponds to Moore's law (Koomey et al., 2011). The electrical efficiency also doubled every 1.5 years (Koomey et al., 2011). The main trend that was found that there is increased efficiency and reduced cost due to smaller transistor size which explains the reduced usage of electricity and improved computational performance (Koomey et al., 2011). The trends included laptop computers, cellphone and personal digital assistance,

if the trends continue this will reduce the power consumption of mobile devices and developing new applications for mobile computing, sensors and controls (Koomey et al., 2011). The strength of this research lies with the amount of data that was available and looking at the current trends along with historical data and being able to predict future trends. However, the weakness as with the previous research lies in the amount of data that is available at a given time.

Literature Review Summary

As reviewed in literature more emphasis has been given towards FRs than NFRs to meet business needs and software schedule deadlines. These factors have increased the rate of software delivery thus ignoring NFRs can have an adverse effect on software system. There has been a trend to give more or equal emphasis on NFRs as FRs. The research reviewed has tried to determine the best software development phase to interject NFRs. Most of the research reviewed state that incorporating NFRs at the beginning of the software development is the best approach. The literature survey examined different approaches such as goal driven and Chung's NFR framework, UML approach, visualization approach and other approaches. Most of the methodologies and research examined do not incorporate all of the NFRs where some include certain or subset of NFRs. The methodologies examined tend to extend current tools and methodologies to incorporate NFRs. NFRs cannot be treated equally where one NFR may conflict with one another. There is a potential gap that exists in identifying and classifying NFRs in the early stages of software development for agile process. This is a potential area to focus on to classify, identify, capturing and grouping NFRs. This is also mentioned in Farid's (2011) study that was conducted, in classifying ALC using the NORMAP

methodology to identify NFRs that are irrelevant and to reduce the false positive of irrelevant NFRs. The studies that were reviewed also mentioned the use of historical data to help in identifying NFRs. This is mentioned by Farid (2011) to introduce automation of machine learning abilities based on historical AUCs, ALCs and to integrate potential ACCs based on the historical information provided. This is a potential research area that needs to be investigated further in an agile environment. The automation and historical process will potentially increase the accuracy of NFRs. The complexity of software is increasing and the complexity of NFRs is also increasing in parallel. There is a lack of methodology to capture NFRs in large and complex systems to classify, identify, capture and group the NFRs.

Furthermore, there have been many years of research and development that has resulted in advances in OCR that can recognize well-constrained hand written documents accurately (Peng et al., 2013). The preprocessing is the first step taken by the OCR to identify text within the document and most OCR systems are designed to work with binarized images (Peng et al., 2013). In the OCR process, regions of the texts are identified and separated into meaningful components where the information is forwarded to line finding and recognition system (Peng et al., 2013). There have been a lot of advances made in the OCR to recognize multilingual scripts but it is not easy to re-train data for multilingual scripts (Peng et. al, 2013).

Kluzner et al. (2009) developed a word-recognition technique based on adaptive OCR that performed better than traditional OCR. The adaptive OCR performed better to recognize characters that were highly distorted (Kluzner et al., 2009). The research

conducted by Klunzner et al. (2009) did not take performance of the OCR into consideration.

The research conducted by Wemhoener et al. (2013), showed the reduction of OCR error rate by combining outputs from different scans to generate a composite version. It was shown that composite OCR is more accurate than traditional OCR (Wemhoener et al., 2013). The weakness of this research is that the accuracy is dependent on the versions of the document that is available to create the composite version.

In the historical trending literature review, the research conducted by Salatian et al., (2009), found that looking at data summaries for large amounts of data was beneficial in making medical decisions for patients. The research developed an algorithm to derive intervals in historical data where the attributes are possible value increasing, decreasing or steady holds which are trends of data over the interval (Salatian et al., 2009). The trends of the historical data are dependent on the availability of data in order to look at snap shots of data.

The research conducted by (Koomey et al., 2011), found the main trends in computers was to increase efficiency and reduced cost due to smaller transistor size thus resulting in less usage of electricity and increased computational performance. The amount of data available was ample enough to look at the trends. However, the limitations lie as with the previous research in the amount of data that available at a given time.

Chapter 3

Methodology

Overview of Research Methodology

This chapter covers the methodology used for a newly proposed framework for capturing, eliciting, and prioritizing (CEP) non-functional requirements in agile software development. The chapter introduces the research methodology and covers the CEP methodology, process detail, and artifacts that include the following: optical character recognition (OCR), database, NFR Locator Plus and the NFR Priority. The later section of the chapter includes the overall process of the CEP methodology, validation, resources and summary. The validation was done using ML classifier to evaluate the precision of each NFRs along with three case studies. The first and second case study used the NORMAP and NERV methodology as a baseline to validate the new CEP methodology. The third case study used the images (NFR metadata) contained in the document for potential NFRs to validate the CEP methodology. The OCR artifacts collected the NFRs data from the images of the documents and translate them into text readable format. The database artifact stored the initial NFRs metadata in one table while another table stored the processed NFRs metadata that includes prioritization. The NFR Locator Plus artifact searched through the NFRs metadata to locate NFRs. The NFR Priority artifact prioritized the NFRs metadata by assigning a number weight to the NFRs based on importance of the NFRs.

This research used the system requirements document from the European Union (EU) electronic procurement (eProcurement) included in volumes 1 and 2 (European Dynamics S.A., 2005a) and (European Dynamics S.A., 2005b).

This methodology was validated using the following requirements documents: EU eProcurement requirement document (European Dynamics S.A., 2005a) and (European Dynamic S.A., 2005b). As with the research conducted by Domah (2013), the documents were being selected due to the length of 185 pages that combined both FRs and NFR for a real world large software project in the EU. This data set has been used in previous research conducted by Farid (2011) and Domah (2013) and has been proved to be successful in previous case studies. The metadata collected for NFRs was compared for elicitation effectiveness with the NORMAP and NERV methodology. The CEP methodology introduced the "Non-Functional Requirements Metadata" for elicitation data by rank of importance. The remainder of this chapter describes the CEP methodology in more detail.

Research Methodology

The objective of this research study was to develop an automated framework to capture, elicit, and prioritize NFRs from requirement specification documents that contain images, in the early stages of agile software development. As with the previous studies conducted by Farid (2011) and Domah (2013), this study also addressed the NFR separately from FRs. The framework applied an automatic process to assist the agile stakeholders to identify NFRs during the early stages of agile software development. The study took a hybrid automated approach in developing the framework which included using OCR along with the Slankas and Williams (2013) NFR Locator which uses the

Stanford Natural Language Parser (NLP) to extract NFRs sentences from documents and categorize them into NFR categories. In addition, weight was assigned to NFRs to determine the important NFRs that should take higher priority.

Capture

This section covers the capturing methodology that was used to capture the NFRs in agile software development. NFRs are contained in documents as well as in images of those documents. The objective was to capture both types of NFRs utilizing the appropriate artifacts. The artifact that was utilized to capture the NFRs is OCR. OCR is used to convert images into readable texts format. The OCR artifact scans through the requirement documents and the images contained within those documents. It translates the images into readable texts which were used to identify NFRs within the texts. This is the first study that used OCR to locate NFRs in software design document that contains images. There were potentially NFRs located in these images that are overlooked. The database artifact was used to store the text of the documents. The extracted texts were used to elicit the NFRs, this is discussed in the next section.

Elicit

This section covers the elicitation methodology used to elicit the NFRs from extracted texts of the images and documents. The extracted texts were stored in the database artifact. Slankis and Williams (2013) NFR Locator was used to identify and elicit NFRs. The new NFR Locator referred to as NFR Locator Plus extracted NFRs from images and texts utilizing the OCR artifact. NFR Locator extracts sentences from requirement documents and places them into NFR categories (Slankis and Williams, 2013). A sentence that is tagged as NFR, critical information was extracted from that

sentence (Slankis and Williams, 2013). Using Slankis and William's (2013) NFR Category categorized a set of NFRs that is based on Chung's NFR framework. The NFR Locator categorized the NFRs into selected categories using the *k*-NN classification algorithm (Slankis and Williams, 2013).

Prioritize

This section covers the methodology used to prioritize the NFRs using NFR prioritization artifact. A number was assigned to each NFR to give the NFR a weight. For example, a NFR with a weight of 1 has a higher priority than an NFR with a weight of 5. The αβγ-framework developed by Aasem, Ramzan and Jaffer (2010) was used to prioritize the NFRs where α is used to prioritize requirements subjectively and β is used to prioritize using the win-win method (Aasem et al., 2010). The prioritization artifact is discussed in great detail in the artifact and process detail section of this chapter.

ML classifier was used to determine the number of correctly classified NFRs. The methodology used the 6-phases of the design and development research methodology of Ellis and Levy's (2010). This was the same methodology used by Domah's NERV methodology. Incorporating the above methodology to the proposed hybrid automated approach is the result of the CEP methodology for addressing NFRs in the early stages of agile software development. This automated framework has the potential to assist agile team member during the early stages of agile software development.

Artifacts and Process Details

This section covers the CEP artifacts and processes that describe the details of the study. The methodology begins with the first artifact that is used to extract NFRs by the

OCR, followed by the other artifacts and process that will be described in detail in the paragraphs to follow.

Optical Character Recognition artifact

The emphasis is given during the analysis phase of the software development to include requirements gathering meetings with the clients. In traditional agile process the FRs are gathered on a simple 3 x 5 index card. The meetings with clients can take place on white-boards, informal meeting, conference calls where notes are taken by the software team and requirements are drawn up and prioritized. Metadata is gathered using documents, white-boards or traditional approach of writing on a note card where a picture can be taken using a smart phone or tablet device. These documents, pictures, and images can be stored on a central repository that is created for the client. OCR is used to translate images to text documents. OCR and the process details for extracting NFRs metadata is explained in the following paragraphs.

There are several open source OCR scanners available: GoogleDocs, OpenOCR and Free OCR. The GoogleDocs option gives users the option to upload documents such as images taken from smart phones directly to GoogleDocs that are translated into text. The OpenOCR is available from Cognitive Technologies that includes different languages for download ("OpenOCR", 2014). OpenOCR is a multilingual open source system, it was used to split recognized text into words and placed into PDF/A files where text layers can be easily recognized (Usilin, Nikolaev, & Postnikov, 2010). Free OCR is a free service offering where images are uploaded to their site and the text is extracted from the images ("Free OCR", 2014). Free OCR can recognize texts from images in the format of BMP, GIF, JPG, TIFF, and PDF formats where the images cannot be larger

than 5000 pixels (Hwang, Huang, & You, 2011). Furthermore, Free OCR can handle 29 languages and multi-column texts (Hwang et al., 2011). The Google drive is available from Google where images or PDF files can be uploaded and the files are converted to Google documents where the document is translated to text (Google, 2014). The Library Service Center at John Hopkins University determined the best approach for translating requests from around the world for articles that are received in English along with different languages is to use Google Translate along with OCR Terminal (Spellman, 2011).

A combination of all the OCR scanners mentioned earlier was combined as a hybrid OCR tool and used to ingest a set of requirement documents which scans the images in the documents for potential NFRs metadata. Multiple OCRs are used in order to increase the extraction rate and duplicates are removed. The ingest process was a back-end Ruby on Rails program that takes the documents and ingest them into the OCR. The OCR scanned the images in the document and translated them into texts. The text was stored in the database tables for further analysis. The database artifact and tables are explained in the next section of the proposal. The OCR also scans the texts in documents and also stores those in the database. The steps below outline the OCR process in detail along with the Figure 2 below.

1. OCR scanner was fed a set of documents with the help of an ingest Ruby on Rails program.
2. OCR scanned images in the documents for potential NFRs metadata and took the text with the help of an external program and placed them in the database.

3. OCR scanner also scanned the documents texts and also stored the potential text NFRs metadata in the database.

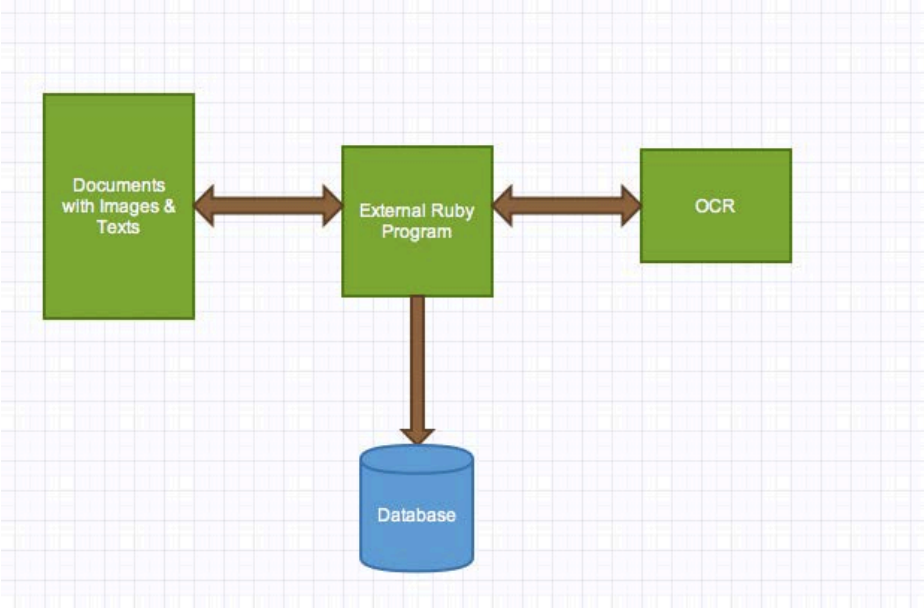


Figure 2. Ruby program ingests documents to OCR and pushing metadata to database.

Database Artifact

The database is the central artifact that was used to store the NFRs metadata. There were three tables that were used in the database. The initial table stored the metadata that was received from the requirements documents translated by the OCR. The other table was used to place and rank the NFRs. One table was used to store potential NFRs from images while the other table stored potential NFRs from documents. The other table was used to store the actual NFRs with their predicted priority and tagged information that contained information where in the document the NFRs were found.

The initial two tables contained translated texts from images and documents. Once the OCR translates them into text, the external Ruby on Rails program separates the texts into sentences before inserting them into the tables. The Image Metadata table is shown below in the table 1; this contains text metadata from images of the requirement

documents. The primary key of the table is the ID and field is the image text metadata. The Doc Metadata is shown below in table 2, this contain the text metadata from the requirement documents.

Table 1. The Image Metadata table

Image Metadata
PK ID INT 11
IMG_Metadata TEXT

Table 2. The Doc Metadata table

Doc Metadata
PK ID INT 11
DOC_Data TEXT

The next table is the NFRs Metadata table where NFRs are identified and placed in this table. The field includes the ID, NFR sentence, NFR priority and NFR type. In table 3 below shows the table and the fields for the NFR metadata table. The primary key is the ID field. The fields are explained in detail in later sections of the methodology.

Table 3. The NFRs Metadata

NFRs Metadata
PK ID INT 11
NFR Sentence TEXT
NFR Priority INT 11
NFR Type TEXT

NFR Locator Plus artifact

This section covers the NFR Locator artifact that was developed by Slankas and Williams (2013). The NFR Locator took the stored NFRs metadata from the database and extract NFRs from those texts (Slankas and Williams, 2013). This was the weakness of the NFR Locator which was not able to extract NFRs from images and tables contained within documents as mentioned by Slankas and Williams (2013). In this case the images were converted to texts and placed in the database for the NFR Locator to analyze and extract NFRs from those documents. There are potential NFRs that are missed from images.

Therefore, the approach was to use OCR before using the NFR Locator. The new NFR Locator called NFR Locator Plus combined OCR with Slankis and Williams (2013) NFR Locator. NFR Locator parses the natural language into internal representation and then classifies sentences into NFR categories as shown in Figure 3 or returns "not applicable" (Slankas & Williams, 2013). The first process is to enter the text into the system that is sentence representation (SR); SR is represented by a direct graph where the vertices are words and the edges are relationships between words (Slankas & Williams, 2013). The NFR Locater uses the Stanford Natural Language Parser (NLP) where each sentence outputs a graph in the Stanford Type Dependency Representation (Slankas & Williams, 2013). In addition, Farid's NORMAP methodology also used the Stanford Natural Language Parser (Farid, 2011). The *k*-NN algorithm is used to classify each sentence into a NFR category (Slankas & Williams, 2013). The NFR locator has 14 NFR categories as follows: access control, audit, availability, capacity and performance, legal, look and feel, maintainability, operational, privacy, recoverability, reliability, security,

usability and other (Slankas & Williams, 2013). The NFR Locator can be modified to include other NFRs groups (Slankas & Williams, 2013).

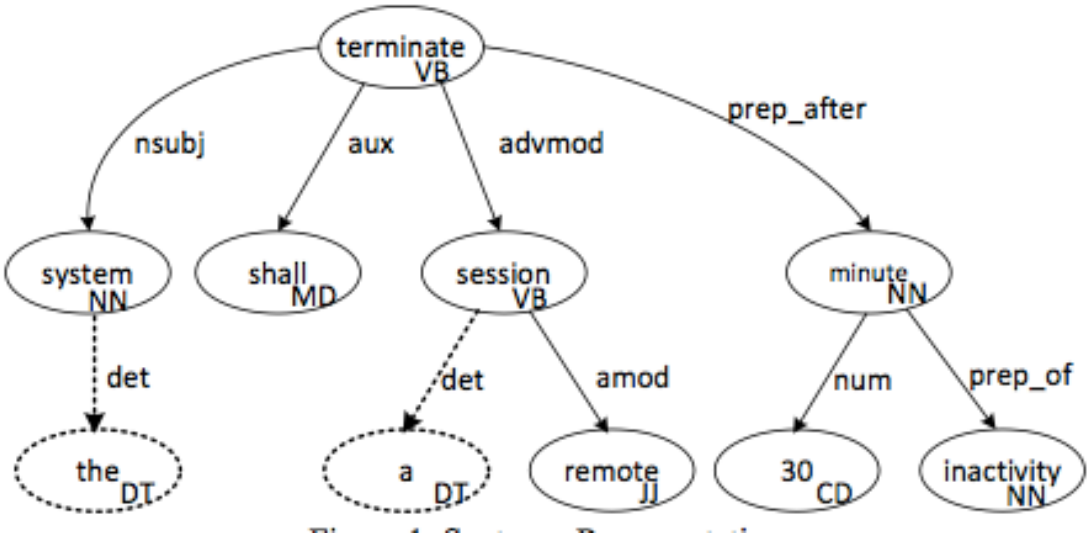


Figure 3. NFR Locator – Sentence Representation (Slankas & Williams, 2013).

Once the NFRs metadata was parsed and classified using the NFR Locator Plus, the metadata was placed in the NFR table. The database stored the NFRs metadata into a MySQL database with the database artifact mentioned earlier. NFR Locator Plus was written in Java and Ruby with Rails due to ease of developing web frameworks to extract NFRs metadata from translated OCR documents. The next section looks at the artifact for prioritization of NFRs

NFR Priority Artifact

By assigning weight to stakeholder groups the overall value of the requirement can be computed based on the weighted sum of the value of each stakeholder groups which ranks each set of requirements accordingly (Veerappa & Letier, 2011). The similarity between stakeholders' ratings is determined according to the distance between the stakeholders' ratings (Veerappa & Letier, 2011). A smaller distance indicates the

similarity between the ratings (Veerappa & Letier, 2011). If there are two ratings indicated as r_i and r_j from stakeholders i and j for the same requirement, the distance between them is indicated as $d = ,r_i - r_j$, (Veerappa & Letier, 2011). In n requirements: R_1, R_2… R_n, the distance is calculated as Euclidean distance between the two sets of ratings for all n requirements as shown in the formula below (Veerappa & Letier, 2011):

$$d=\sqrt{[(r_{1i}-r_{1j})^2+(r_{2i}-r_{2j})^2+\ldots+(r_{ni}-r_{nj})^2]} \quad (2)$$

.

The NFRs were prioritized similarly to FRs as shown on the αβγ-framework developed by Aasem, Ramazan and Jaffer (2010), process α is used to prioritize requirements subjectively in order to reduce the number of alternatives to n-requirements where the 100-dollar test prioritization is recommended. Process-β should be executed by key stakeholders using the win-win method (Aasem et al., 2010). The objective of process-β is to prioritize the requirements for the given project (Aasem et al., 2010). As mentioned earlier, examples of key stakeholders are customers, user groups, project manager, the development team and the test team. Whereas, process-γ is automated using the pair wise comparison that is Analytical Hierarchy Process (AHP) technique where the output is presented using the B-Tree prioritization (Aasem et al., 2010).

Visualization Artifact

The NFRs metadata is viewed in web framework and workbench developed in Ruby with Rails. The Ruby development platform was selected due to the ease of developing web frameworks. In Table 4, the NFR metadata (NFRM) is gathered and classified in a visual format and that was grouped in the 14 NFR Locator categories mentioned earlier along with additional NFRs groups used in NORMAP and NERV

methodology with a total of 18 NFR Locator categories. The data was extracted from the NFR metadata table. The NFR metadata group, description and priority of the NFR are listed on the table as shown in Table 4. The classification is based on NFR Locater that takes any natural language document and parses the natural language into internal representation in the NFR metadata in order to classify sentences into specific NFR categories as mentioned earlier in detail (Slankas & Williams, 2013).

Table 4. NFR metadata grouping

NFRs Metadata Group	Description of NFRs	Priority of NFRs
1. Access Control	Xxxxxxxxxxxxxxxxxxxxxxx	**2**
2. Audit	Xxxxxxxxxxxxxxxxxxxxxxx	**5**
3. Availability	xxxxxxxxxxxxxxxxxxxxxxx	**1**
4. Capacity and Performance	Xxxxxxxxxxxxxxxxxxxxxxx	**4**
5. Legal	Xxxxxxxxxxxxxxxxxxxxxx	**3**
6. Look and Feel	Xxxxxxxxxxxxxxxxxxxxxx	**6**
7. Maintainability	Xxxxxxxxxxxxxxxxxxxxxx	**7**
8. Operational	Xxxxxxxxxxxxxxxxxxxxxx	**8**
9. Privacy	Xxxxxxxxxxxxxxxxxxxxxx	**9**
10. Recoverability	Xxxxxxxxxxxxxxxxxxxxxx	**10**
11. Reliability	Xxxxxxxxxxxxxxxxxxxxxx	**11**
12. Security	Xxxxxxxxxxxxxxxxxxxxxx	**12**
13. Usability	Xxxxxxxxxxxxxxxxxxxxxx	**13**
14. Other	Xxxxxxxxxxxxxxxxxxxxxxx	**14**

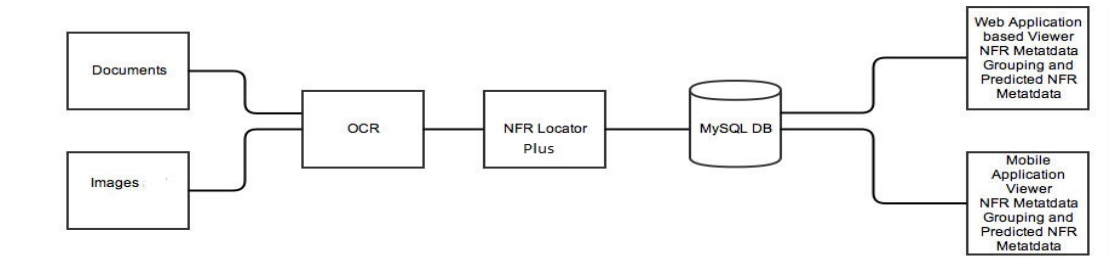


Figure 4. Flow diagram for capturing, eliciting, and prioritizing NFRs.

Overall Process of CEP

The combination of capturing, eliciting, and prioritizing NFRs metadata (NFRM) as shown in Figure 4 is the CEP methodology. The documents and images are gathered from customer's requirement documentation which was put through the OCR process to extract text information from documents and images. The extracted texts were put through the NFR Locater to locate NFRs within the extracted text. Once, the NFRs are located they were stored in a relational database which can be viewed as a web application or on a mobile device. In summary, this methodology uses OCR along with the NFR Locator Plus and prioritization of NFRs using αβγ-framework. This is a hybrid approach that combines known techniques and frameworks to capture NFRs. This gives more refined requirement specification for NFRs that is needed in early stages of agile software development.

Result Validation

This section describes how the result validations were done with the following three case studies. The case studies used the European Union (EU) electronic procurement (eProcurement) included in volume 1 and 2 (European Dynamics S.A., 2005a) and (European Dynamics S.A., 2005b). The two volume documents contain 180 pages that contain NFRs and FRs. These documents were selected because they

represent an actual software system used by the citizens of the EU. The first case study compared the NORMAP methodology as a baseline, the second case study used the NERV methodology as a baseline and the third case study used the EU eProcurement images contained in the documents for potential NFRs.

Case Study 1: EU eProcurement Document and the NORMAP methodology

The case study used the EU eProcurement. The EU eProcurement documents contain 26 requirements that include NFRs. The NORMAP methodology utilizing the semi-automatic tool NORMATIC was able to fully or partially identify 18 NFRs out of the 26 requirements given (Farid, 2011). The 18 NFRs identified in the NORMAP methodology (Farid, 2011) were as follows: Accessibility, Accuracy, Auditability, Availability, Configuration, Compliance, Confidentiality, Documentation, Efficiency, Interoperability, Legal, Multilingual Support, Performance, Usability, User Interface, Scalability, Security, and Reliability. The NORMAP data was used as a baseline for the newly developed automated CEP methodology to determine the improvement of elicitation of NFRs in comparison to the NORMAP methodology. The baseline consisted of 57 sentences with potential NFRs contained within those sentences.

Case Study 2: EU eProcurement Document and the NERV methodology

The second case study used the EU eProcurement documents as the previous case study and the NERV methodology data as a baseline to compare with the newly developed automated CEP methodology. The same 18 set of NFRs identified by the NORMAP methodology were used by the NERV methodology for validation for NFR elicitation (Domah, 2013). This same set of NFRs was used to validate the CEP methodology against the NERV methodology. This case study determined whether there

was an improvement over the baseline of 57 sentences with potential NFRs contained within those sentences. The NERV methodology was able to identify NFRs in 55 out of 57 sentences (Domah, 2013).

Case Study 3: EU eProcurement Document and CEP methodology's NFRs from images

The third case study used the EU eProcurement documents and the images contained within those documents. There are potential important NFRs contained within those documents that will be translated into text sentences using the CEP methodology. The same 18 set of NFRs identified by the NORMAP and NERV methodology was used in the CEP study. There are a number of images on each page in the EU eProcurement 180 pages, 2 volumes documents. The CEP methodology identified potential NFRs contained within those text sentences for NFRs elicitation from images contained within the requirement documents.

Format and Validation of the Results

The result section included the number of NFRs categorized in the 18 areas as mentioned above and compares it to the baseline which is the methodology of Farid's NORMAP (2011) and Domah's NERV methodology (2013). Similar to Rashwan's (2012) research, the ML classifier was used to evaluate the metric precision, recall and F-measure. The following formula was used:

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}, \text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}, \text{F-measure} = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

(Rashwan, 2012). Where TP is the true positive which is the number of correctly classified NFRs, FP is the false positive that is the total number of incorrectly classified

NFRs and FN is the false negative which is the NFRs incorrectly not classified (Rashwan, 2012).

Resources

The following resources were required to conduct this study:

1. Three case studies were required to validate the methodology using the European Union eProcurement System analysis model documentation which captures FR and NFRs. This was used to validate the research study conducted by Farid (2011) and Domah (2013).
2. The programming language used was Ruby on Rails and Java. Ruby on Rails can be used to develop powerful web applications and can be downloaded from Ruby on Rails website ("Ruby on Rails", 2014). Java is readily available on Linux systems and Mac OS which was used as the platforms for this study.
3. Multiple OCR tools were used for this study which included the following: Adobe OCR, GoogleDocs, OpenOCR and Free OCR. The Google drive is available from Google where images or PDF files can be uploaded and the files are converted to Google documents where the document is translated to text Google, 2014). OpenOCR is available from Cognitive Technologies which includes different languages for download ("OpenOCR", 2014). Free OCR is a free service offering where images are uploaded to their site and the text is extracted from the images ("Free OCR", 2014). Adobe OCR professional tool is readily available at the university which can be applied to scanned documents ("Adobe OCR", 2015).

4. NFR Locator Plus based on the NFR Locator developed by Slankas and Williams (2013) was used in this study. The NFR Locator Plus parses the natural language into internal representation and then classifies sentences into NFR categories (Slankas & Williams, 2013).
5. MySQL database was used to store the metadata for analysis. The MySQL database was downloaded from the MySQL site ("MySQL", 2014).
6. Scripting languages Perl and JavaScript was used to parse the metadata and push it on to the database. Perl and JavaScript are readily available on the Linux and Mac OS system.

Summary

Chapter 3 discussed the methodology that was used for this study in developing, analyzing, documenting and validation of a newly proposed framework for capturing, eliciting, and predicting (CEP) non-functional requirements in agile software development. The automated framework was designed to help agile team members during the early stages of software development. There were several artifacts that were developed in the CEP methodology. Ellis and Levy's (2010) design and development methodology was used in CEP.

The NFR Locator Plus is based on the Slankas and Williams (2013) NFR Locator and incorporating OCR with the NFR Locator was utilized to capture NFRs in the early stages of agile software development. The visualization of the NFRs is in a tabular format to view the NFRs along with the NFRs metadata of groups, description and priority of the NFRs.

The CEP methodology was validated with three case studies using the European Union eProcurement System. The primary programming resource Ruby on Rails was used to develop the NFRs extraction tool and the visualizations of the NFRs. The MySQL database was used to store the NFRs metadata. This formed the automate hybrid CEP methodology.

Chapter 4

Results

Introduction

This chapter outlines the methodology for capturing, eliciting, prioritizing and validation of non-functional requirements in the early stages of agile software development. The CEP methodology includes an automated framework to gather non-functional requirements from a set of requirements documents utilizing several artifacts in the process. Furthermore, the basis of the CEP methodology is designed to help agile software development team members.

The CEP Method Overview and Investigative Steps

Literature has shown that NFRs are often ignored in the early stages of Agile Software Development and are often incorporated later in an ad-hoc manner. This study investigated an approach to incorporate NFRs in the early stages of Agile software engineering by developing a methodology and tools that can be utilized by Agile Software Developers. This goal was accomplished by developing the CEP methodology which incorporates several artifacts as explained below. The CEP methodology captures elicits and prioritizes NFRs in the early stages of Agile Software Development. The following steps were taken to complete the study. The following artifacts were used: the OCR artifact, the Database artifact, the NFR Locator Plus artifact, the NFR Priority artifact and the Visualization Artifact. The OCR artifact was used to scan the documents and images into text readable format for the NFR Locator Plus artifact. The Database artifact was used to store the NFRs. The NFR Locator Plus artifact was used to locate NFRs in the documents and images. The Visualization artifact was used to view the

results of the NFRs. These artifacts are part of the CEP methodology. The following steps outlined in table 5 below were taken in order to complete this study.

Table 5. Investigation Steps for the CEP methodology

Step	Activities	Tools Used
1	Install the OCR Tools artifact that will be used to scan the images.	Google OCR, Free OCR, Open OCR, Adobe OCR
2	Install the database tools and create the database artifact. Develop the data models that will be used to store the NFRs.	MySQL database
3	Use the OCR tool artifact to convert the EU Procurement documents to text.	Google OCR, Free OCR, Open OCR, Adobe OCR
4	Separate the text data set from the image the image (Figure) data set.	Unix tools, Perl, Ruby
5	Install Eclipse Java platform for the NFR Locator Plus artifact.	Eclipse Java, NFR Locator
6	Update the JSON properties files for the NFR Locator to include the baseline NFRs.	Eclipse Java
7	Compile and test the new NFR Locator Plus artifact.	Eclipse Java
8	Define the baseline NFRs that will be used for this study.	Princeton WordNet 3.1, IEEE 612.12 standard, IEC/ISO 25010 standard
9	Train the NFR Locator Plus artifact to Elicit NFRs on sample data sets.	NFR Locator Top 20 NFRs keywords by NFR Category, Princeton WordNet version 3.1 GZ file, Merriam-Webster dictionary, Chung's NFR Framework, the IEEE standard, and the IEC/ISO 25010 standard
10	NFR Locator Plus artifact will be used elicit data from the EU eProcurement documents text and images along with the baseline dataset.	Eclipse Java, NFR Locator Plus, Unix tools, Perl program

Step	Activities	Tools Used
		Gilb, the GQM process, and prior software development industry
11	Validate NFR Locator Plus artifact Elicitation and compare to previous research (CEP and NERV)	CEP data set, NERV data set, EU eProcurement requirements documents
12	Calculate the NFRs Priority	Aasem, Raman and Jaffer (2010) αβγ-framework to prioritize NFRs and Jaffer (2010)
13	Visualize the NFRs metadata that include the priority	MySQL workbench visualization tools, Ruby on Rails NFR Viewer.

Capturing

The first step was to produce OCR for the European Union (EU) electronic procurement (eProcurement) volume 1 and 2 (European Dynamics S.A., 2005a) and (European Dynamics S.A., 2005b). It was found that using Google Docs OCR there was a limitation to OCR 10 pages. The Open OCR is limited to OCR the first page of the document. FreeOCR is based on Tesserant OCR engine and is open source code, it was simple to install and took the entire PDF file to OCR. The Open OCR and Google OCR are also based on the Tesserant OCR engine. In Figure 5 below shows the Free OCR tool as the files are scanned and processed into text.

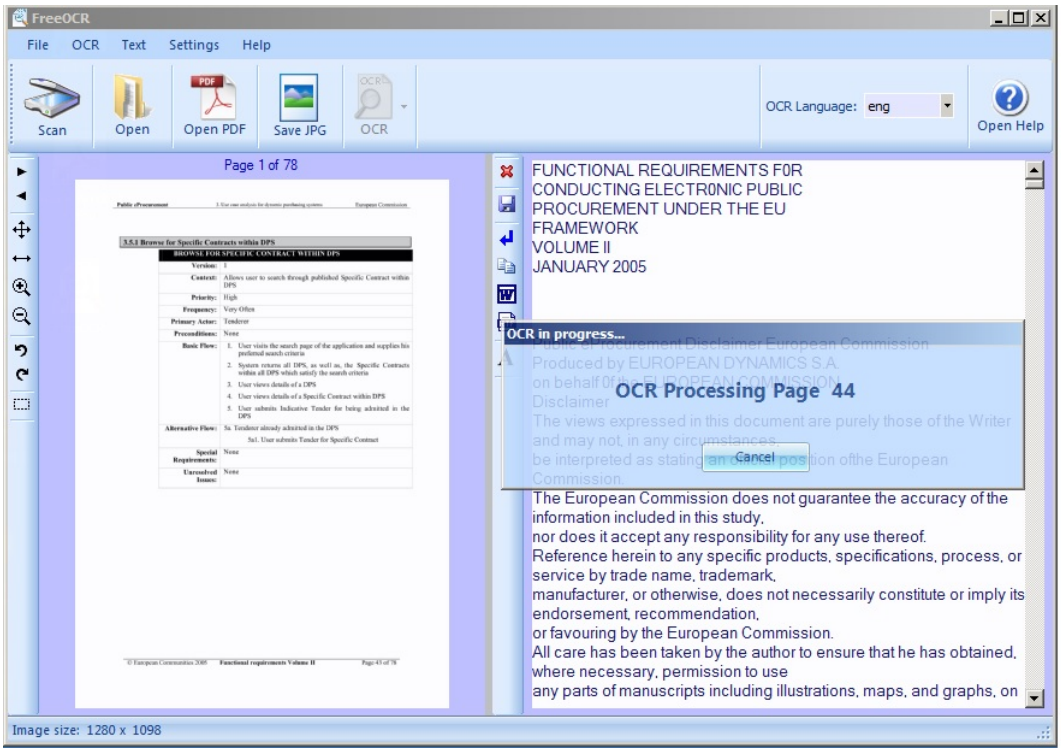


Figure 5. The Free OCR tool used to scan the requirements documents.

European Union (EU) electronic procurement (eProcurement) volume 1 and 2 (European Dynamics S.A., 2005a) and (European Dynamics S.A., 2005b) were OCRed using the Free OCR tool. The PDF file and the images in the file were translated into text. The Free OCR produced the following results on the document: European Union (EU) electronic procurement (eProcurement) volume 1 had file containing 271194 characters, 39074 words and 4600 lines (European Dynamics S.A., 2005a). European Union (EU) electronic procurement (eProcurement) volume 2 had text containing 106925 characters, 16028 words and 3145 lines (European Dynamics S.A., 2005b). The processing of some of the images in the EU documents did not translate properly. The Adobe OCR was also used to scan the documents which captured better information than the other OCRs. The European Union (EU) electronic procurement (eProcurement) volume 1 after using Adobe OCR, produced a text file containing 290045 characters,

39674 words and 5593 lines (European Dynamics S.A., 2005a). The European Union (EU) electronic procurement (eProcurement) volume 2 produced a text file containing 120727 characters, 16791 words and 3192 lines (European Dynamics S.A., 2005b). Table 6 below shows the distribution of characters, words and lines for the European Union (EU) electronic procurement (eProcurement) volumes 1 and 2.

Table 6. Overall characters, word and line counts on OCR EU vol. 1 & 2 Text

Document Text	Characters	Words	Lines
EU volume 1	290045	39674	5593
EU volume 2	120727	16791	3192

The images texts were separated into volume 1 and volume 2 files. The volume 1 OCR images text contains 30891 characters, 4035 words and 936 lines. The volume 2 OCR images text contain 6857 characters, 925 words and 323 lines. The Adobe OCR generated the least spelling errors in comparison with the other OCRs and some of the errors were the difference in spelling between the European English and American English. Table 7 below shows the distribution of characters, words and lines for the European Union (EU) electronic procurement (eProcurement) images from volumes 1 and 2. There is a wealth of information contained in these files.

Table 7. Overall characters, word and line counts on OCR EU vol. 1 & 2 Images

Document Images	Characters	Words	Lines
EU volume 1	30891	4035	936
EU volume 2	6857	925	323

Elicit NFRs from Text and Image Metadata

The next step was to elicit the NFRs from the text and image metadata set. This is an automatic classification system to classify NFRs in a document. A sample data set was loaded into the NFRs Locator Plus artifact to identify NFRs. These data sets are JSON files based on the study conducted by Slankis and Williams (2013). The NFR Locator Plus artifact was used to train additional baseline NFRs in supervised and unsupervised learning where supervised learning searches data for common patterns (Slankis & Williams, 2013). Once the training process was complete the EU Procurement data set that contained images and texts were loaded to identify baseline NFRs contained in those documents. The texts were normalized to American English since the EU Procurement documents are based on European English. The baseline NFRs from the NORMAP and NERV methodology were used to classify the NFRs found in both the text and the Figures of the EU Procurement documents. The following eighteen NFRs were used: *Accessibility (AC), Accuracy (AR), Auditability (AU), Availability (AV), Compliance (CE), Confidentiality (CO), Configuration (CN), Documentation (DO), Efficiency (EF), Interoperability (IN), Legal (LG), Multilingual (ML), Performance (PS), Reliability (RE), Scalability (SC), Security (SE), Usability (US) and User Interface (UI).* The NFR Locator Plus artifact did require the WordNet (2015) GZ file to be included in the program. The WordNet version 3.1 Gzip package was used with the NFR Locator Plus. These includes the verbs, nouns, adjectives, adverbs, synonyms, antonyms, and hyponyms as a lemma in the NFRs Locator Plus where the base word from a set of words that is used to take in part of the speech (Slankas and Williams, 2013). For example, the words sang, sing and sung all have the same lemma

"sing" which makes the lemma more precise as part of the speech is taken into account (Slankas and Williams, 2013). This study also included the related concepts similar to the NERV methodology to include IEEE std. 612.12 (1990), ISO/IEC JTCI/SC7 (2008), WordNet 3.1, and Merriam-Webster (2013) as sources used to train the NFRs Locator.

NFR Locator Plus Artifact Data Gathered from EU text Document and Images

This section shows the overall count of NFRs in the EU Documents using the NFR Locator Plus artifact. It identified potential NFRs in the Figures/images of the EU eProcurment documents volume I and II. The documents were converted to text format using OCR in order for the NFR Locator Plus artifact to read the entire document with the images removed. The NFR Locator Plus artifact only reads text only files. Furthermore, the images were separated into another text file. A screenshot of NFR Locator Plus artifact is shown in Figure 6, this is a modification of Slankis and Williams (2013) NFR Locator.

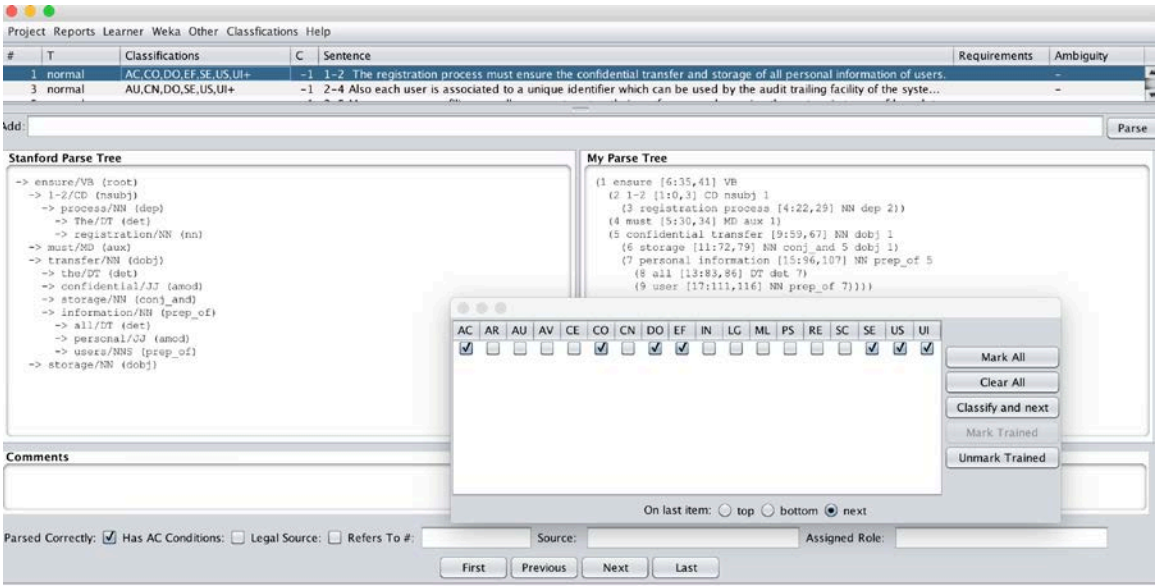


Figure 6. NFR Locator Plus artifact based on NFR Locator.

The results show that a total of 12,845 matches of baseline NFRs keywords and phrases were found in the EU eProcurement volumes I and II. Volume I found 9218 NFRs keywords and Volume II found 3627 NFRs keywords. As shown in Figure 7 below, Usability, Documentation, and Auditability being the top three NFRs.

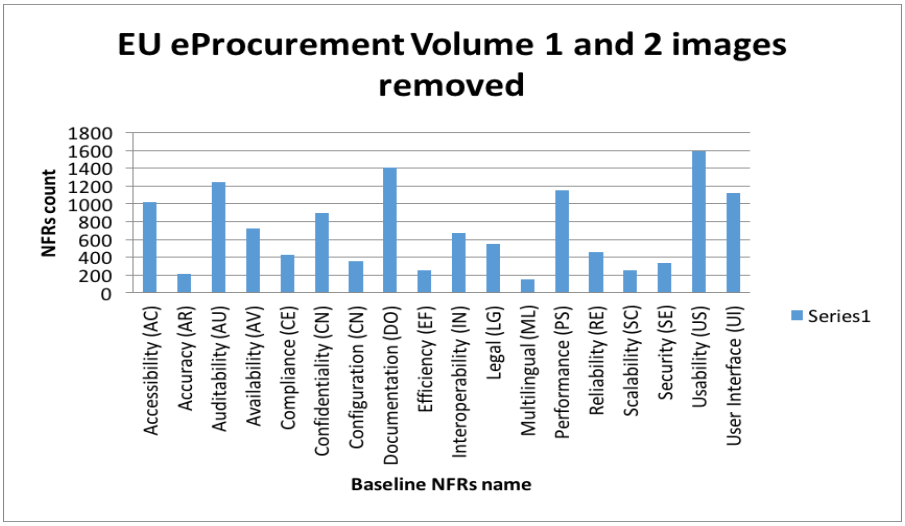


Figure 7. Total of the text NFRs gathered from EU eProcurment Doc volume I & II.

The images were used to gather potential NFRs, these include Figures, flow diagrams, state diagrams and use case diagrams. These images were converted to text using the OCR artifact and potential baseline NFRs were extracted from those images. In the image dataset as shown in Figure 8 the Documentation NFR is the highest followed by Auditability and Accessibility. The total number of NFRs keywords extracted from all of the images and Figures from the EU eProcurment Documents volume I and II were 829.

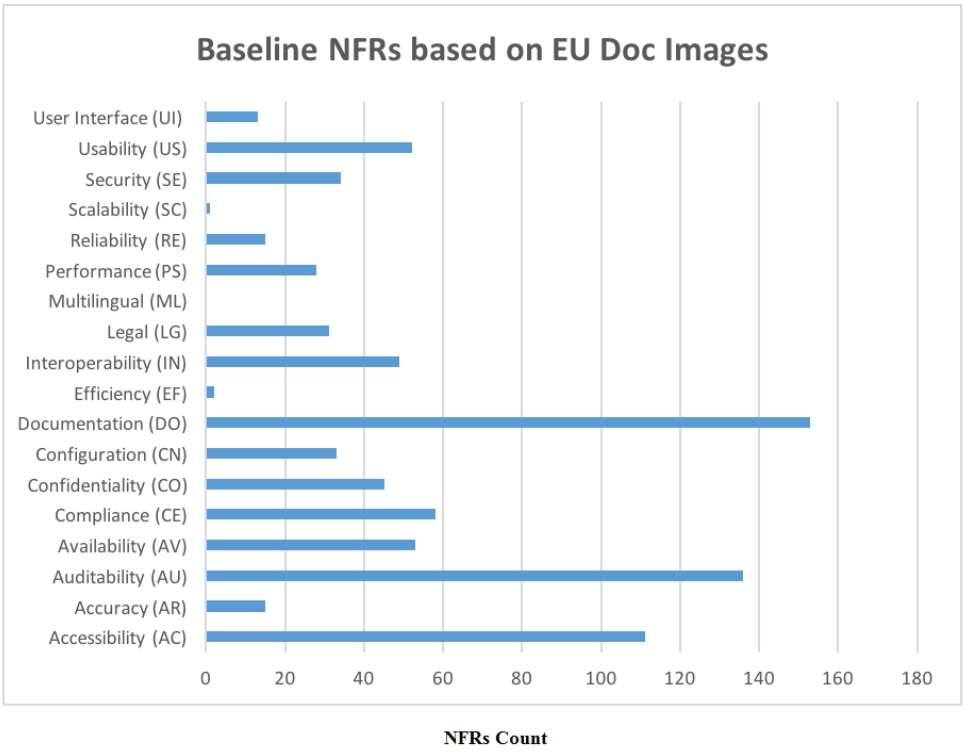


Figure 8. Total of the image NFRs gathered from EU eProcurment Doc volume I & II.

CEP methodology Validation Results

The baseline data set was used to validate the CEP methodology from the following previous research: NORMAP methodology (Farid, 2011) and the NERV methodology (Domah, 2013). The CEP methodology used the similar validation criteria as the NERV methodology (Domah, 2013); namely (1) If NFRs that were found were similar to the baseline from "keywords" and "phrases" a "success" factor was flagged, (2) If most of the similar NFRs were found a "partial success" was flagged, (3) If there was an NFRs found from an image related to requirement a "partial success" was flagged and (4) If no NFRs were found it was flagged as "failed". The totals of the NFRs finding of the CEP methodology were compared to the baseline NORMAP methodology. Furthermore, the baseline NFRs findings (successes and partial successes) of the CEP methodology were also compared to the NERV methodology. Additionally, the

Precision, Recall and F-measure were calculated for the number of correctly classified NFR for TP, incorrectly classified NFR for FP and incorrectly not classified for FN. In this case, the not classified and incorrectly classified were treated the same based on the baseline.

Case Study 1: EU eProcurement Document and the NORMAP methodology

The case study used the EU eProcurement. The EU eProcurement documents contain 26 requirements that include NFRs (Appendix O). The CEP methodology used 18 baseline NFRs indicated earlier. The NORMAP methodology was used as a baseline for the automated CEP methodology to determine the percentage of improvement for elicitation of NFRs in comparison to the baseline. The NORMAP methodology baseline included 57 sentences with potential NFRs contained within those sentences.

CEP methodology Result Analysis

This section validates the CEP methodology and describes the results obtained. The results show that the CEP methodology was successful in identifying 56 out of 57 requirement sentences that contain NFRs. The results also show that the CEP methodology was successful in eliciting 98.24% of the baseline NFRs compared to the NORMAP methodology of 87.71%. This represents an improvement of 10.53%. Successful and partially successful results were combined as successful findings. The CEP methodology used "keywords" and top 20 "keywords by category" from Slankis and Williams (2013) as well as "phrases" to train the NFR Locator Plus artifact. Additionally, the CEP methodology utilized images, diagrams and Figures that were related to the NFRs known as NFR metadata (NFRM). For example, requirement 1.2 (Appendix L): "*The registration process must ensure the confidential transfer and*

storage of all personal information of users." The following keywords were identified by the NFR Locator Plus artifact: *registration, process, confidential, personal, information, and users.* Furthermore, Figure 2-3-01 "Creation for a Call for Tender" is related to this requirement. The Figure contained the following sentences captured from the OCR process "*Connect to the eProcurement System"* and *"Create a new Call for Tender Workspace"*. The keywords/phrases and related concepts identified from the NFR Locator Plus artifact were the following: *connect, create and eProcurement System*. The NFRs found by the NFR Locator Plus artifact were the following: *Accessibility, Configuration, Confidentiality, Documentation, Efficiency, Usability, User Interface and Securit*y. The CEP methodology was successful in eliciting the baseline NFRs on *Confidentiality and Security.* Additional NFRs were found from the requirement sentence as well as the Figure 2-3-01. The NFR *Accessibility* was elicited from both the sentence and image/Figure (NFRM) which further validates the NFRs. The *Configuration* NFR was only found in the image/Figure (NFRM).

Successful Findings

The CEP methodology was successful in identifying NFRs from 56 out of 57 requirement sentences from the baseline as mentioned in the introduction with a complete success of identifying NFRs from 50 out of 57 sentences. In requirement 2.4, "*Also, each user is associated to a unique identifier, which can be used by the audit trailing facility of the system, in order to record all user activities, and to identify the initiator/actor of each activity*" (Appendix L). The following keywords/phrases were identified by the NFR Locator Plus artifact: *user, used, audit, trailing, system, activities and identify*. Additionally, Figure 2-3-01 "Creation for the Call for Tenders" was used to elicit NFRs

from Figures/images (NFRM). This Figure is associated with requirement 2.4. The following sentences were captured from the image/Figure (NFRM): "*Connect to the eProcurement system*" and "*Create a new Call for Tenders workspace*". The following keywords/phrases were elicited from the image/Figure (NFRM): *connect, create and eProcurement System*. This part of the Figure was also associated with requirement 1.2 as shown above. Therefore, there is an overlap of the requirement associated with Figure 2-3-01. The baseline listed the following as NFRs: *Confidentiality and Security*. The NFR Locator Plus artifact was able to identify the following NFRs: *Accessibility, Auditability, Configuration, Documentation, Security, Usability, and User Interface*. The NFR Locator Plus artifact was successful in eliciting the following baseline NFRs: *Confidentiality and Security*. The *Accessibility* NFR was only found in the image/Figure (NFRM) whereas *Configuration* NFR was found both in the requirement text and the image/Figure (NFRM).

In requirement 7.1, "*The new Public Procurement Directives require contracting authorities to use the CPV to advertise their procurement needs*" (Appendix L). The following keyword and phrases were identified by the NFR Locator Plus artifact: *public, contracting, authorities, use and procurement*. In Figure 2-3-02 "Preparation and Publication of a Prior Information Notice (PIN)" was associated with this requirement and the following sentences were captured from the OCR process: "*Create or Edit or Update PIN*", "*Dispatch PIN to OJEU for publication*", "*Sent acknowledgement to eProcurment system confirming dispatch of the PIN*" and "*Publish PIN and dispatch message to eProcument system to confirm date of publication"* (Appendix L). The following keyword/phrases were elicited from the image/Figure (NFRM): *edit,*

publication, eProcurment system, publish and message. The baseline identified the following as the NFRs: *Usability*. The following NFRs were identified by NFR Locator Plus: *Auditability, Confidentiality, Configuration, Documentation, Usability, User Interface, Availability, Efficiency, Legal and Security*. The NFR Locator Plus artifact was successful in eliciting the following baseline NFRs: *Usability*, *Auditability* and *Confidentiality* were both found in the associated image/Figure (NFRM) and text of the requirement. *Documentation* was elicited from the image/Figure (NFRM).

Partial Successful Finding

The CEP methodology partially elicited NFR from 6 sentences that were classified as "partially successful" out of 57 sentences. Based on the elicitation rules that were presented previously, if most of the similar NFRs were found a "partial success" was flagged and if there was an NFRs found from an image related to the requirement a "partial success" was flagged. In requirement 12.6, "*Once the Contract Notice has been published by the OJEU, it may also be published at the national level, and all interested parties should be given unrestricted and full access to the Contract Documents*". (Appendix L). The following keywords were identified by the NFR Locator Plus artifact: *contract, published, parties, unrestricted, full access, contract and documents*. This requirement is associated with Figure 2-3-03b and the following sentences were captured from the OCR process: "*Dispatch Contract Notice to OJEU for publication*", "*Sent acknowledgement to eProcurment system confirming dispatch date of the Contract Notice*", "*Publish Contract Notice and dispatch message to eProcument system to confirm date of publication (if sent electronically, Contract Notice is published on OJEU no longer than 5 days after its dispatch date)*", "*As soon as the Contract Notice is*

published, the eProcurement system provides to the general public unrestricted and full direct access to Contract Documents", and "*Publication of Contract Notice & Contract Documents*". The following keywords/phrases were identified by NFR Locator Plus artifact*: contract, publication, days, publish, message, longer, unrestricted, full, public, published, documents and eProcurement system*. The NFR Locator Plus artifact identified the following NFRs: *Accessibility, Auditability, Availability, Confidentiality, Configuration, Documentation, Legal, Performance and Security*. The baseline NFRs were the following: *Accessibility, Compliance and Security*. The NFR Locator Plus artifact was able to elicit *Accessibility* and *Security* but did not elicit *Compliance* for the baseline therefore a "*partial success*" was flagged for this requirement. The following NFRs were found both in the text of the requirement and the associated image/Figure(NFRM): *Accessibility, Auditability, Availability, Confidentiality and Documentation*. *Performance* NFR was only found in the image/Figure.

In requirement 18.2, "To 'open' or 'unlock' Tenders, two or more authorized procurement officers need to perform simultaneous actions" (Appendix L). The NFR Locator Plus artifact identified the following keywords: *open, authorized, officers, perform and simultaneous.* The following Figure 2-3-07 is associated with this requirement. The OCR process captured the followed sentences: "*Open Tenders by simultaneous action of at least two authorized procurement officers (unlocking) eProcurement system*", "*Report Tender integrity and authenticity*", and '*Report data or locking infringements and violation of any confidentiality rules*". The NFR Locator Plus artifact identified the following keywords/phrases from the image/Figure (NFRM): *office, procurement, open, authorized, simultaneous, eProcurement System, integrity, report,*

authenticity, confidentiality, infringements, and *violation*. The following keyword was found in both of the requirement text and the image/Figure (NFRM)*: authorized and simultaneous.* The NFR Locator Plus artifact elicited the following NFRs*: Accessibility, Availability, Compliance, Confidentiality, Configuration, Legal, Performance, Scalability, Security, and Efficiency*. The baseline NFRs were the following: *Performance* and *Compliance*. The NFR Locator Plus artifact was able to identify both of these NFRs, however, *Compliance* was elicited from the Figure/image (NFRM) only therefore this requirement was flagged as a "partial success". *Availability, Compliance, Confidentiality* and *Configuration* were elicited from the image/Figure (NFRM) whereas *Performance* and *Security* were elicited in both the requirement text and image/Figure (NFRM).

For requirements 6.1, 8.1, and 13.2, the baseline NORMAP methodology (Farid, 2011) claimed "None" under "Manual Classification", however, the NERV methodology (Domah, 2013) was able to identify several NFRs and flagged "partial success" for those three requirements above. This study also flagged "partial success" for requirements 6.1, 8.1 and 13.2 in order to maintain a similar comparison "apples to apples" for the CEP methodology with NORMAP and NERV methodologies. The CEP methodology elicited 7 NFRs from requirement 6.1 with three of the requirements being from both requirement texts and Figure/images (NFRM) and three from Figure/images (NFRM). The CEP methodology also elicited 7 NFRs from requirement 8.1with three NFRs being from both requirement texts and Figure/images (NFRM) and one being from Figure/images (NFRM). The CEP methodology elicited 8 NFRs from requirement 13.2 with 4 of the NFRs from Figures/images.

Failure Findings

For requirement 3.2, "*This is necessary for system to display the appropriate data to users, as well as, to make available the appropriate activities to be executed according to a user's role*". The following "keywords" and "phrases" were identified from the requirement sentence: *system, display, appropriate, make, available, activities, user's and role.* The Figure associated with this requirement is 2-3-01 "Creation for the Call for Tender" and the following sentences were captured by the OCR process: "*Connect to the eProcurement System*" and "*Create a new Call for Tenders workspace*". The following "keywords" and "phrases" were identified from the image/Figure sentences: *connect, create and eProcurement System*. The NFR Locator Plus artifact identified the following NFRs: *Accessibility, Confidentiality, Configuration, Availability, Interoperability, Reliability, Usability, and User Interface*. The *Accessibility* and *Configuration* NFR were from both the requirement text and image/Figure (NFRM). The baseline identified *Security* as the NFR. The CEP methodology failed to identify NFR *Security* from the "keyword" and "phrases" from both the requirement text and the image/Figure (NFRM) associated with the requirement text.

Comparison of Results between NORMAP and CEP methodologies

The summary of the success, partial success, failure and combined success/partial success is shown below in Table 8. The CEP methodology was successful in eliciting 98.24% of the baseline NFRs in comparison to the NORMAP methodology of 87.71% which is an improvement of 10.53%. The automated CEP methodology showed broad improvement over the baseline NORMAP methodology, especially for "success" and "failure" findings.

Table 8. CEP Baseline comparison (Text + Images) with NORMAP on NFRs in Req. Sentences

Criteria	NORMAP methodology		CEP methodology	
	Requirement sentences with NFRs	%	Requirement sentences with NFRs	%
Success	42	73.68%	50	87.71%
Partial Success	8	14.03%	6	10.52%
Failure	7	12.28%	1	1.75%
Success and Partial Success Count/Percentage	50	87.71%	56	98.24%

The CEP methodology showed improvement overall with more successes and less partial successes and failures. The table 9 below shows the comparison between the CEP and NORMAP methodologies in the number of NFRs identified within the 57 requirement sentences. The NFR count for the CEP methodology was 97.73 % compared to NORMAP methodology of 85.24 % which is an improvement of 12.49%. The Precision, Recall and F-measure were 97.73%.

Table 9. CEP Baseline comparison with NORMAP on NFRs count

Criteria	NORMAP methodology		CEP methodology	
	# NFR Found	%	# NFR Found	%
Success	67	76.14%	80	90.91%
Partial Success	8	9.10%	6	6.82%
Failure	13	14.77%	2	2.27%
Success and Partial Success Count/Percentage	75	85.24%	86	97.73%

Table 10. CEP methodology result detail count of NFRs

Non Functional Requirements			CEP methodology Detail Results					
NFRs Baseline		#	Success		Partial Success		Failure	
			#	%	#	%	#	%
1.	Accessibility	9	9	10.23%	0	0	0	0
2.	Accuracy	2	2	2.27%	0	0	0	0
3.	Auditability	2	2	2.27%	0	0	0	0
4.	Availability	9	9	10.23%	0	0	0	0
5.	Compliance	7	5	5.68%	1	1.14%	1	1.14%
6.	Confidentiality	7	7	7.95%	0	0	0	0
7.	Configuration	1	1	1.14%	0	0	0	0
8.	Documentation	6	6	6.82%	0	0	0	0
9.	Efficiency	1	1	1.14%	0	0	0	0
10.	Interoperability	1	1	1.14%	0	0	0	0
11.	Legal	1	0	0	1	1.14%	0	0
12.	Multilingual	2	2	2.27%	0	0	0	0
13.	Performance	5	4	4.55%	1	1.14%	0	0
14.	Reliability	1	1	1.14%	0	0	0	0
15.	Scalability	1	1	1.14%	0	0	0	0
16.	Security	18	17	19.32%	0	0	1	1.14%
17.	Usability	7	7	7.95%	0	0	0	0
18.	User Interface	5	5	5.68%	0	0	0	0
19.	NONE	3	0	0	3	3.41%	0	0
Total		88	80	90.91%	6	6.82%	2	2.27%

Furthermore, table 10 above shows the detail of success, partial success, and failure counts and percentage for the CEP methodology.

Case Study 2: EU eProcurement Document and the NERV methodology

This case study also used the EU eProcurement. The EU eProcurement documents contain 26 requirements that include NFRs. The 18 base line NFRs were also used in this case study. The NERV methodology result of the baseline was used to compare the automated CEP methodology to determine the improvement of elicitation of NFRs in comparison to the NERV methodology.

CEP methodology Result Analysis

This section validates the CEP methodology. As mentioned in the previous case study, the CEP methodology results show that it was successful in identifying 56 out of 57 requirement sentences that contain NFRs. The results show that the CEP methodology was successful in eliciting 98.24% of the baseline compared to the NERV methodology of 96.49%. The CEP methodology showed an improvement of 1.75% over the NERV methodology. The summary of the success, partial success, failure and combined success/partial success is shown below in Table 12. The result analysis of the success, partial success and failures were explained in the previous case study. The CEP methodology was successful in eliciting NFRs from 50 sentences and partially successful in eliciting NFRs from 6 sentences with one failure.

Successful Findings

The CEP methodology had a "success" finding in identifying NFRs in 50 out of 57 requirement sentences that contained NFRs. In requirement 9.3, "*Similarly to CPV, the inclusion of NUTS codes in a Contract Notice allows Economic Operators to easily identify the locations to which they will be required to deliver the goods/services/works of the contract irrespective of the language of the Contract Notice*" (Appendix L). The NFR Locator Plus artifact identified the following keywords/phrases: *inclusion, contract, easily, identify, goods, services, work, language and contract*. In Figure 2-3, 03a is associated with this requirement and the following sentences were extracted by the OCR process: "*Create or Edit or Update Contract*", "*Create or Edit or Update Contract Documents*", "*Upload Contract Documents to system*", "*Provide secure storage for Contract Documents, which remain inaccessible to the general public until Contract*

Notice is published on OJEU" and "*Preparation of Contract Notice & Contract Document*s". The NFR Locator Plus artifact identified the following keywords/phrases: *edit, contract, documents, inaccessible, contract, public, published, storage, and secure*. The NFR Locator Plus artifact identified the following NFRs: *Auditability, Accessibility, Configuration, Documentation, Legal, Multilingual, Scalability, Security, Usability, Availability, and Multilingual*. The following NFRs were only identified by Figures/images (NFRM): *Accessibility and Configuration*. The following NFRs were both identified on requirement text and images/Figures (NFRM): *Auditability, Documentation, Security and Availability*. The CEP methodology was successful to elicit the baseline NFRs: *Usability and Multilingual*. The NERV methodology was also successful in eliciting the baseline.

Partial Successful Findings

As mentioned in the prior case study, the CEP methodology partially elicited NFR from 6 sentences that were classified as "partially successful" out of 57 sentences. These 6 partially successful findings were based on the elicitation rules previously established. In requirement 21.1, "*Another requirement of the legislation is related to the capability of the contracting authority to prepare regulatory reports, which provide information on all aspects of the competition*" (Appendix L). The NFR Locator Plus artifact identified the following keywords/phrases: *legislation, capability, contracting, authority, prepare and report*. The following Figure 2-3-09 is associated with this requirement and the following sentences were captured from the OCR process: "*Create or Edit or Update Contract Award Notice*", "*Dispatch Contract Award Notice to OJEU for publication*", "*Notify Tenderers on the award of the contract*", "*Winning Tenderers are invited to*

finalize contract", "*eProcurement System*", "*Sent acknowledgement to eProcurment system confirming dispatch date of the Contract Award Notice*" , "*Publish Contract Award Notice and dispatch message to eProcurement system to confirm date of publication*", and "*Contract Award*". The NFR Locator Plus artifact identified the following keywords/phrases: *edit, contract, publication, publish, message and eProcurment System*. The NFR Locator Plus artifact elicited the following NFRs: *Accessibility, Auditability, Configuration, Documentation, Interoperability,* and *Legal*. The following NFRs were identified by the image/Figure (NFRM): *Accessibility* and *Configuration*. The following NFRs were identified by image/text: *Auditability* and *Legal*. The NFR Locator Plus artifact was partially successful in identifying the baseline NFR of *Legal* and did not elicit *Compliance*. The NERV methodology was also partially successful in eliciting the baseline for requirement 10.2.

Failure Finding

The failure finding for requirement 3.2 was explained in detail in the previous case study. The NFR Locator Plus artifact failed in eliciting the baseline NFR *Security* from keyword, phrases or images. The NERV methodology was successful in eliciting the baseline NFRs.

Comparison of Results between NERV and CEP methodologies

The summary of the success, partial success, failure and combined success/partial success is shown below in Table 11 below. The CEP methodology was successful in eliciting 98.24% of the baseline NFRs in comparison to the NERV methodology eliciting 96.49% of the baseline NFRs. This is an improvement of 1.75%. The automated CEP methodology showed more successes in eliciting NFRs than the NERV methodology.

Table 11. CEP Baseline comparison (Text + Images) with NERV on NFRs in Req. Sentences

Criteria	NERV methodology		CEP methodology	
	Requirement sentences with NFRs	%	Requirement sentences with NFRs	%
Success	46	80.70%	50	87.71%
Partial Success	9	15.79%	6	10.52%
Failure	2	3.51%	1	1.75%
Success and Partial Success Count/Percentage	55	96.49%	56	98.24%

The CEP methodology showed improvement with more overall successes and less partial successes and failures. The table 12 below shows the comparison between the CEP and NERV methodologies in the number of NFRs identified within the 57 requirement sentences. The NFR count for the CEP methodology was 97.73 % compared to NERV methodology of 93.18 % which is an improvement of 4.55%. The Precision, Recall and F-measure were 97.73%.

Table 12. CEP Baseline comparison with NERV on NFRs count

Criteria	NERV methodology		CEP methodology	
	# NFR Found	%	# NFR Found	%
Success	72	81.82%	80	90.91%
Partial Success	10	11.36%	6	6.82%
Failure	6	6.82%	2	2.27%
Success and Partial Success Count/Percentage	82	93.18%	86	97.73%

The detail of success, partial success, and failure counts and percentage for the CEP methodology were presented in the earlier case study.

Case Study 3: EU eProcurement Document and CEP methodology's NFRs from images

There are important images that were utilized from the images of the European Union Procurement document. The 57 baseline requirement sentences were used as with the previous case studies presented along with their associated Figures/images (NFRM). The graph below shows the total number of baseline NFRs that were gathered from the baseline requirements presented in the previous case studies. The top NFRs captured and elicited by the NFR Locator Plus artifact from the requirements linked to the images/Figures (NFRM) are the following NFR: *Accessibility, Auditability, Configuration* and *Documentation*. The graph below shows the overall NFRs that were elicited by the NFR Locator Plus artifact from the baseline image requirements. The total number of NFRs elicited from the baseline requirement images was 274. The images in the European Procurement Documents were the following; Information Flow Diagrams, Activity Diagram, Business Logic Diagram, Conceptual Model Diagram and Use Case diagrams. There was a wealth of information relating to NFRs that were gathered from these images/Figures (NFRM). These images/Figures (NFRM) were linked to relevant baseline requirement sentences to validate the CEP methodology. The distribution of the 18 set of baseline NFRs with the baseline requirements are presented below in Figure 9.

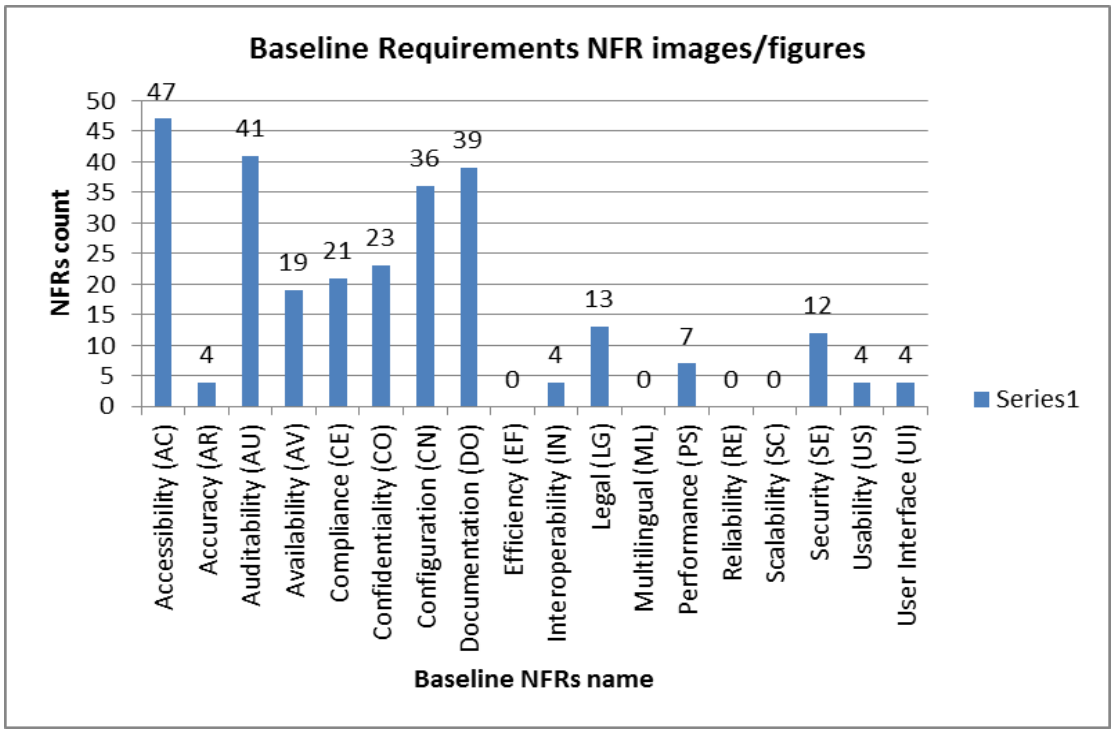


Figure 9. NFRs distribution of images & Figures.

The baseline requirement text NFRs count is shown below in Figure 10. The NFRs *Accessibility, Documentation, and* Auditability are the highest. The distribution of the baseline NFRs for the baseline requirements are presented below in Figure 10. The total number of NFRs elicited from the baseline 57 sentences was 359 NFRs. The combined number of NFRs elicited from both the baseline requirement text along with the associated Figures/images (NFRM) was 633 NFRs as shown in the table 13 below. There were a number of NFRs that were found in both the requirement text and images/Figures (NFRM) as show in Appendix L. The previous case studies presented and this case study presents the NFRs that overlap between the baseline requirement text and the images/Figures (NFRM) associated with those requirements.

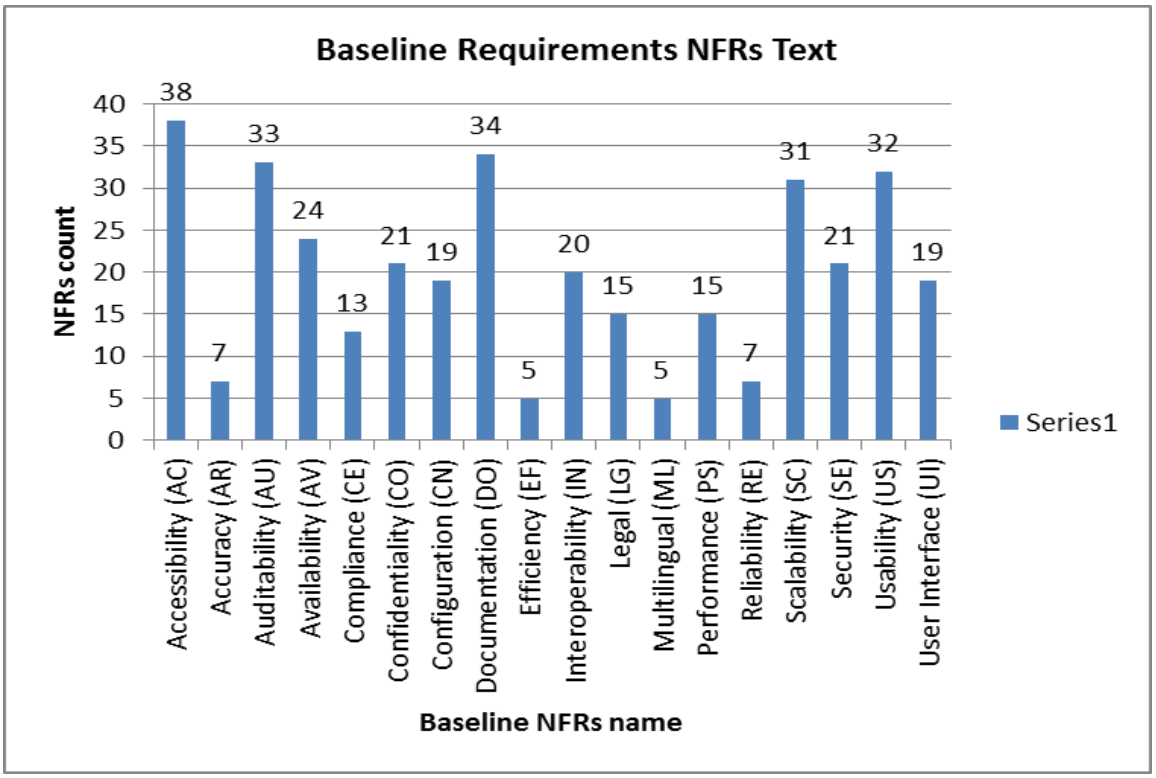


Figure 10. NFRs distribution of Requirement Text/Sentences.

Table 13. NFR count from images/Figures and requirement text.

Criteria	**CEP methodology**
	# NFR Found
NFR from requirement text	359
NFR from requirement images/Figures	274
Total	633

As shown in table 14, there were 129 NFRs that were found both in the requirement text and the associated images. There were 29 baseline NFRs found in the associated image linked to the requirement text.

Table 14. NFRs in both req. sentence and associated Figure/image

Criteria	CEP methodology
	# NFR Found
NFRs in both requirement sentence and associated Figure/image	129
NFRs Image in Baseline	29

Successful Findings

In requirement 15.3, "*All request for Additional Documents and the Additional Document themselves need to be made publicly available to all interested parties, and in due time before the end of the time-limit for submission to ensure nondiscrimination and equal treatment of Economic Operators"* (Appendix L). The NFR Locator Plus artifact elicited the following NFRs: *Accessibility, Accuracy, Auditability, Availability, Compliance, Confidentiality, Configuration, Documentation, Interoperability, Performance, Scalability, Usability and Reliability.* Additionally, the NFR Locator Plus artifact elicited the following keywords/phrases from the requirement sentence: *additional, document, publicly, available, parties, time, time-limit, nondiscrimination, and equal*. The OCR artifact was used to capture the sentences from Figure 2-3-06. Part of the Figure was used since it was relevant part to the requirement. The following sentences were captured from the OCR artifact process: "*Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize or download specifications (Contract Notice, Contract Documents, Additional Documents*)", "*Submit a Tender prior to Tender Submission deadline*", and "*eProcurment System*". The following keywords/phrases were identified by the NFR Locator Plus artifact: *add, contract, submit, documents, submission and eProcurement System*. The following NFR

were elicited from the image/Figures (NFRM) using the CEP methodology: *Auditability, Accessibility, Compliance, Configuration* and *Documentation.* The following NFRs were found both in the requirement text and the associated Figures/images: *Accessibility, Auditability, Compliance, Configuration, and Documentation*. The CEP methodology was successful in eliciting the baseline NFRs: *Availability, Documentation and Performance*. The baseline NFR Documentation was found both in the requirement sentence and the requirement image/Figure (NFRM) associated with that sentence.

Partially Successful Findings

In requirement 18.2, "To 'open' or 'unlock' Tenders, two or more authorized procurement officers need to perform simultaneous action" (Appendix L) which was presented in the earlier case studies was flagged "partially successful" since one of the NFR baseline was identified from the Figure/images (NFRM) and not from the requirement sentence text. The following NFRs were identified from the sentence texts using the NFR Locator Plus artifact: *Accessibility, Legal, Performance, Scalability, Security and Efficiency*. The following NFRs were identified from the image/Figures (NFRM) using the NFR Locator artifact: *Availability, Compliance, Confidentiality, Configuration, Performance and Security*. The *Performance* and *Security* were both identified in the requirement sentence and the images/Figures (NFRM) associated with that requirement. The following Figure 2-3-07 is associated with requirement 18.2, the baseline *Compliance* was found in the image/Figure (NFRM). Therefore, this requirement was flagged partially successful.

Failure Findings

In requirement 3.2, "This is necessary for the system to display the appropriate data to users, as well as, to make available the appropriate activities to be executed according to a user's role in the system" as explained in the previous case studies the CEP methodology failed to identify the NFR "Security" from both the requirement sentence text and the Figure 2-3-01 which is the image/Figure (NFRM) associated with requirement sentence. The NFR Locator Plus artifact elicited the following NFRs: *Accessibility, Configuration, Availability, Interoperability, Reliability, Scalability, Usability, User Interface* and *Confidentiality*. The following NFRs were from both the requirement sentence and the image/Figure (NFRM): *Accessibility* and *Configuration*.

NFR Priority Artifact

This study utilized and developed a new NFR Priority artifact. The prioritization of FRs has been main stream where not much emphasis has been given to the prioritization of NFRs. It is important to rank and prioritize NFRs similarly to FRs. This is the first study developed to rank and prioritize NFRs. Therefore, a NFR Priority artifact was developed to determine the prioritization of NFRs. As explained previously, assigning weight to a stakeholder groups the overall value of the requirement was computed based on the weighted sum of the value of the stakeholder group that ranks each set of requirements (Veerappa & Letier, 2011). The same approach was taken to determine the weight of each NFR. The stakeholders in this case are from the previous research from the NORMAP and NERV methodologies. The NFR data from the NORMAP and NERV methodologies along with the CEP methodology was used to determine the overall value of the NFRs. The similarity of the stakeholders' ratings was

determined according to the distance as explained previously (Veerappa & Letier, 2011). For example, in requirement 2.1 the CEP methodology identified 8 baseline NFRs therefore, NERV methodology identified 5 baseline NFRs and NORMAP identified 2 baseline NFRs. The higher the rating the more importance is given to the NFR. The smaller the distance between ratings implies more similarity between the ratings (Veerappa & Letier, 2011). According to Veerappa & Letier (2011), the weight of each group is left up to the decision maker. The weight of 33% was used in the CEP methodology similar to the weight used in research conducted by Veerappa & Letier (2011). Table 15 below shows the weighted sum of requirements 1.2, 2.4 and 2.5. The rest of the requirement weighted sum of the NFRs are in Appendix M.

Table 15. Requirement weighted SUM of NFRs

	CEP	NERV	NORMAP	Weighted Sum Value
	0.33	0.33	0.33	
R 1.2	8	5	2	4.95
R 2.4	7	5	1	4.29
R 2.5	6	3	2	3.3

NFRs were prioritized in this study using the αβγ-framework developed by Aasem, Ramazan and Jaffer (2010) used to prioritizeNFRs. The αβγ-framework is flexible enough where any sub-process can be replaced by any other technique (Aasem, Ramazan and Jaffer, 2010). For the α, as recommended by Aasem, Ramazan and Jaffer (2010) the 100-dollar test was used to assign each NFRs a value. For the requirements where the CEP methodology found an NFR each one was assigned 100-dollars. For example, in R1.2 the CEP methodology found 8 NFR therefore with the 100-value test a

value of 800-dollars was assigned to α. The process β is rank aspect which is usually executed by key stakeholder (Aasem, Ramazan and Jaffer, 2010). In this case, process β was replaced with the weighted sum of each requirement found in the previous section. For the γ process a modified version of the AHP process was used by comparing the weight of each requirement with the average weight of all the requirements. The closer the number was to the average, equal importance was given and the greater the difference a higher difference in importance was given. An equal or close importance was given a value of 1, the greater the difference such as a moderate difference was assigned a value of 2 and so forth. Table 16 shows the rank of some of the requirements. For requirement 1.2 it was ranked 40, requirement 2.4 was ranked 47 and requirement 2.5 was ranked 57. In Appendix N shows the ranks of all the requirements.

Table 16. NFR priority

Requirement	A	β	γ	Req. Rank
R 1.2	800	4.95	1	40
R 2.4	700	4.29	1	47
R 2.5	600	3.63	1	57

Another artifact of this study was to develop The NFR viewer. The agile team member can sort the priorities from low to high or high to low. The viewer in Figure 11 shows the requirement by their IDs. Next, the NFR Viewer shows the requirement sentence, priority and the NFRs found in the sentence. This is sorted by requirement ID. The NFRs are abbreviated which is listed in Appendix C.

	PK_ID	NFR_SENTENCE	NFR_PRIORITY	NFR_TYPE
1	R1.2	The registration process must ensure the co...	40	AC CN CO DO EF US UI SE
2	R2.4	Also each user is associated to a unique ide...	57	AC AU CN DO SE US UI
3	R2.5	Moreover user profiling can allow users to se...	57	AC CN US UI CO SC
4	R3.1	This functional requirement allows users to i...	23	AC AV CN DO IN PS SE US UI AV
5	R3.2	This is necessary for the system to display the	11	AC AV CN IN RE SC US UI SC
6	R4.3	User authorization can enable the eProcure...	41	AC AV CN DO IN SC SE US UI

Figure 11. NFR Viewer listing the first six requirements.

PK_ID	NFR_Sentence	NFR_Priority	NFR_Type
R12.3	An eProcurement system can provide a functionality for modeling these internal w...	1	AC AR AU AV CE CN DO EF LG PS RE SC US UI
R24.5	Furthermore an eProcurement system supporting DPS must ensure the confidentia...	2	AC AR AU AV CE CN DO IN LG ML PS SC SE US UI
R15.3	All requests for Additional Documents and the Additional Documents themselves ...	3	AC AR AU AV CE CO CN DO IN RE PS SC US
R7.5	An eProcurement system can prompt Procurement Officers to make use of the CP...	4	AC AU AR AV CE CO CN DO US UI SC IN LG
R7.1	The new Public Procurement Directives require contracting authorities to use the C...	5	AU AV CO CN DO EF LG SE US UI SE

Figure 12. NFR Viewer listing the top five NFR Priority requirements.

The NFR Viewer also allows the user to sort by NFR Priority to view the top priorities first as shown in Figure 12 above. This allows agile software teams to prioritize requirements accordingly.

NFR Elicitation Limitation and Obstacles on EU eProcurement Documents

There were a number of obstacles encountered during the case studies using the EU eProcurement documents. Some of the obstacles were overcome by workaround as outlined in the paragraphs below

The length of the EU eProcurement documents caused the NFR Locator to read slowly and caused the Java based NFR Locator Plus program to crash. The EU eProcurement documents had to be normalized by removing headers, tables of contents, page numbers etc. and other information that were not required to locate NFRs. Also, the NFR Locator Plus's Stanford Natural Language (NLP) parser encountered problems with punctuations and special characters which caused sentences to breakup into multiple

groups. The punctuations, parentheses and forward slashes had to be removed for the baseline 57 NFRs such as in requirements 5.4, 7.4 and 9.3.

The associated Figure and image (NFRM) data set had to be normalized. The OCR process involved extracting texts from these images and at time there were spelling and format errors. These texts had to be regrouped and corrected before they were put through the NFR Locator Plus.

Linking the associated Figure/image with the requirement proved to be challenging unless the requirement text specifically mentioned the Figure in the requirement. The title and other related information from the requirement were used to link the requirement to a specific associated Figure/image. This is the first study that utilizes the associated Figures and images to FRs. There is room for improvement in the linking process of associated Figure/images to FRs.

Summary

The research conducted in the CEP methodology of capturing, eliciting and prioritizing of NFRs in agile processes was validated and compared to previous research conducted by Farid (2011) and Domah (2013) using two cases studies. The third case study examined the images and NFRs contained within those images and Figures. These images/Figures (NFRM) were related to the requirement texts. A number of NFRs found in the image/Figures (NFRM) were the same as the NFRs found in the baseline requirement texts. This further validates the NFRs found in the image/Figures (NFRM). The validation conducted on the EU Procurement System a real life system, includes the EU eProcurement requirements (European Dynamics S.A., 2005a) and (European Dynamics S.A., 2005b). Also, the CEP methodology introduced a number of artifacts

that include the OCR artifact, the NFR Locator Plus artifact, the NFR Priority artifact and the Visualization artifact. This is the first study to prioritize NFRs similar to FRs, resulting in providing agile software team members with a method to prioritize NFRs.

The first case study compared the CEP methodology with the baseline NORMAP methodology for the effectiveness in eliciting NFRs from requirement sentences. The CEP methodology also used the associated Figures/images metadata (NFRM) that were related to requirement sentences. There were 57 sentences that contained NFRs in the EU eProcurement documents. The CEP methodology was successful in identifying 56 out of 57 requirement sentences that contained NFRs compared to the baseline of 50. The CEP methodology was successful in eliciting 98.24% of the baseline NFRs in comparison to the NORMAP methodology of 87.71% resulting in an improvement of 10.53% over the baseline. The CEP methodology successfully elicited 86 out of 88 NFR compared to the baseline NORMAP methodology of 75. The NFR count elicitation success for the CEP methodology was 97.73 % compared to NORMAP methodology of 85.24 % which is an improvement of 12.49%. The Precision, Recall and F-measure were 97.73%.

The second case study compared the CEP methodology with the NERV methodology results of the baseline for the effectiveness in eliciting NFRs from requirement sentences. Once again, the CEP methodology also utilized the associated Figures/images metadata (NFRM) that were related to requirement sentences. There were 57 sentences that contained NFRs in the EU eProcurement documents. The CEP methodology was successful in identifying 56 out of 57 requirement sentences that contained NFRs compared to the NERV methodology of 55. The CEP methodology was

successful in eliciting 98.24% of the baseline NFRs in comparison to the NERV methodology of 96.49 resulting in an improvement of 1.75%. The CEP methodology successfully elicited 86 out of 88 NFR compared to the NERV methodology of 82. The NFR count elicitation success for the CEP methodology was 97.73 % compared to NERV methodology of 93.18 % which is an improvement of 4.55%. The Precision, Recall and F-measure were 97.73 %.

The third case study examined the images and NFRs contained within those images and associated Figures. The total number of NFRs elicited from the baseline requirement images was 274. The images in the European Procurement Documents were the following: Information Flow Diagrams, Activity Diagram, Business Logic Diagram, Conceptual Model Diagram and Use Case diagrams. There was a wealth of information found in the images and Figures that were utilized for the requirement. Similar NFRs were found in the image/Figure text as in the requirement sentence text.

A new artifact was developed called the NFR Priority artifact. More emphasis has been given to the prioritization of FRs and NFRs have not been prioritized. This is the first study that looked into prioritization of NFRs similar to FRs. It is important to rank and prioritize NFRs as well as FRs. Weight was assigned to a stakeholder group where the previous NERV and NORMAP research considered groups. Also, the overall value of the requirement was computed based on the weighted sum of the value of the stakeholder group that ranks each set of requirements (Veerappa & Letier, 2011). The same approach was taken to determine the weight of each NFR. NFRs were prioritized using the αβγ-framework developed by Aasem, Ramazan and Jaffer (2010). The flexibility of the αβγ-framework allows the sub-processes to be replaced by other

techniques (Aasem, Ramazan and Jaffer, 2010). For the α, the 100-dollar test was used to assign each NFRs a value. For the requirements where the CEP methodology found an NFR each NFR was assigned 100-dollars. Process β included the weighted sum of each requirement. For the γ process a modified version of the AHP process was used by comparing the weight of each requirement with the average weight of all the requirements. Each of the requirements was given a priority based on the calculation determined by the αβγ-framework. The top five requirements based on NFR prioritization were found to be the following: 12.3, 24.5, 15.3, 7.5, and 7.1 (Appendix N). The CEP methodology also utilized the OCR artifact to capture texts from images and Figures (NFRM). Other artifacts utilized were the NFR Locator Plus artifact to elicit NFRs and the database artifact which was used to store and view the data.

Chapter 5

Conclusion, Implication, Recommendations, and Summary

Introduction

According to Literature, Functional Requirements (FRs) in Agile Software Engineering have taken precedence over Non-Functional Requirements (NFRs). Furthermore, NFRs are often overlooked until the later stages of software development. Agile software developers put emphasis on the functional needs of software in order to fulfill the business needs and NFRs are usually handled in an ad-hoc manner during the testing phase of the agile software development process (Nyguyen, 2009). When NFRs are missed cost issues become a significant problem. An example of a cost issue is the following: an U.S. Army intelligence sharing application costs 2.7 billion dollars (USD) to develop which has been found to be useless (Slakas & Williams, 2013). In order for a system to be successful both the FRs and NFRs must be considered (Slankas & Williams, 2013).

Study Conclusion

The study investigated the possibility of addressing NFRs in the early stages of agile software development and proposed the CEP methodology of capturing, eliciting and prioritizing NFRs. The following research questions were raised at the beginning of the study:

1. How effective is the CEP methodology in identifying and linking metadata with NFRs such as images with other FRs and NFRs in the early stages of agile software engineering?

2. To what degree can the additional NFRs gathered combined significantly improve gathering of NFRs and reduce the number of false positives from the NORMAP and NERV methodology?

With respect to the first research question, the CEP methodology utilized OCR technology effectively to identify and link metadata with FRs and NFRs such as images in the early stages of agile software engineering. The CEP methodology was successful in identifying 56 out of 57 requirement sentences that included NFRs. The 57 requirement sentence included 88 NFRs and CEP methodology utilizing OCR was able to identify 86 of them with combined success and partial success findings. The CEP methodology was successful in identifying NFRs in sentences with a result of 98.24% compared to the baseline NORMAP methodology of 87.71 %, resulting in an improvement of 10.53%. The NERV methodology was successful in identifying NFRs with a result of 96.49% of the baseline. The CEP methodology showed an improvement of 1.75% over the NERV methodology baseline result. The CEP methodology elicited 86 out of 88 NFRs compared to the baseline NORMAP methodology of 75 and NERV methodology of 82. This NFR count elicitation success rate for the CEP methodology was 97.73 % compared to NORMAP methodology of 85.24 % representing an improvement of 12.49%. The NFR count for the NERV methodology was 93.18% of the baseline, which resulted in an improvement of 4.55% for the CEP methodology. The Precision, Recall and F-measure were 97.73%.

The two artifacts utilized in the CEP methodology included the OCR artifact for capturing the images, and the NFR Locator Plus artifact to elicit NFRs. The OCR artifact captured and translated images into text readable format. In a previous study the

weakness of the NFR Locator was not being able to read from images. The NFR Locator Plus utilizing trainable data sets (Appendix F & G) in order to locate NFRs in the requirements documents and baseline requirements (Appendix L). The NFR Locator Plus was trained to recognize different English language such as European English and American English. The documents were translated to American English due to the ease of dealing with a single standard data set.

The second research question investigated was to what degree can additional NFRs gathered combined both image and requirement text NFRs significantly improve gathering of NFRs and reduce the number of false positives from the NORMAP and NERV methodologies. The CEP Methodology successfully improved NFRs identification in requirement sentences by 10.53% compared to the NORMAP methodology and 1.75% compared to the NERV methodology. The CEP methodology NFR count had an improvement of12.49% compared to the NORMAP methodology and 4.55% compared to the NERV methodology. The CEP methodology utilized the associated Figures/images (NFRM) and linked them to the related requirements to improve results of the NORMAP and NERV methodologies (Appendix L). There were 29 baseline NFRs that were found in the associated Figures/images (Appendix L). There were 129 NFRs that were both in the requirement sentence and the associated Figure/images (Appendix L). This further validates the gathering of NFRs from associated Figure/images (NFRM) and using the baseline data validates the findings of the NFRs in the Figures/images (NFRM) in reducing the false positives.

The CEP methodology also prioritized the NFRs (Appendix N). There has been a lack of NFRs prioritization unlike that of FRs. NFRs should be prioritized similar to

FRs. The αβγ-framework was utilized to prioritize NFRs. The flexibility of the αβγ-framework is the ease of allowing sub-processes to be replaced by other techniques (Aasem, Ramazan and Jaffer, 2010). This is a very attractive feature for agile team members to replace parts of the framework in an agile manner to suit their needs in prioritizing NFRs. The 100-dollar test was used to assign each NFRs a value for α process. Each NFRs was assigned $100 dollars. This can be modified to place higher dollar value on more important NFRs per agile stakeholders. Process β included the weighted sum of each requirement. For the γ process a modified version of the AHP process was used by comparing the weight of each requirement with the average weight of all the requirements. The top five requirements based on NFR prioritization were found to be the following: 12.3, 24.5, 15.3, 7.5, and 7.1 (Appendix N). The prioritization of NFRs fit the agile software development cycle where time lines are short. This in turn helps agile software developers and project managers to plan accordingly to budget and time-line constraints.

Study Implications

This dissertation made a number of contributions towards addressing NFRs during the early stages of agile software development. The study utilized known methodologies to develop the CEP methodology to handle NFRs during the early stages of agile software development. The study developed and utilized several artifacts including the NFR Locator artifact created by Slankas and Williams (2013) and extending to create the NFR Locator Plus artifact to handle metadata from images and Figures. The NFR Locator Plus uses the Stanford Natural Language (NLP) parser to

extract NFRs from documents and categorize them into NFR categories which is partially based on Chung's NFR framework.

The OCR artifact was developed which is a well-known in in library technology. The OCR is a simple yet powerful artifact that can translate images and Figures to text based documents which can be utilized to extract NFRs. The initial step was to capture the NFRs using the OCR artifact. Numerous documents can be fed into the OCR artifact which will be translated into text readable format. A wealth of information can be gathered from these Figures and images. There are a number of open source OCR technology that is available and can be utilized to extract important NFRs information. This is an easy to use tool which can be utilized by agile team members.

The NFR Locator Plus artifact was used to locate NFRs in documents and images/Figures (NFRM). This step elicited the NFRs from the documents and the associated Figure/images (NFRM). The NFR locator utilized a series of trained data sets (Appendix F & G). The trained data includes verbs, nouns, adjectives, adverbs, synonyms, antonyms, and hyponyms as a lemma in the NFRs Locator Plus where the base word from a set of words is used to take in part of the speech (Slankas and Williams, 2013). Also, the top 20 NFR keywords by category from the previous NFR Locator data sets were used (Appendix F). The NFR Locator loads trained data sets and load the document in text format to locate NFRs. The tool is flexible enough where agile members can modify it to expand or use different NFRs groups. Part of Chung's NFR group was used for the NFR Locator Plus. The tool is simplified enough to where agile members can make adjustments and NFRs group per need of stakeholders.

The Database artifact provided an important tool for storing and retrieving the data. This provided the central artifact for storing and updating of NFRs. The NFRs were stored by their requirement IDs, NFR sentence, NFR priority and NFR type. The database was utilized for storing the 57 baseline FRs. This is a simple yet powerful artifact which is common to most agile stakeholders and can be easily utilized by members of the team.

The NFR priority artifact was introduced in the CEP methodology. Most FRs requirements are prioritized while NFRs are often overlooked. By prioritizing NFRs helps agile members plan according to budget and time constraints in-line with the nature of agile software development. The αβγ-framework was utilized to prioritize NFRs as explained earlier. The flexibility of the αβγ-framework is the ease of allowing sub-processes to be replaced by other techniques (Aasem, Ramazan and Jaffer, 2010).
A dollar value was used to assign to α process. Agile members can assign different dollar values to NFRs. For example, NFR security can be assigned $500 dollars and NFRs Documentation can be assigned $100 dollars. Process β included the weighted sum of each requirement from the NFR count of each requirement. Process γ a modified version of the AHP process was used. The simplicity of the αβγ-framework provides a simple way to prioritize NFRs.

The NFR Visualization artifact is a simple viewer to look at NFRs and their requirements. The artifact allows agile stakeholder to sort the NFRs by the NFR priority from low to high or high to low. The GUI includes the requirement ID, requirement sentence, NFR priority and NFR type grouping which may include multiple NFR groups.

This allows agile members to make decisions based on prioritizing requirements and NFRs based on budged and time constraint.

Study Recommendations

The goal of this study was to create an automated methodology to capture, elicit and prioritize NFRs during the early stages of agile software development. The CEP methodology was developed along with several artifacts to fulfill the goal of this study. There are areas that could potentially be improved upon the CEP methodology that will contribute to the greater body of knowledge.

One area of improvement is on the OCR artifact. This artifact can be extended to recognize hand written text in 3 x 5 cards generally used in agile processes such as Extreme Programming and Scrum. There are several OCR technologies that can take advantage of using an app on a smart phone to take a picture and capture information from 3 x 5 index cards. The pictures are stored and the OCR will translate the hand writings on the 3 x 5 cards to text and the information used to elicit NFRs.

Another improvement area is to utilize the NFR Locator Plus on multiple data sets from the cloud storage. The NFR Locator Plus can be developed into a mobile app which would enable agile members to quickly load requirement documents from multiple sources and to utilize cloud storage to share information with other agile members in different locations.

A third area of improvement would be to expand the NFR categories. The baseline categories used were based on the Chung's NFR framework. By making the NFR Locator Plus into a mobile app and utilizing cloud storage can allow multiple NFR categories to be loaded from different sources.

A fourth area of improvement would be auto-link the image/associate Figure to the requirement. This can involve by developing logic utilizing headers and related information to link Figure to FRs. The auto-link feature would be useful in identifying Figures that are related to the FRs.

A fifth area of improvement would be to add historical trending to the CEP methodology. Historical trending can be used to predict additional NFRs that are overlooked by architects and can be included along with FRs in the early stages of agile software development. There is no known research study that takes gathered NFRs that are either historical or current and try to predict additional NFRs that will be used along with FRs in the early stages of software development. In addition, NFRs such as performance; usability, reliability, and maintainability are often overlooked during the initial stages of software development. It would be beneficial to use historical trending to predict additional NFRs overlooked during the early stages of software development. These additional NFRs are based on the metadata gathered from previous NFRs and to link these to existing NFRs will improve the quality of software. The cloud storage above can be utilized to gather historical NFRs data from other agile team members. The historical data can be used to predict additional NFRs based on the requirement. A potential research question for historical trending NFRs could be the following:

Potential Research Question A1: Can historical trending based on the gathered and historical metadata have an impact in predicting additional NFRs which may not have been identified in the initial software development process and be able to group them in NFRs categories?

Potential Research Question A2: If so, what categories of NFRs can they be grouped in?

Summary

In Software Engineering, Functional Requirements (FRs) have taken precedence over Non-Functional Requirements (NFRs) and NFRs are often overlooked until the later stages of software development. Software developers pay more attention to the functional needs of a software that fulfill the business needs and NFRs such as performance, usability, reliability, security, and scalability are usually handled later in an ad-hoc manner during the system testing phase (Nyguyen, 2009). The goal of this study was to accurately capture, elicit and prioritize NFRs during the early stages of agile software development.

In order to accomplish the goals, the CEP methodology "Capturing Eliciting and Prioritizing" was proposed and developed. A number of artifacts were created for capturing NFRs from associated Figures/images, eliciting NFRs from images and requirement texts and prioritizing NFRs. The CEP methodology was validated using three case studies that used the European Union (EU) eProcurement Online System requirements (European Dynamics S.A., 2005a) and (European Dynamics S.A., 2005b).

This study created a number of artifacts among which the main ones include the OCR artifact, the Database artifact, the NFR Locator Plus artifact, the Prioritization artifact and the Visualization Artifact. The OCR artifact was used to scan through the document and translate images into readable text. The weakness of the NFR Locator from previous research was not being able to capture NFRs from images therefore the OCR artifact was developed to accommodate the NFR Locator Plus artifact. The OCR artifact was used to capture metadata from associated Figures/images and to link the data

requirements. The NFR Locator Plus artifact was used to locate NFRs in requirement sentences and associated Figure/images (NFRM). The NFRs priority artifact was used to prioritize NFRs using the αβγ-framework. The framework is flexible enough to allow agile members to modify the framework to suit their needs. The CEP methodology is the first study conducted that prioritized NFRs similarity of FRs. The Database artifact was used to store FRs and NFRs information. The Visualization artifact includes the requirement ID, requirement, NFR priority and NFR grouping.

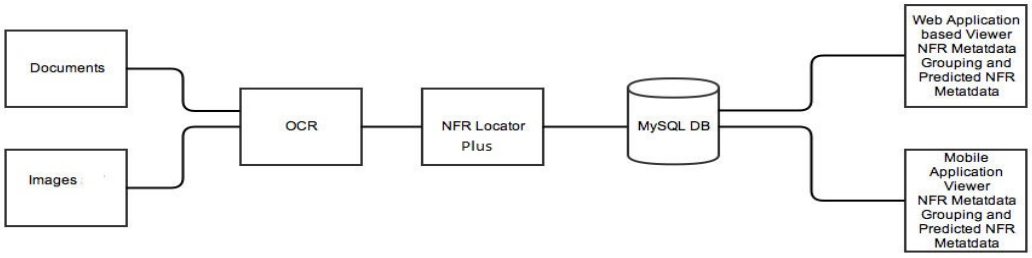
Results showed that the CEP methodology successfully identified NFRs in 56 out of 57 requirement sentences that contained NFRs compared to 50 of the NORMAP baseline and 55 of the NERV methodology. The CEP methodology was successful in eliciting 98.24% of the baseline compared to 87.71% for the NORMAP methodology representing an improvement of 10.53%. Compared to the baseline results for the NERV methodology of 96.49%, the CEP methodology showed an improvement of 1.75%. The CEP methodology successfully elicited 86 out of 88 NFR compared to the baseline NORMAP methodology of 75 and NERV methodology of 82. The NFR count elicitation success for the CEP methodology was 97.73 % compared to the NORMAP methodology of 85.24 % which is an improvement of 12.49%. Compared to the NERV methodology result of 93.18%, the CEP methodology had an improvement of 4.55%. CEP methodology utilized the associated metadata/Figures/images and linked them to the related requirements to improve over the NORMAP and NERV methodology (Appendix L). There were 29 baseline NFRs found in the associated Figures/images (Appendix L) and 129 NFRs were both in the requirement sentence and the associated Figure/images (Appendix L).

Lastly, the CEP methodology prioritized the NFRs (Appendix N) of this study. NFRs need to be prioritized similarly to FRs and the αβγ-framework was utilized for prioritization. The αβγ-framework is flexible enough to be modified to allow sub-processes to be replaced by other techniques (Aasem, Ramazan and Jaffer, 2010). The sub-processes were modified in this study. This modification is a very attractive feature for agile team members to replace parts of the framework to suit their needs in prioritizing NFRs. The top five requirements based on NFR prioritization were the following: 12.3, 24.5, 15.3, 7.5, and 7.1 (Appendix N). The prioritization of NFRs fits the agile software development cycle and allows agile developers and team members to plan according to time and budget constraints.

The CEP methodology developed artifacts and validated the results for NFRs capturing, eliciting and prioritizing during the early stages of agile software development. There are several areas of improvement that can be made to the CEP methodology and add to the greater body of knowledge. Utilizations of the artifacts in a real life agile software development organization would provide valuable gain towards the research findings of this study. The CEP methodology is flexible enough and can be extended to contribute to the greater body of knowledge.

Appendix A

Flow diagram for capturing, eliciting, and prioritizing NFRs



Appendix B

NFR metadata grouping

NFRs Metadata Group	Description of NFRs	Priority of NFRs
1. Access Control	Xxxxxxxxxxxxxxxxxxxxxxx	**2**
2. Audit	Xxxxxxxxxxxxxxxxxxxxxxx	**5**
3. Availability	xxxxxxxxxxxxxxxxxxxxxxx	**1**
4. Capacity and Performance	Xxxxxxxxxxxxxxxxxxxxxxx	**4**
5. Legal	Xxxxxxxxxxxxxxxxxxxxxx	**3**
6. Look and Feel	Xxxxxxxxxxxxxxxxxxxxxx	**6**
7. Maintainability	Xxxxxxxxxxxxxxxxxxxxxx	**7**
8. Operational	Xxxxxxxxxxxxxxxxxxxxxx	**8**
9. Privacy	Xxxxxxxxxxxxxxxxxxxxxx	**9**
10. Recoverability	Xxxxxxxxxxxxxxxxxxxxxx	**10**
11. Reliability	Xxxxxxxxxxxxxxxxxxxxxx	**11**
12. Security	Xxxxxxxxxxxxxxxxxxxxxx	**12**
13. Usability	Xxxxxxxxxxxxxxxxxxxxxx	**13**
14. Other	Xxxxxxxxxxxxxxxxxxxxxxx	**14**

Appendix C

Baseline Non-Functional Requirements and Abbreviation

Accessibility	AC
Accuracy	AR
Auditability	AU
Availability	AV
Compliance	CE
Confidentiality	CO
Configuration	CN
Documentation	DO
Efficiency	EF
Interoperability	IN
Legal	LG
Multilingual	ML
Performance	PS
Reliability	RE
Scalability	SC
Security	SE
Usability	US
User Interface	UI

Appendix D

Non-Functional Requirements List

Accessibility	Access Control	Accuracy	Adaptability
Adjustability	Affordability	Agility	Auditability
Audit	Availability	Buffer Space Performance	Capability
Capacity Clarity	Code-Space Performance	Cohesiveness	Commonality
Communication Cost	Communication Time	Compatibility	Completeness
Component Integration Cost	Component Integration Time	Comprehensibility	Conceptuality
Conciseness	Confidentiality	Configurability	Consistency
Controllability	Coordination Cost	Correctness Cost	Coupling
Customer Loyalty	Customizability	Data-Space Performance	Decomposability
Domain Analysis Time	Dependability	Development Cost	Degradation of Service
Development Time	Diversity	Domain Analysis Cost	Efficiency
Elasticity	Execution Cost	Extensibility	External Consistency
Fault-Tolerance	Feasibility	Flexibility	Formality
Generality	Guidance	Hardware Cost	Impact Analyzability
Independence	Inspection Cost	Inspection Time	Integrity
Inter-Operability	Internal Consistency	Intuitiveness	Learnability
Legal	Look & Feel	Main-Memory Performance	Maintainability
Maintenance	Maintenance Cost	Maintenance Time	Maturity
Mean Performance	Measurability	Mobility	Modifiability
Modularity	Naturalness	Observability	Off-Peak-Period Performance
Operability	Operational	Operating Cost	Peak-Period Performance
Performance	Planning Cost	Planning Time	Plasticity
Portability	Precision	Predictability	Process Management Time
Productivity	Project Stability	Project Tracking Cost	Promptness
Privacy	Prototyping Cost	Prototyping Time	Re-Configurability

Recoverability	Recovery	Reengineering Cost	Reliability
Scalability	Performance & Scalability	Secondary-Storage Performance	Security
Sensitivity	Similarity	Simplicity	Software Cost
Software Production Time	Space Boundaries	Space Performance	Specificity
Stability	Subjectivity	Supportability	Subjectivity
Supportability	Surety	Survivability	Sustainability
Testability	Testing Time	Throughput	Time Performance
Timeliness	Tolerance	Traceability	Trainability
Transferability	Transparency	Understandability	Uniform Performance
Uniformity	User-Friendliness	Validity	Variability
Verifiability	Verifiability	Versatility	Visibility

Appendix E

Baseline Non-Functional Requirements Definition

Accessibility	The quantity of being at hand when needed. The attribute of being easy to meet or deal with (WordNet).
Accuracy	1. A qualitative assessment of correctness, or freedom from error. 2. A quantitative measure of the magnitude of error (IEEE and ISOIEC)
Auditability	An independent examination of a work product or set of work products to assess compliance with specifications, standards, contractual agreements, or other criteria (IEEE Std 610.12-1990).
Availability	The degree to which a component or system is operational and accessible when required for use. Often expressed as a percentage (IEEE 610).
Compliance	The capability of the software product to adhere to standards, conventions or regulations in laws and similar prescriptions (ISO 9126).
Confidentiality	a characteristic that applies to information. To protect and preserve the confidentiality of information means to ensure that it is not made available or disclosed to unauthorized entities. In this context, entities include both individuals and processes (ISO 27001).
Configuration	The composition of a component or system as defined by the number, nature, and interconnections of its constituent parts (IEEE).
Documentation	(1) A collection of documents on a given subject. (2) Any written or pictorial information describing, defining, specifying, reporting, or certifying activities, requirements, procedures or results (IEEE).
Efficiency	The capability of the software product to provide appropriate performance, relative to the amount of resources used under stated conditions (ISO 9126).

Interoperability	The ability of two or more systems or component to exchange information and to use the information that has been exchange (IEEE and ISOEEC)
Legal	established by or founded upon law or official or accepted rules (WordNet)
Multilingual	using or knowing more than one language (WordNet)
Performance	The degree to which a system or component accomplishes its designated functions within given constraints regarding processing time and throughput rate (IEEE 610).
Reliability	The ability of the software product to perform its required functions under stated conditions for a specified period of time, or for a specified number of operations (ISO 9126).
Scalability	The capability of the software product to be upgraded to accommodate increased loads (IEEE).
Security	Attributes of software products that bear on its ability to prevent unauthorized access, whether accidental or deliberate, to programs and data (ISO 9126).
Usability	The capability of the software to be understood, learned, used and attractive to the user when used under specified conditions (ISO 9126).
User Interface	An interface that enables information to be passed between a human user and hardware or software components of a computer system (IEEE Std-610.12).

Appendix F

NFR Locator Plus Trained Data Set I
Top 20 Keywords by Category (Slankas and Williams, 2013)

Access Control (AC)	choose, lhcp, hcp, visit, privilege, read, office, add, representative, sort, name, administrator, personal, dlhcp, view, status, accessor, edit, role, list
Audit (AU)	authorship, trail, arise, worksheet, auditable, exclusion, reduction, deletion, examine, editing, stamp, non-repudiation, inclusion, id, alteration, finalize, disable, summarize, attestation, log
Availability (AV)	achieve, 24, availability, 98, addition, available, 99, hour, day, online, schedule, confidentiality, resource, technical, year, transmit, integrity, maintenance, %, period
Legal (LG)	Infeasible, custodian, hipaa, breach, dua, discovery, iihus, publication, iihi, recipient, delay, secretary, definition, harm, scope, jurisdictional, affect, derive, vocabulary, reuse
Look & Feel (LF)	appearance, scheme, tree, radio, appeal, color, look, navigation, sound, feel, ship, left, shot, menu, ccr, button, corporate, page, openemr, employer
Maintenance (MT)	4010, Washington, ibr, x12n, asc, 2002, addenda, 837, September, 1999, 1.1, tele-communication, 5.1, astm, draft, February, January, 2010, context-ware, infobutton
Operational (OP)	mysql, Microsoft, euhr, soms, letter, infrastructure, interoperability, connect, cchcs, machine, browser, platform, cardmember, central, cdcd, extraction, cchc, model, registry, interchange
Privacy (PR)	health, protected, entity, disclose, covered, use, disclosure, individual, such, purpose, law, permit, other, section, plan, event, failure, organization, business, hour
Recoverability (RC)	Restore, credentials, backup, back, recovery, disaster, previous, emergency, establish, copy, state, need, implement, loss, plan, event, failure, organization, business, hour
Performance & Scalability	fast, simultaneous, 0, second, scale,

	capable, increase, peark, longer, average, acceptable, lead, handle, flow, response, capacity, 10, maximum, cycle, distribution
Reliability (RL)	reliable, dependent, validate, validation, input, query, accept, loss, failure, operate, alert, laboratory, prevent, database, product, appropriate, even, application, capability, ability
Security (SC)	cookie, encrypted, ephi, http, predetermined, strong, vulnerability, username, inactivity, portal, ssl, deficiency, uc3, authenticate, certificate, session, path, string, password, incentive
Usability (US)	easy, enterer, wrong, learn, word, community, drop, realtor, help, symbol, voice, collision, training, conference, easily, successfully, let, map, estimator, intuitive

Appendix G

NFR Locator Plus Trained Data Set II

NFRs	verb, nouns, adverbs, adjectives, synonyms, antonyms, hyponym, NFR catalogs information, related concepts and top 20 NFR keywords by category
Accessibility (AC)	access, accessible, availability, accessibleness, accessibly, accessibility, approachable, reachable, attainable, obtainable, procurable, available, inacessible, restricted, limited, unavailable, unattainable, unobtainable, omnipresent, prevalent, ubiquitous, widespread, unrestricted, command, print, handy, accessible, available, convenience, suitable, suitableness, quality, attribute, abstraction, abstract entity, easily used, easily obtained, easily accessed, access code, memory access, approach, reach, attain, obtain, handy, easily met, at hand, choose, lhcp, hcp, visit, privilege, read, office, add, presentation, sort, name, administrator, personal, dlhcp, view, status, accessor, edit, role, list
Accuracy (AR)	accurate, consistent, time, precise, correct, exact, definite, accuracy, certainty, correctness, definiteness, accurateness, closeness, exactness, fineness, perfection, preciseness, rigor, ultra-precision, imprecise, inaccurate, inaccuracy, falseness, inconsistency, nonconformity, exactitude, minuteness, preciseness, precision, trueness, fidelity, timely accurately, one on one accuracy, property accuracy, value accuracy, consistency, external consistency, internal consistency, near true value, error free, precise, correct, conform to a standard, precision, magnitude of error, standard
Auditability (AU)	infringe, copyright, audit, examination, comply, compliance, analyze, scrutinize, contract, review, auditable, auditee, auditability, Inspection, check, examination, scan, see, review, go-over, scrutiny, survey, view, study, examine, canvass, learn, read, take, train, prepare, drill, exercise, practice, functional configuration audit, physical configuration, comply with standard, auditor, accounting audit, financial audit, methodical review and examination, independent examination, assess compliance with standards, contractual agreement, authorship, trail, arise, worksheet, auditable, exclusion, reduction, deletion, examine, editing, stamp, non-repudiation, inclusion,

	alteration, finalize, finalize, disable, summarize, summarize, attestation, log
Availability (AV)	achieve, 24, availability, 98, addition, available, 99, hour, day, online, schedule, confidentiality, resource, technical, year, transmit, integrity, maintenance, %, period, Handiness, accessibility, convenience, dependability, maintainability, reliability, availableness, availably, accessible, acquirable, attainable, obtainable, limited, restricted, procurable, inaccessible, unattainable, unavailable, unobtainable, suitable, suitability, convenient, partial, continuous, full, intermittent, tolerance, probability, error tolerance, ready for immediate use, use, service, service interruption tolerance, system, system degradation toleration, business continuity, operational and accessible when needed for use, probability
Compliance (CE)	require, compliantly, compliant, compliance, conformity, conformation, abidance, comply, submit, submission, accede, bow, put, forth, nonconformity, noncompliance, acquiescence, biddability, compliancy, deference, obedience, abidance, adherence, conformance, conformity, submission, subord, ination, keeping, obedience, observation, submissiveness, formality, line, honoring, cooperation, collaboration, teamwork, prostration, adjust, adapt, custom, get used to, legal standards, conform to requirements, follow rule, act in accord with accepted standards, conform to official requirements, satisfy government regulations, official
Confidentiality (CO)	confidential, confidentially, confidentiality, behind-the-scenes, private, esoteric, hushed, intimate, privy, nonpublic, secret, common, open, public, shared, well-known, advertised, announced, blazed, broadcast, declared, disclosed, divulged, enunciated, heralded, proclaimed, professed, promulgated, publicized, published, reporting, reported, spotlighted, widespread, privacy, private, privateness, secrecy, concealment, discretion, discreetness, circumspection, prudence, data, data protection, unauthorized disclosure, information, information protection, information privacy, keep information secret, unauthorized disclose of data and information, accidental or deliberate disclosure protection, authority
Configuration (CN)	conFigure, configuration, configurational, configurationally, configurative, configurability, architecture, armature, cadre, frame, edifice, fabric,

	framework, framing, infrastructure, shell, skeleton, structure, composition, material, matter, stuff, substance, assemble, piece, put together, set up, tack together, make, create, connect, tie, link up, reassemble, computer configurability, hardware configuration, software configuration, configuration management system, set up for specific purpose, computer configuration of parts, interconnections of components, system
Documentation (DO)	document, documentary, documentation, documentational, attestation, confirmation, corroboration, proof, evidence, substantiation, testament, testimonial, testimony, validation, voucher, witness, disproof, certificate, document, exhibit, demonstration, illustration, authentication, identification, manifestation, verification, confirmation, information, info, message, content, subject matter, substance, communication, reinforcement, re-enforcement, corroborate, software documentation, certification, corroboration, support, program listing, technical manuals, program use and operation, software, software program, computer software, system, software system, software package, package, document validation, documents collection, describe, define, specify, report information, certify activities, requirements, procedures and results, documents management, identify, acquire, process, store, disseminate documents
Efficiency (EF)	efficient, efficiently, efficiency, inefficiency, edge, effectiveness, effectualness, efficaciousness, efficacity, efficacy, productiveness, ineffectiveness, ineffectuality, ineffectualness, Figure of merit, ratio, economy, Storage efficiency, efficiency in use, ratio of output to input, perform functions, minimum resources, ualness, Figure of merit, ratio, economy, storage efficiency, efficiency in use, ratio of output to input, perform functions, minimum resources
Interoperability (IN)	operable, operably, operability, interoperable, interoperability, available, employable, exploitable, fit, functional, operable, practicable, service, serviceable, useful, impracticable, inoperable, nonfunctional, unavailable, unemployable, unusable, ability, quality, adaptability, compatibility, working together, two or more systems, exchange and use information, operate harmoniously, system
Legal (LG)	legality, legally, legal, court ordered, jural, ratified, sanctioned judicial, juristic, statutory, legislative, legislature, legislation, illegal, valid, invalid, lawful,

	legitimate, licit, allowable, authorized, noncriminal, permissible, justifiable, warrantable, constitutional, dejure, regulation, statutory, good, innocent, just, proper, right, illegitimate, illicit, lawless, unlawful, wrongful, establish, accepted founded on law, Official, official rules, accepted rules, infeasible, custodian, hipaa, breach, dua, discovery, iihus, publication, iihi, recipient, delay, secretary, definition, harm, scope, jurisdictional, affect, derive, vocabulary, reuse
Multilingual (ML)	multilingual, multi languages, support, multiple, language, support, more than one language, multiple languages, express in several languages, multi-lingual format
Performance (PS)	perform, interpretation, account, reading, rendition, version, nonfulfillment, nonperformance, space, time, main, memory, response, time, throughput, off-peak throughput, peak throughput, peak mean throughput, peak uniform throughput, Time behavior, resource utilization, second, minutes, hour, day, week, month, year, byte, kilobyte, megabyte, gigabyte, execution, instruction, execution, perform, efficiently, manner of operating, functioning, functional, function, operate, operational, fast, simultaneous, scale, capable, increase, peark, longer, average, acceptable, lead, handle, flow, response, capacity, maximum, cycle, distribution
Reliability (RE)	reliably, reliability, undependableness, unreliability, unreliable, dependability, dependableness, reliableness, responsibility, solidity, solidness, sureness, trustability, infallibility, reproducibility, duplicability, responsibleness, trustworthiness, trustiness, accountability, answerability, availability, fault tolerance, recoverability, MTBF, probability of availability, continual operation, perform, perform required functions, under specific conditions, specific period of time, maintain specific performance under specific conditions, dependent, validate, validation, input, query, accept, loss, failure, operate, alert, laboratory, prevent, database, product, appropriate, event, application, capability, ability, time
Scalability (SC)	system, scalable, scalability, able, capable, equal, fit, good, qualified, suitable, incompetent, inept, poor, unfit, unfitted, unqualified, quantifiability, measurability, ratability, capable to scale, ease to expand, upgrade on demand, fast, simultaneous, second, scale, capable, increase, peark, longer, average, acceptable, lead, handle, flow, response, capacity, maximum, cycle,

	distribution
Security (SE)	authority, authorities, security, secure, securely, unsecure, insecurity, assurance, invulnerable, impregnable, inviolable, secure, strong, unassailable, unattackble, vulnerable, hazard, risk, threat, instability, precariousness, harm s way, exposure, liability, openness, violability, vulnerability, susceptibility, susceptibleness, danger, distress, endangerment, imperilment, jeopardy, peril, trouble, secureness, protection, shelter, safety, availability, integrity, confidentiality, operational security, completeness, accuracy, internal consistency, external consistency, external confidentiality, internal confidentiality, operational internal confidentiality, protection from accidental, malicious access, access, unauthorized use, modification destruction, disclosure, unauthorized access, confidentiality, integrity, non repudiation, accountability, accountable, authenticity, authenticate, identify, authorize, authorized, authorization, immunity, survivability, cookie, encrypted, ephi, http, predetermined, strong, username, inactivity, portal, ssl, deficiency, uc3, authenticate, certificate, session, path, string, password, incentive
Usability (US)	usable, usableness, usability, usably, use, user, available, employable, exploitable, fit, functional, operable, service, serviceable, useful, actionable, applicable, applicative, applied, functional, practicalble, serviceable, ultrapractical, usable, useable, useful, workable, working, impracticable, inoperable, nonfunctional, unavailable, available, unemployable, unusable, impracticable, impractical, inapplicable, nonpractical, unusable, unworkable, useless, utility, usefulness, function, purpose, role, helpfulness, use, instrumentality, practicality, practicability, usable, useable, serviceable, user-friendly, operability, serviceability, serviceableness, usableness, useableness, learn to operate, use efficiently, use with satisfaction, use effectively, easy to learn, use and operate, prepare inputs, interpret outputs, easy, enterer, wrong, learn, word, community, drop, realtor, help, symbol, voice, collision, training, conference, easily, successfully, let, map, estimator, intuitive, prepared, Operators
User Interface (UI)	user interface, user, interface, interfacial, interfaced, interfacing, command line, graphical user interface, program, programme, computer program, computer programme, GUI, display, user friendly, human

	computer interface, control display, user interaction with system, system, interact, coordinate harmoniously, usability, use

Appendix H

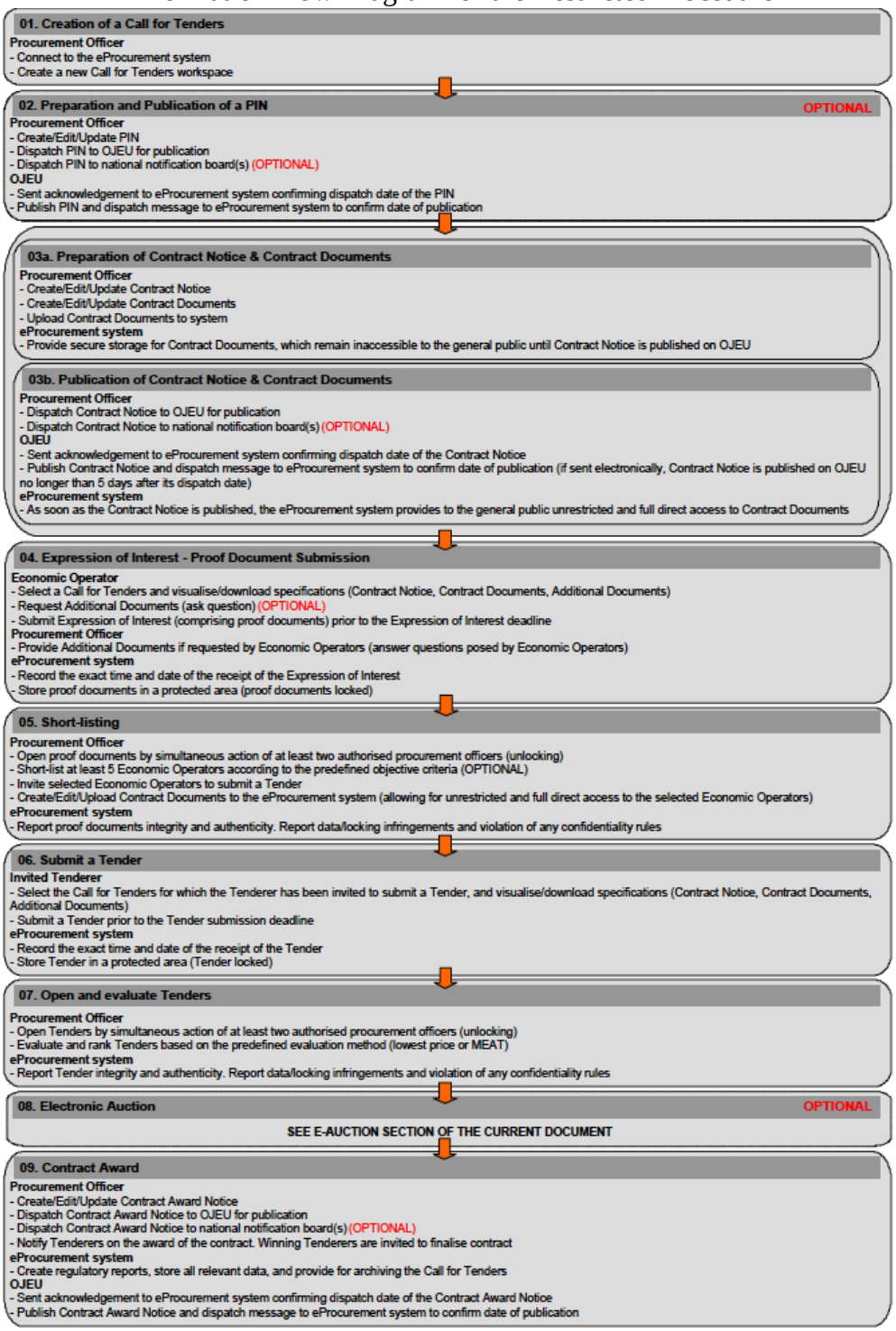
CEP Methodology Baseline NFR Selection

NFR	PROMISE NFR Data Set	EU eProcurement Document	HP FURPS	IEC/ISO-25010	TOTAL	CEP Selection
Accessibility (AC)	X	X			2	X
Accuracy (AR)		X		X	2	X
Auditability (AU)	X	X			2	X
Availability (AV)	X	X		X	3	X
Compliance (CE)		X		X	2	X
Confidentiality (CO)		X		X	2	X
Configuration (CN)		X		X	2	X
Documentation (DO)		X	X		2	X
Efficiency (EF)		X	X	X	2	X
Interoperability (IN)		X		X	2	X
Legal (LG)	X	X			2	X
Multilingual (ML)		X			1	X
Performance (PS)	X	X	X		3	X
Reliability (RE)	X	X	X	X	4	X
Scalability (SC)	X	X			2	X
Security (SE)		X	X		2	X
Usability (US)	X	X	X	X	4	X
User Interface (UI)		X			1	X

Appendix I

European eProcurement Document Vol I. Figure 2-3

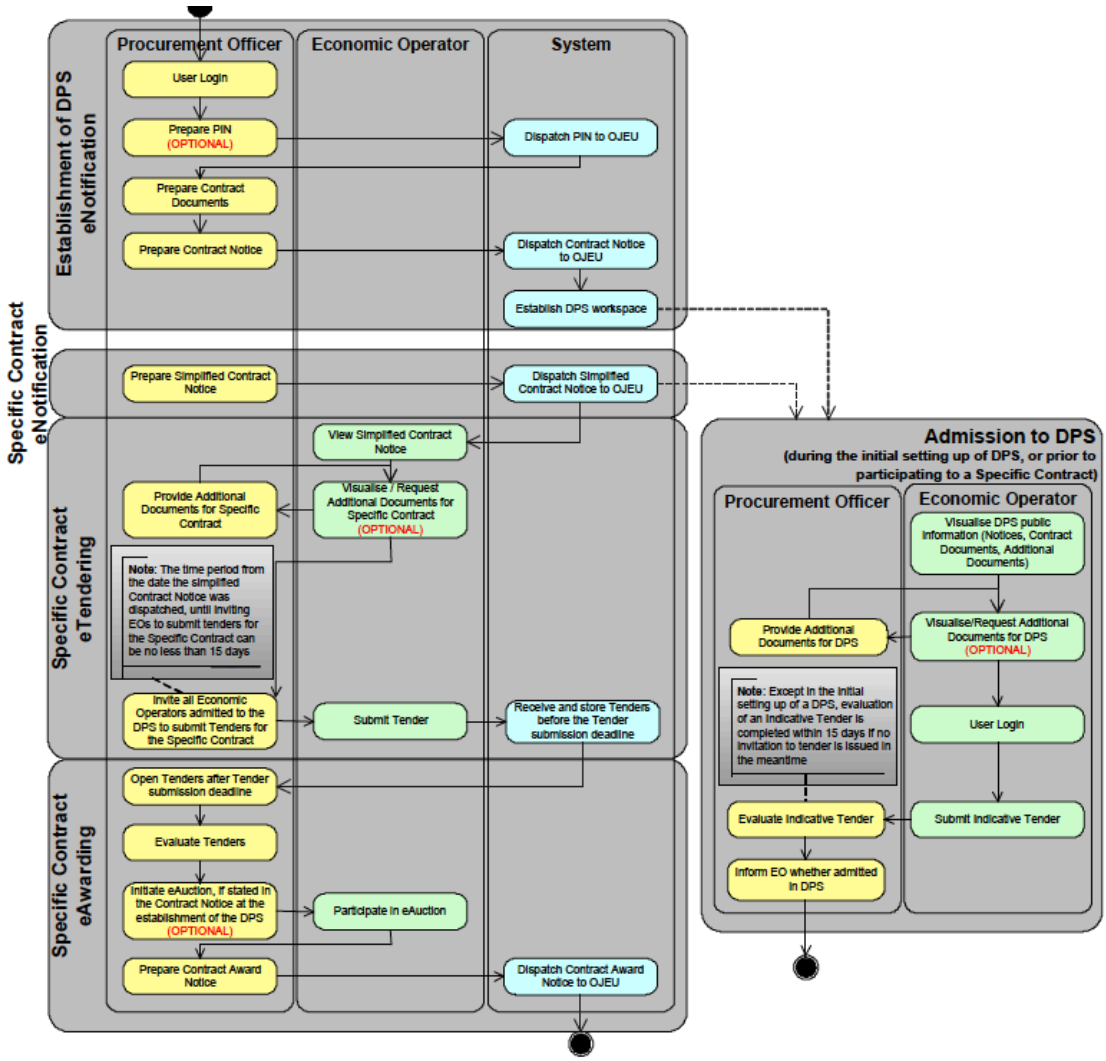
Information Flow Diagram for the Restricted Procedure



Appendix J

European eProcurement Document Vol I. Figure 2-6

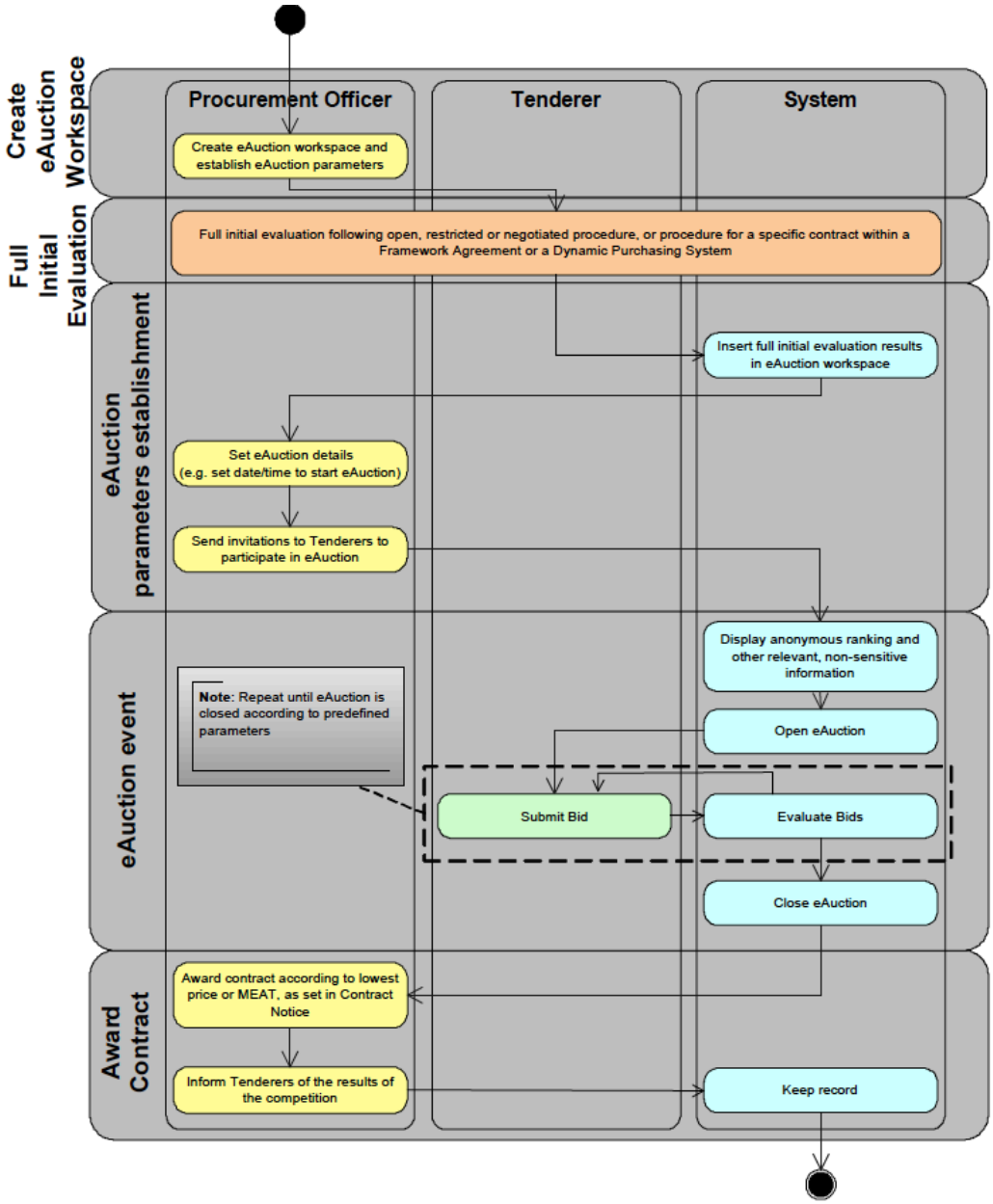
Activity Diagram for the Dynamic Purchasing System



Appendix K

European eProcurement Document Vol I. Figure 2-10

Activity Diagram for e-Auction



Appendix L

CEP methodology NFR Elicitation Results

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
1.2 The registration process must ensure the confidential transfer and storage of all personal information of users. Fig 2-3-01 Creation for a Call for Tender Procurement Officer Connect to the eProcurement System Create a new Call for Tenders workspace	registration, process, confidential, personal information, users. eProcurement System, connect, create	Confidentiality, Security	Confidentiality, Efficiency, Security, Usability, User Interface	Accessibility (AC), Configuration (CN), Confidentiality (CO), Documentation (DO), Efficiency (EF), Security (SE), Usability (US), User Interface (UI)	**Success**	NFR Accessibility were found both in the requirement sentence and associate Figure/image (NFRM). NFR Configuration was found from the associated Figure/image (NFRM).
2.4 Also, each user is associated to a unique identifier, which can be used by the audit trailing facility of the system, in order to record all user activities, and to identify the initiator/actor of each activity. Fig 2-3-01 Creation for a Call for Tender Procurement Officer Connect to the eProcurement System Create a new Call for Tenders workspace	user, used, audit, trailing, system, activities, identify, eProcurement System, connect, create	Auditability	Auditability, Documentation, Usability, User Interface	Accessibility (AC), Auditability (AU), Configuration (CN), Documentation (DO), Security (SE), Scalability (SC), Usability (US), User Interface, (UI)	**Success**	NFR Accessibility was found from the image. NFR Configuration were found from both requirement sentence and associated Figure/image (NFRM).
2.5 Moreover, user profiling can allow users to setup their preferences when using the	users, data, searched, displayed, eProcurement	Usability, User Interface	Configuration, Usability, User Interface	Accessibility (AC), Configuration (CN), Usability (US),	**Success**	NFRs Accessibility and Configuration were found in

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
system, in terms of how data is searched, displayed, etc. Fig 2-3-01 Creation for a Call for Tender Procurement Officer Connect to the eProcurement System Create a new Call for Tenders workspace	System, connect, create			User Interface (UI)		associated Figure/images (NFRM).
3.1 This functional requirement allows users to identify themselves to the eProcurement system. Fig 2-3-01 Creation for a Call for Tender Procurement Officer Connect to the eProcurement System Create a new Call for Tenders workspace	functional, users, identify, eProcurment system, eProcurement System, connect, create	Security	Documentation, Interoperability, Security, User Interface	Accessibility (AC), Availability (AV), Configuration (CN), Documentation (DO), Interoperability (IN), Performance (PS), Security (SE), Scalability (SC), Usability (US), User Interface (UI),	**Success**	NFRs Accessibility and Configuration were found in both the associated image/Figure (NFRM) and the requirement sentence.
3.2 This is necessary for the system to display the appropriate data to users, as well as, to make available the appropriate activities to be executed according to a user's role in the system. Fig 2-3-01 Creation for a Call for Tender Procurement Officer	system, appropriate, make, available, appropriate, activities, user's, role, eProcurement System, connect, create	Security	Accessibility, Availability, Interoperability, Security, User Interface	Accessibility (AC), Configuration (CN), Confidentiality (CO), Availability (AV), Interoperability (IN), Reliability (RE), Scalability (SC,) Usability (US), User Interface (UI),	**Fail**	NFRs Accessibility and Configuration were found in both the associated Figure/image (NFRM) and the requirement sentence. NFR baseline Security was not found.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
Connect to the eProcurement System Create a new Call for Tenders workspace						
4.3 User authorization can enable the eProcurement system to be aware of the role of a user. Fig 2-3-01 Creation for a Call for Tender Procurement Officer Connect to the eProcurement System Create a new Call for Tenders workspace	user, authorization, enable, eProcurement System, role, connect, create	Security	Availability, Configurability, Documentation, Interoperability, Security, User Interface, Usability	Availability (AV), Accessibility (AC), Configuration (CN), Documentation (DO), Interoperability (IN), Scalability (SC), Security (SE), Usability (US) User Interface (UI)	**Success**	NFRs Accessibility and Configuration were found in both the associated Figure/image (NFRM) and the requirement sentence.
4.4 Depending on the user rights for each user, the system can control which activities a user can perform, as well as, what data a user should have access to. Fig 2-3-01 Creation for a Call for Tender Procurement Officer Connect to the eProcurement System Create a new Call for Tenders workspace	user, rights, system, activities, perform, access, eProcurement System, role, connect, create	Accessibility, Security	Performance, Security, User Interface, Usability	Accessibility (AC), Configuration (CN), Documentation (DO), Interoperability (IN), Legal (LG), Performance (PS), Security (SE), Usability (US), User Interface (UI)	**Success**	NFRs Accessibility and Configuration were found in both the associated Figure/image (NFRM) and the requirement sentence.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
5.1 When creating a Call for Tenders, the eProcurement system can make available to the Procurement Officers a virtual workspace for storing all Call-related information. Fig 2-3-01 Creation for a Call for Tender Procurement Officer Connect to the eProcurement System Create a new Call for Tenders workspace	eProcurement system, make, available, Officers, workspace, information, connect, create	Availability	Availability, Configurability, Documentation, Interoperability	Accessibility (AC), Availability (AV), Configuration (CN), Documentation (DO), Interoperability (IN), Performance (PS), Scalability (SC), Usability (US), User Interface (UI)	**Success**	NFRs Accessibility and Configuration were found in both the associated Figure/image (NFRM) and the requirement sentence.
5.2 This virtual workspace allows authorized users to provide core information about the Call, like its name, description, estimated value, etc., and provides the functionality for uploading documents, like Notices, Contract Documents, Additional Documents, etc. Fig 2-3-01 Creation for a Call for Tender Procurement Officer Connect to the eProcurement System Create a new Call for Tenders workspace	workspace, authorized, information, name, functionality, documents, additional, eProcurement System, connect, create	Security	Auditability, Documentation, Security	Accessibility (AC), Auditability (AU), Availability (AV), Configuration (CN), Documentation (DO), Interoperability (IN), Performance (PS), Security (SE), Usability (US), User Interface (UI), Legal (LG)	**Success**	NFR Accessibility was found in both the associated Figure/image (NFRM) and requirement sentence. NFR configuration was found on the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
5.4 A Tender workspace needs to be well integrated with the User authorization of the system (Functional Req. 4: "User authorization"), as information stored in a Tender workspace should be accessed and/or manipulated by authorized users only. Fig 2-3-01 Creation for a Call for Tender Procurement Officer Connect to the eProcurement System Create a new Call for Tenders workspace	workspace, user, authorization, functional, information, stored, accessed, authorized, eProcurement System, connect, create	Accessibility, Security	Accessibility, Documentation, Security, Usability	Accessibility (AC), Availability (AV), Configuration (CN), Documentation (DO), Interoperability (IN) Performance (PS), Scalability (SC), Security (SE), Usability (US), User Interface (UI)	**Success**	NFR Accessibility was found in the associated Figure/image (NFRM) and requirement sentence. NFR Configuration was found in the associated Figure/image (NFRM).
6.1 Procurement Officers may be assisted in creating a PIN by using an application for the preparation of the Notice to be published in the Official Journal. Fig 2-3-02 Preparation and Publication of a Prior Information Notice (PIN), Procurement Officer - Create/Edit/Update PIN - Dispatch PIN to OJEU for publication - Dispatch PIN to national	officers, application, preparation, published, edit, publication, eProcurement System, publish, message, publication	NONE	Confidentiality, Compliance, Legal	Accessibility (AC), Auditability (AU), Confidentiality (CO), Documentation (DO), Efficiency (EF), Legal (LG), Reliability (RE)	**Partial Success**	The baseline did not contain any NFRs therefore this was a flagged partial success. The CEP methodology found several NFRs. NFRs Accessibility and Confidentiality were both found in the associated Figure/image (NFRM) and requirement sentence. NFRs Auditability, Documentation and Legal were found in the associated

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
notification board(s) (OPTIONAL) OJEU - Sent acknowledgement to eProcurement system confirming dispatch date of the PIN - Publish PIN and dispatch message to eProcurement system to confirm date of publication						Figure/image (NFRM).
7.1 The new Public Procurement Directives require contracting authorities to use the CPV to advertise their procurement needs. Fig 2-3-02 Preparation and Publication of a Prior Information Notice (PIN), Procurement Officer - Create/Edit/Update PIN - Dispatch PIN to OJEU for publication - Dispatch PIN to national notification board(s) (OPTIONAL) OJEU - Sent acknowledgement to eProcurement system confirming dispatch date of the PIN - Publish PIN and dispatch message to eProcurement system to confirm date of publication	public, contracting, authorities, use, procurement, edit, publication, eProcurement System, publish, message, publication	Usability	Auditability, Availability, Confidentiality, Documentation, Efficiency, Interoperability, Security, User Interface, Usability	Accessibility (AC), Auditability (AU), Availability (AV), Confidentiality (CO), Configuration (CN) Documentation (DO), Efficiency (EF), Legal (LG), Security (SE), Usability (US), User Interface (UI)	**Success**	NFRs Accessibility and Confidentiality were found in the associated Figure/image (NFRM) and requirement sentence. NFRs Auditability, Documentation and Legal was found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
7.3 The CPV exists in the 20 official languages of the EU. Fig 2-3-02 Preparation and Publication of a Prior Information Notice (PIN), Procurement Officer - Create/Edit/Update PIN - Dispatch PIN to OJEU for publication - Dispatch PIN to national notification board(s) (OPTIONAL) OJEU - Sent acknowledgement to eProcurement system confirming dispatch date of the PIN - Publish PIN and dispatch message to eProcurement system to confirm date of publication	official, languages, edit, publication, eProcurement System, publish, message, publication	Multilingual	Compliance, Legal, Multilingual	Accessibility (AC), Auditability (AU), Compliance (CE), Confidentiality (CO), Documentation (DO), Legal (LG), Multilingual (ML)	**Success**	NFRs Accessibility, Auditability, Confidentiality, Documentation, and Legal were found in the associated Figure/images (NFRM).
7.4 Thanks to this classification, Economic Operators can easily identify the goods/services/works a contracting authority wishes to procure, irrespective of the language of the PIN and to perform specific searches on the TED database. Fig 2-3-02 Preparation and Publication of a	easily, identify, goods, services, works, contracting, language, perform, database, edit, publication, eProcurement System, publish, message, publication	Usability	Multilingual, Performance, Reliability, Security	Accessibility (AC), Availability (AV), Auditability (AU), Confidentiality (CO), Documentation (DO), Interoperability (IN), Legal (LG), Multilingual (ML), Performance (PS), Reliability (RE), Scalability	**Success**	NFR Accessibility was found in the associated Figure/image (NFRM). NFRs Auditability, Confidentiality, Documentation and Legal were found both in the associated Figure/image (NFRM) and the requirement sentence.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
Prior Information Notice (PIN), Procurement Officer - Create/Edit/Update PIN - Dispatch PIN to OJEU for publication - Dispatch PIN to national notification board(s) (OPTIONAL) OJEU - Sent acknowledgement to eProcurement system confirming dispatch date of the PIN - Publish PIN and dispatch message to eProcurement system to confirm date of publication				(SC), Security (SE), Usability (US)		
7.5 An eProcurement system can prompt Procurement Officers to make use of the CPV classification standard when creating a PIN. Fig 2-3-02 Preparation and Publication of a Prior Information Notice (PIN), Procurement Officer - Create/Edit/Update PIN - Dispatch PIN to OJEU for publication - Dispatch PIN to national notification board(s)	system, officers, make, use, standard, edit, publication, eProcurement System, publish, message, publication	Usability, User Interface	Accuracy, Compliance, Configuration, User Interface, Usability	Accessibility (AC), Auditability (AU), Availability (AV), Accuracy (AR), Configuration (CN), Compliance (CE), Confidentiality (CO), Documentation (DO), Interoperability (IN), Legal (LG), Scalability (SC), Usability (US), User Interface (UI)	**Success**	NFR Accessibility were found both in the associated Figure/image (NFRM) and requirement sentence. NFRs Auditability, Confidentiality, Documentation, Legal were found in the associated Figure/image.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
(OPTIONAL) OJEU - Sent acknowledgement to eProcurement system confirming dispatch date of the PIN - Publish PIN and dispatch message to eProcurement system to confirm date of publication						
8.1 Once the PIN is created, Procurement Officers can be assisted to dispatch an appropriate electronic message to the OJEU, containing all information of the PIN, to request for its publication. Fig 2-3-02 Preparation and Publication of a Prior Information Notice (PIN), Procurement Officer - Create/Edit/Update PIN - Dispatch PIN to OJEU for publication - Dispatch PIN to national notification board(s) (OPTIONAL) OJEU - Sent acknowledgement to eProcurement system confirming dispatch date of the PIN - Publish PIN and	created, officers, appropriate, message, information, publication, edit, publication, eProcurement System, publish, message, publication	NONE	Configurability, Confidentiality, Documentation	Accessibility (AC), Auditability (AU), Confidentiality (CO), Configuration (CN), Documentation (DO), Legal (LG), Reliability (RE)	**Partial Success**	The baseline did not contain any NFRs therefore this was a flagged partial success. The CEP methodology found several NFRs. NFR Auditability was found in the associated Figure/image (NFRM). NFRs Accessibility, Confidentiality, Documentation, and Legal were found both in the requirement sentence and associated Figure/mage (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
dispatch message to eProcurement system to confirm date of publication						
9.3 Similarly to the CPV, the inclusion of NUTS codes in a Contract Notice allows Economic Operators to easily identify the locations to which they will be required to deliver the goods/services/works of the contract irrespective of the language of the Contract Notice. Fig 2-3, 03a. Preparation of Contract Notice & Contract Documents Procurement Officer - Create/Edit/Update Contract Notice - Create/Edit/Update Contract Documents - Upload Contract Documents to system eProcurement	inclusion, contract, easily, identify, goods, services, works, language, edit, contract, documents, eProcurment System, inaccessible, public, published, secure	Multilingual, Usability	Auditability, Documentation, Security, Usability	Auditability (AU), Accessibility (AC), Availability (AV), Configuration (CN), Documentation (DO), Legal (LG), Multilingual (ML), Scalability (SC), Security (SE), Usability (US)	**Success**	Auditability, Availability, and Documentation were found both in the associated Figure/image (NFRM) and requirement sentence. NFRs Accessibility and Configuration were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
system - Provide secure storage for Contract Documents, which remain inaccessible to the general public until Contract Notice is published on OJEU						
9.4 An eProcurement system can prompt Procurement Officers to make use of the NUTS classification standard when creating a Contract Notice. Fig 2-3, 03a. Preparation of Contract Notice & Contract Documents, Procurement Officer - Create/Edit/Update Contract Notice - Create/Edit/Update Contract Documents - Upload Contract Documents to system eProcurement system - Provide secure storage for Contract Documents, which remain inaccessible to the general public until	system, officers, make, use, standard, contract, edit, contract, documents, eProcurment System, inaccessible, public, published, secure	Usability, User Interface	Auditability, Availability, Compliance, Configuration, Documentation, User Interface	Accessibility (AC), Availability (AV), Auditability (AU), Configuration (CO), Confidentiality (CN), Documentation (DO), Interoperability (IN), Scalability (SC), Security (SE), Usability (US) User Interface (UI)	**Success**	NFRs Accessibility, Auditability, and Configuration were found both in the associated Figure/image (NFRM) and requirement sentence. NFRs Availability, Confidentiality, Documentation, and Security were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
Contract Notice is published on OJEU						
10.3 In both cases, the evaluation model to be used must be specified in the Contract Notice or the Contract Documents. Fig 2-3, 03a. Preparation of Contract Notice & Contract Documents, Procurement Officer - Create/Edit/Update Contract Notice - Create/Edit/Update Contract Documents - Upload Contract Documents to system eProcurement system - Provide secure storage for Contract Documents, which remain inaccessible to the general public until Contract Notice is published on OJEU	used, contract, documents, edit, contract, documents, eProcurment System, inaccessible, public, published, secure	Documentation	Accessibility, Auditability, Compliance, Documentation	Accessibility (AC), Auditability (AU), Configuration (CO), Confidentiality (CN), Documentation (DO), Security (SE), Usability (US), User Interface (UI)	**Success**	NFRs Accessibility, Configuration, Confidentiality, Documentation, and Security are from associated Figure/images (NFRM). NFR Auditability is from both the associated Figure/image (NFRM) and requirement sentence.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
10.5 If the evaluation is based on the Most Economically Advantageous Tender, contracting authorities are required to define the exact evaluation criteria to be used, as well as to indicate their weightings either in the Contract Notice or in the Contract Documents. Fig 2-3, 03a. Preparation of Contract Notice & Contract Documents, Procurement Officer - Create/Edit/Update Contract Notice - Create/Edit/Update Contract Documents - Upload Contract Documents to system eProcurement system - Provide secure storage for Contract Documents, which remain inaccessible to the general public until Contract Notice is published on OJEU	contracting, authorities, required, define, exact, used, contract, documents, edit, contract, documents, eProcurment System, inaccessible, public, published, secure	Documentation	Auditability, Compliance, Documentation	Accuracy (AR), Accessibility (AC), Auditability (AU), Confidentiality (CO), Configuration (CN), Documentation (DO), Security (SE), Usability (US), User Interface (UI)	**Success**	NFRs Auditability, Configuration, and Documentation were found in the associated Figure/image (NFRM) and requirement sentence. NFRs Accessibility, Confidentiality, and Security were found in the associated Figure/images (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
10.6 In the latter case this reference to the Contract Documents must be stated in the Contract Notice. Fig 2-3, 03a. Preparation of Contract Notice & Contract Documents, Procurement Officer - Create/Edit/Update Contract Notice - Create/Edit/Update Contract Documents - Upload Contract Documents to system eProcurement system - Provide secure storage for Contract Documents, which remain inaccessible to the general public until Contract Notice is published on OJEU	contract, documents, edit, contract, documents, eProcurment System, inaccessible, public, published, secure	Documentation	Auditability, Compliance	Accessibility (AC), Auditability (AU), Availability (AV), Configuration (CN), Confidentiality (CO), Documentation (DO), Security (SE)	**Success**	NFRs Auditability, Documentation were found both in the associated Figure/image (NFRM) and requirement sentence. NFRs Accessibility, Availability, Configuration, Confidentiality and Security were found in the associated Figure/image (NFRM).
10.8 When the evaluation parameters of a Call based on MEAT can be established with precision, a contracting authority may decide that the award of the contract shall be preceded by an electronic auction. Fig 2-3, 03a. Preparation of Contract Notice & Contract Documents,	established, precision, contracting, contract, edit, contract, documents, eProcurment System, inaccessible, public, published, secure	Accuracy	Accuracy, Auditability, Legal	Accuracy (AR), Accessibility (AC), Auditability (AU), Availability (AV), Confidentiality (CO), Configuration (CN), Documentation (DO), Legal (LG), Security (SE)	**Success**	NFRs Accessibility and Auditability were found both in the associated Figure/images (NFRM) and requirement sentence. NFRs Availability, Confidentiality, Configuration, Documentation and Legal were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
Procurement Officer - Create/Edit/Update Contract Notice - Create/Edit/Update Contract Documents - Upload Contract Documents to system eProcurement system - Provide secure storage for Contract Documents, which remain inaccessible to the general public until Contract Notice is published on OJEU						
10.9 The intention of using an electronic auction as part of the awarding procedure needs to be mentioned in the Contract Notice of the Call. Fig 2-3, 03a. Preparation of Contract Notice & Contract Documents, Procurement Officer - Create/Edit/Update Contract Notice - Create/Edit/Update Contract Documents - Upload Contract Documents to system eProcurement system - Provide secure storage for Contract Documents, which	contract, edit, contract, documents, eProcurment System, inaccessible, public, published, secure	Documentation	Documentation	Auditability (AU), Availability (AV), Accessibility (AC), Confidentiality (CO), Configuration (CN), Documentation (DO), Security (SE)	**Success**	NFRs Auditability and Documentation were found in the associated Figure/image (NFRM) and requirement sentence. NFRs Availability, Confidentiality, Configuration, and Security were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
remain inaccessible to the general public until Contract Notice is published on OJEU						
10.10 To accommodate the above, an eProcurement system can prompt Procurement Officers to define the evaluation mechanism to be used, as well as automatically include the details of the evaluation mechanism in the Contract Notice and/or Contract Documents. Fig 2-3, 03a. Preparation of Contract Notice & Contract Documents, Procurement Officer - Create/Edit/Update Contract Notice - Create/Edit/Update Contract Documents - Upload Contract Documents to system eProcurement	system, officer, define, used, contract, documents, eProcurment System, inaccessible, public, published, secure	Documentation	Accessibility, Auditability, Compliance, Documentation, Interoperability, User Interface	Availability (AV), Accessibility (AC), Auditability (AU), Confidentiality (CO), Configuration (CN), Documentation (DO), Usability (US) User Interface (UI), Security (SE)	**Success**	NFRs Accessibility and Documentation were found both in the associated Figure/image (NFRM) and requirement sentence. NFRs Auditability, Availability, Configuration, Confidentiality, Documentation, and Security were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
system - Provide secure storage for Contract Documents, which remain inaccessible to the general public until Contract Notice is published on OJEU						
11.1 Once the Contract Notice of a Call for Tenders is completed, it needs to be made publicly available. Fig 2-3,03b Publication of Contract Notice & Contract Documents Procurement Officer - Dispatch Contract Notice to OJEU for publication - Dispatch Contract Notice to national notification board(s) (OPTIONAL) OJEU - Sent acknowledgement to eProcurement system confirming dispatch date of the Contract Notice - Publish Contract Notice and dispatch message to eProcurement system to confirm date of publication (if sent electronically, Contract Notice is	contract, completed, publicly, available, contract, publication, eProcurement system, days, publish, message, longer, unrestricted, full, public, published, documents	Availability	Auditability, Availability	Accessibility (AC), Auditability (AU), Availability (AV), Confidentiality (CO), Documentation (DO), Interoperability (IN), Legal (LG), Performance (PS), Scalability (SC), Usability (US),	**Success**	NFRs Accessibility, Auditability, Availability, and Confidentiality were both from associated Figure/image (NFRM) and requirement sentence. NFRs Documentation, Legal and Performance were from associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
published on OJEU no longer than 5 days after its dispatch date) eProcurement system - As soon as the Contract Notice is published, the eProcurement system provides to the general public unrestricted and full direct access to Contract Documents						
12.3 An eProcurement system can provide a functionality for modeling these internal workflows which can assist Procurement Officers to comply with the internal workflows of their contracting authority in a more efficient and time-effective manner. Fig 2-3,03b Publication of Contract Notice & Contract Documents, Procurement Officer - Dispatch Contract Notice to OJEU for publication - Dispatch Contract Notice to national notification board(s) (OPTIONAL) OJEU - Sent acknowledgement to eProcurement system confirming	system, functionality, workflows, officers, comply, contracting, efficient, time-effective, contract, publication, eProcurement system, days, publish, message, longer, unrestricted, full, public, published, documents	Compliance, Efficiency, Performance, User Interface	Auditability, Availability, Compliance, Configurability, Documentation, Efficiency, Interoperability, Performance, Reliability, User Interface	Accessibility (AC), Accuracy (AR), Auditability (AU), Availability (AV), Compliance (CE), Confidentiality (CO), Configurability (CN), Documentation (DO), Efficiency (EF), Legal (LG), Performance (PS), Reliability (RE), Scalability (SC), Usability (US), User Interface (UI)	**Success**	NFRs Accessibility, Auditability, and Performance were from both the associated Figure/image (NFRM) and requirement text. NFRs Availability, Confidentiality, Documentation and Performance were from requirement Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
dispatch date of the Contract Notice - Publish Contract Notice and dispatch message to eProcurement system to confirm date of publication (if sent electronically, Contract Notice is published on OJEU no longer than 5 days after its dispatch date) eProcurement system - As soon as the Contract Notice is published, the eProcurement system provides to the general public unrestricted and full direct access to Contract Documents						
12.4 While a document is in "not published" state, it is accessible only to the Procurement Officers associated with it. Fig 2-3,03b Publication of Contract Notice & Contract Documents, Procurement Officer - Dispatch Contract Notice to OJEU for publication - Dispatch Contract Notice to national notification board(s) (OPTIONAL) OJEU - Sent acknowledgement to eProcurement system confirming	document, published, accessible, contract, publication, eProcurement system, days, publish, message, longer, unrestricted, full, public, published, documents	Accessibility, Security	Accessibility, Availability, Documentation, Legal, Security	Auditability (AU), Accessibility (AC), Availability (AV), Confidentiality (CO), Documentation (DO), Legal (LG), Performance (PS), Security (SE),	**Success**	NFRs Auditability, Accessibility, Availability, Confidentiality, and Documentation were from both associated Figure/image (NFRM) and requirement sentence. NFRs Performance and Legal were from associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
dispatch date of the Contract Notice - Publish Contract Notice and dispatch message to eProcurement system to confirm date of publication (if sent electronically, Contract Notice is published on OJEU no longer than 5 days after its dispatch date) eProcurement system - As soon as the Contract Notice is published, the eProcurement system provides to the general public unrestricted and full direct access to Contract Documents						
12.5 The finalized Contract Documents approved by the contracting authority shall not be made publicly available until the Contract Notice is dispatched to the OJEU for publication. Fig 2-3,03b Publication of Contract Notice & Contract Documents, Procurement Officer - Dispatch Contract Notice to OJEU for publication - Dispatch Contract Notice to national notification board(s) (OPTIONAL)	finalized, contract, documents, contracting, authority, publicly, available, contract, publication, contract, publication, eProcurement system, days, publish, message, longer, unrestricted, full, public, published, documents	Availability	Availability, Accessibility, Interoperability, Usability	Accessibility (AC), Auditability (AU), Availability (AV), Confidentiality (CO), Documentation (DO), Interoperability (IN), Legal (LG), Performance (PS), Scalability (SC), Security (SE), Usability (US)	**Success**	NFRs Auditability, Availability, Confidentiality, Documentation, and Legal were both in the associated Figure/image (NFRM) and requirement sentence. NFRs Performance was in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
OJEU - Sent acknowledgement to eProcurement system confirming dispatch date of the Contract Notice - Publish Contract Notice and dispatch message to eProcurement system to confirm date of publication (if sent electronically, Contract Notice is published on OJEU no longer than 5 days after its dispatch date) eProcurement system - As soon as the Contract Notice is published, the eProcurement system provides to the general public unrestricted and full direct access to Contract Documents						
12.6 Once the Contract Notice has been published by the OJEU, it may also be published at the national level, and all interested parties should be given unrestricted and full access to the Contract Documents. Fig 2-3,03b Publication of Contract Notice & Contract Documents, Procurement Officer - Dispatch Contract Notice to OJEU for publication	contract, published, parties, unrestricted, full access, documents, contract, publication, eProcurement system, days, publish, message, longer, unrestricted, full, public, published, documents	Accessibility, Compliance, Security	Accessibility, Auditability, Documentation, Security	Accessibility (AC), Auditability (AU), Availability (AV), Confidentiality (CO), Configuration (CN), Documentation (DO), Legal (LG), Performance (PS), Security (SE)	**Partial Success**	NFR Compliance was missed from the baseline. Therefore, this was flagged partial success. NFRs Accessibility, Auditability, Availability, Confidentiality and Documentation were from both associated Figure/images (NFRM) and requirement sentences. NFR Performance was from associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
- Dispatch Contract Notice to national notification board(s) (OPTIONAL) OJEU - Sent acknowledgement to eProcurement system confirming dispatch date of the Contract Notice - Publish Contract Notice and dispatch message to eProcurement system to confirm date of publication (if sent electronically, Contract Notice is published on OJEU no longer than 5 days after its dispatch date) eProcurement system - As soon as the Contract Notice is published, the eProcurement system provides to the general public unrestricted and full direct access to Contract Documents						
13.1 At this step, the Call for Tender is considered "open", as it is publicly available. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications	open, publicly, available, add, contract, submit, documents, submission, eProcurement System	Availability	Accessibility, Availability, Interoperability, Usability	Accessibility (AC), Auditability (AU), Availability (AV), Compliance (CE), Confidentiality (CO), Configuration (CN), Documentation (DO), Interoperability (IN), Scalability (SC), Usability (US)	**Success**	NFRs Accessibility and Auditability were both from the associated Figure/image (NFRM) and requirement sentence. NFRs Compliance, Configuration, and Documentation were from the associated Figure/ image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
(Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement system - Record the exact time and date of the receipt of the Tender - Store Tender in a protected area (Tender locked)						
13.2 An eProcurement system may provide a search Calls mechanism to any interested party, so that it can search through all publicly "open" Calls and locate interesting ones, for which s/he might wish to participate. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement system	system, publicly, open, add, contract, submit, documents, submission, eProcurement System	NONE	Configuration, User Interface	Accessibility (AC), Auditability (AU), Availability (AV) Compliance (CE), Confidentiality (CO) Configuration (CN), Documentation (DO), Scalability (SC)	**Partial Success**	The baseline did not contain any NFRs therefore this was flagged partial successful. The CEP methodology was able to find several NFRs. Accessibility, Auditability, Compliance, Configuration, and Documentation were found in associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
- Record the exact time and date of the receipt of the Tender - Store Tender in a protected area (Tender locked)						
14.1 Any interested party should be provided with the functionality to access all publicly available information of a Call, comprising PIN, Contract Notice, Contract Documents, Additional Documents, etc. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement system - Record the exact time and date of	functionality, access, publicly, available, information, contract, documents, additional, add, contract, submit, documents, submission, eProcurement System	Accessibility, Availability	Accessibility, Configurability, Documentation, Interoperability, User Interface	Accessibility (AC), Auditability (AU), Availability (AV), Compliance (CE), Confidentiality (CO), Configuration (CN), Documentation (DO), Interoperability (IN), Performance (PS), Scalability (SC), Usability (US)	**Success**	NFRs Accessibility and Auditability are both from the associated Figure/image (NFRM) and requirement sentence. NFRs Compliance, Configuration and Documentation were from the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
the receipt of the Tender - Store Tender in a protected area (Tender locked)						
14.2 An eProcurement system may require interested parties to provide some personal information, so that they are notified if and when new information about the Call is published (Additional Documents, new Contract Documents, etc.) Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement	system, parties, personal information, published, additional, documents, contracts,	Security	Auditability, Confidentiality, Documentation, Interoperability	Accessibility (AC), Auditability (AU), Availability (AV), Compliance (CE), Confidentiality (CO), Configuration (CN), Documentation (DO), Scalability (SC), Security (SE)	**Success**	NFRs Accessibility Auditability, Configuration and Documentation were found both in associated Figure/image (NFRM) and requirement sentence. NFR Compliance was found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
system - Record the exact time and date of the receipt of the Tender - Store Tender in a protected area (Tender locked)						
14.3 The eProcurement system should ensure that full and unrestricted access to all publicly available information is provided equally to all interested parties. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement system - Record the exact time and date of the receipt of the Tender	system, unrestricted, access, publicly, available, information, equally, parties, add, contract, submit, documents, submission, eProcurement System	Accessibility, Availability	Accessibility, Availability, Configuration, Documentation, Interoperability	Accessibility (AC), Auditability (AU), Availability (AV), Compliance (CE), Confidentiality (CO) Configuration (CN), Documentation (DO), Interoperability (IN), Scalability (SC), Usability (US), User Interface (UI)	**Success**	NFRs Accessibility, Auditability and Configuration were both in associated Figure/image (NFRM) and requirement sentence. NFR Compliance was in associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
- Store Tender in a protected area (Tender locked)						
15.3 All requests for Additional Documents and the Additional Documents themselves need to be made publicly available to all interested parties, and in due time before the end of the time-limit for submission to ensure nondiscrimination and equal treatment of Economic Operators. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender	Additional, Documents, publicly, available, parties, time, time-limit, nondiscrimination, equal, add, contract, submit, documents, submission, eProcurement System	Availability, Documentation, Performance	Accessibility, Availability, Documentation, Interoperability, Performance, Reliability, Usability	Accessibility (AC), Accuracy (AR), Auditability (AU), Availability (AV), Compliance (CE), Confidentiality (CO), Configuration (CN), Documentation (DO), Interoperability (IN), Performance (PS), Reliability (RE) Scalability (SC), Usability (US)	**Success**	NFRs Accessibility, Auditability, Compliance, Configuration, and Documentation were found both in associated Figure/image (NFRM) and requirement sentence.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
submission deadline eProcurement system - Record the exact time and date of the receipt of the Tender - Store Tender in a protected area (Tender locked)						
15.4 The identities of Economic Operators posting requests for Additional Documents should not be disclosed, neither to the general public nor to other Economic Operators. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement system - Record the exact time and date of	identities, additional, documents, disclosed, public, add, contract, submit, documents, submission, eProcurement System	Confidentiality	Confidentiality	Accessibility (AC), Auditability (AU), Availability (AV) Compliance (CE), Confidentiality (CO), Configuration (CN), Documentation (DO)	**Success**	NFRs Accessibility, Auditability, Configuration and Documentation were both in associated Figure/image (NFRM) and requirement sentence.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
the receipt of the Tender - Store Tender in a protected area (Tender locked)						
16.3 As described in Functional Requirement 15, such a notification mechanism must ensure equal treatment of all Economic Operators and operate within the time limit for submission of tenders. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement system	described, functional, equal, operate, time, limit, submission, add, contract, submit, documents, submission, eProcurement System	Compliance, Performance	Compliance, Performance, Reliability	Accessibility (AC), Auditability (AU), Compliance (CE), Configuration (CN), Documentation (DO), Interoperability (IN), Performance (PS), Reliability (RE), Scalability (SC) Usability (US) Accuracy (AR)	**Success**	NFRs Compliance and Documentation are both in associated Figure/image (NFRM) and requirement sentence. NFRs Accessibility, Auditability and Configuration were in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
- Record the exact time and date of the receipt of the Tender - Store Tender in a protected area (Tender locked)						
17.1 Economic Operators interested in a Call shall have the possibility to submit electronically the Tenders that they have prepared through generally available, nondiscriminatory, and interoperable means of communication. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline	operators, submit, prepared, available, interoperable, communication, add, contract, submit, documents, submission, eProcurement System	Availability, Compliance, Interoperability	Accessibility, Availability, Compliance, Interoperability, Usability	Accessibility (AC), Auditability (AU), Availability (AV), Compliance (CE), Configuration (CN), Documentation (DO), Interoperability (IN), Scalability (SC), Usability (US)	**Success**	NFRs Accessibility, Auditability, Compliance, and Documentation were both in associated Figure/image and requirement sentence. NFR Configuration was in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
eProcurement system - Record the exact time and date of the receipt of the Tender - Store Tender in a protected area (Tender locked)						
17.2 Contracting authorities examine whether the Tenders received are compliant with the requirements defined in the Tender specifications. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement system - Record the exact time and date of the receipt of the Tender - Store Tender in a protected area	contracting, authorities, compliant, requirement, defined, add, contract, submit, documents, submission, eProcurement System	Compliance	Compliance, Documentation	Accessibility (AC), Auditability (AU), Compliance (CE), Configuration (CN), Documentation (DO)	**Success**	NFRs Auditability, Compliance, Configuration, and Documentation were found both in associated Figure/image (NFRM) and requirement sentence. NFRs Accessibility was found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
(Tender locked)						
17.4 The eProcurement system must ensure that all Tenders for a Call are stored in a secure environment and cannot be accessed until authorized Procurement Officers authorize their opening following the four-eye principle. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement	system, stored, secure, accessed, authorized, officer, authorize, opening, add, contract, submit, documents, submission, eProcurement System	Accessibility, Security	Accessibility, Availability, Configurability, Documentation, Interoperability, Legal, Security, User Interface	Accessibility (AC) Auditability (AU) – image Availability (AV) Compliance (CE) , Configuration (CN), Documentation (DO), Interoperability Legal (LG), Security (SE), Scalability (SC)	**Success**	NFR Documentation was found both in the associated Figure/image (NFRM) and requirement sentence. NFRs Auditability, Compliance and Configuration were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
system - Record the exact time and date of the receipt of the Tender - Store Tender in a protected area (Tender locked)						
17.5 If access prohibition is infringed, it should be reasonably ensured that the infringement is clearly detectable. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement system - Record the exact time and date of the receipt of the Tender - Store Tender in a protected area	access, infringed, detectable, add, contract, submit, documents, submission, eProcurement System	Accessibility, Auditability	Accessibility, Compliance, Security	Accessibility (AC), Auditability (AU), Compliance (CE), Configuration (CN), Documentation (DO), Scalability (SC), Security (SE)	**Success**	NFRs Accessibility and Auditability were from both the associated Figure/image (NFRM) and requirement sentence. NFRs Compliance, Configuration and Documentation were from the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
(Tender locked)						
17.6 Official time-stamping facility can ensure the exact submission date and time of a Tender is recorded, guaranteeing there are no misconceptions about the submission time of a Tender. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement system - Record the exact	Official, time-stamping, exact, submission, time, submission time, add, contract, submit, documents, submission, eProcurement System	Accuracy, Performance, Reliability	Accuracy, Compliance, Legal, Performance, Reliability	Accuracy (AR), Accessibility (AC), Auditability (AU), Compliance (CE), Configuration (CN), Documentation (DO), Performance (PS), Reliability (RE), Legal (LG)	**Success**	NFRs Accessibility, Auditability, Configuration, and Documentation were from the associated Figure/image (NFRM). NFR Compliance was from both the associated Figure/image (NFRM) and requirement sentence.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
time and date of the receipt of the Tender - Store Tender in a protected area (Tender locked)						
17.7 Security arrangements for all data transmitted to/from the eProcurement system and stored in the eProcurement system should ensure the integrity of the Tenders, as well as, the authenticity of the Economic Operators that have submitted them. Figure 2-3,06 06. Submit a Tender Invited Tenderer - Select the Call for Tenders for which the Tenderer has been invited to submit a Tender, and visualize/download specifications (Contract Notice, Contract Documents, Additional Documents) - Submit a Tender prior to the Tender submission deadline eProcurement	security, transmitted, system, stored, integrity, authenticity, submitted, add, contract, submit, documents, submission, eProcurement System	Security	Availability, Configuration, Confidentiality, Documentation, Interoperability, Security, User Interface	Accessibility (AC), Availability (AV), Auditability (AU), Compliance (CE), Configuration (CN), Documentation (DO), Security (SE), Scalability (SC), User Interface (UI)	**Success**	NFRs Auditability, Compliance and Configuration were found in the associated Figure/image (NFRM). NFR Documentation were found in the associated Figure/image (NFRM) and requirement sentence.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
system - Record the exact time and date of the receipt of the Tender - Store Tender in a protected area (Tender locked)						
18.1 An eProcurement system needs to ensure that access to Tenders cannot be obtained by anyone, until authorized procurement officers proceed to the opening of Tenders following the four-eye principle. Fig 2-3-07 07. Open and evaluate Tenders Procurement Officer - Open Tenders by simultaneous action of at least two authorized procurement officers (unlocking) - Evaluate and rank Tenders based on the predefined evaluation method (lowest price or MEAT) eProcurement system - Report Tender integrity and authenticity. Report	system, access, obtained, authorized, officers, opening, officer, procurement, authorized, simultaneous, eProcurement System, integrity, report, authenticity, confidentiality, infringements, violation, report	Accessibility, Security	Accessibility, Availability, Configurability, Documentation, Interoperability, Security, User Interface	Accessibility (AC), Availability (AV), Compliance (CE), Confidentiality (CO), Configuration (CN), Legal (LG), Performance (PS), Scalability (SC), Security (SE)	**Success**	NFRs Accessibility and Confidentiality were in both associated Figure/image (NFRM) and requirement sentence. NFRs Availability, Configuration, and Performance were in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
data/locking infringements and violation of any confidentiality rules						
18.2 To “open” or “unlock” Tenders, two or more authorized procurement officers need to perform simultaneous actions. Fig 2-3-07 07. Open and evaluate Tenders Procurement Officer - Open Tenders by simultaneous action of at least two authorized procurement officers (unlocking) - Evaluate and rank Tenders based on the predefined evaluation method (lowest price or MEAT) eProcurement system - Report Tender integrity and authenticity. Report data/locking infringements and violation of any confidentiality rules	open, authorized, officer, perform, simultaneous, officer, procurement, authorized, simultaneous, eProcurement System, integrity, report, authenticity, confidentiality, infringements, violation, report	Compliance, Performance	Efficiency, Performance, Security	Accessibility (AC), Availability (AV), Compliance (CE), Confidentiality (CO), Configuration (CN), Efficiency (EF), Legal (LG), Performance (PS), Scalability (SC), Security (SE)	**Partial Success**	This was flagged partial success since NFR Compliance was identified from the associated Figure/image (NFRM) only. NFRs Legal, Performance and Security were both in the image and requirement sentence. NFRs Availability, Compliance, Confidentiality, and Configuration were in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
19.1 Once Tenders are opened they can only be accessed by authorized personnel, ensuring that the confidentiality of Tenders is not violated. Fig 2-3-07 07. Open and evaluate Tenders Procurement Officer - Open Tenders by simultaneous action of at least two authorized procurement officers (unlocking) - Evaluate and rank Tenders based on the predefined evaluation method (lowest price or MEAT) eProcurement system - Report Tender integrity and authenticity. Report data/locking infringements and violation of any confidentiality	opened, accessed, authorized, confidentiality, officer, procurement, authorized, simultaneous, eProcurement System, integrity, report, authenticity, confidentiality, infringements, violation, report	Confidentiality	Accessibility, Confidentiality, Legal, Security	Accessibility (AC), Availability (AV), Compliance (CE), Confidentiality (CN), Configuration (CO), Legal (LG), Performance (PS), Security (SE)	**Success**	NFRs Accessibility, Availability, Compliance, Configuration, and Performance were from the associated Figure/image (NFRM). NFRs Confidentiality, Legal, and Security were from both associated Figure/image (NFRM) and requirement sentence.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
rules						
20.2 Initially, all Tenders should be evaluated in order to ensure that participating Tenderers satisfy the Conditions for Participation stated in the Contract Notice or Contract Documents of the Call. Fig 2-3-07 07. Open and evaluate Tenders Procurement Officer - Open Tenders by simultaneous action of at least two authorized procurement officers (unlocking) - Evaluate and rank Tenders based on the predefined evaluation method (lowest price or MEAT) eProcurement system - Report Tender integrity and authenticity. Report data/locking	contract, documents, officer, procurement, authorized, simultaneous, eProcurement System, integrity, report, authenticity, confidentiality, infringements, violation, report	Compliance	Auditability, Compliance, Documentation	Accessibility (AC), Auditability (AU), Availability (AV), Confidentiality (CO), Compliance (CE), Configuration (CN), Documents (DO) Legal (LG), Performance (PS), Security (SE)	**Success**	NFRs Accessibility, Availability, Confidentiality, Configuration, Legal, Performance and Security were from the associated Figure/image (NFRM). NFRs Compliance was from both the associated Figure/image (NFRM) and requirement sentence.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
infringements and violation of any confidentiality rules						
21.1 Another requirement of the legislation is related to the capability of the contracting authority to prepare regulatory reports, which provide information on all aspects of the competition. Fig 2-3,09 09. Contract Award Procurement Officer - Create/Edit/Update Contract Award Notice - Dispatch Contract Award Notice to OJEU for publication - Dispatch Contract Award Notice to national notification board(s) (OPTIONAL) - Notify Tenderers on the award of the contract. Winning Tenderers are invited to finalise contract	legislation, capability, contracting, authority, prepare, reports, edit, contract, publication, eProcurement System, publish, message	Compliance, Legal	Confidentiality, Documentation, Interoperability, Legal	Accessibility (AC), Auditability (AU), Configuration (CN), Documentation (DO), Interoperability (IN), Legal (LG)	**Partial Success**	NFR compliance was missed from the baseline therefore this was flagged a partial success. NFRs Auditability and Legal were found both in associated Figure/image (NFRM) and the requirement sentence. NFRs Accessibility and Configurability were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
eProcurement system - Create regulatory reports, store all relevant data, and provide for archiving the Call for Tenders OJEU - Sent acknowledgement to eProcurement system confirming dispatch date of the Contract Award Notice - Publish Contract Award Notice and dispatch message to eProcurement system to confirm date of publication						
22.4 The identity of all Economic Operators involved must remain confidential. Fig 2-3,05 Short-listing Procurement Officer - Open proof documents by simultaneous action of at least two authorized procurement officers (unlocking) - Short-list at least 5 Economic Operators according to the predefined objective criteria (OPTIONAL) - Invite selected Economic Operators to submit a Tender - Create/Edit/Upload Contract Documents to the eProcurement system (allowing	remain, confidential, officer, procurement, open, documents, proof, authorized, simultaneous, short-list, predefined, operators, edit, eProcurement System, unrestricted, contract, full, documents, operator, integrity, report, documents, proof, authenticity, confidentiality ,infringements ,violation, confidentially , Short-listing	Confidentiality	Confidentiality, Security	Accessibility (AC), Availability (AV), Compliance (CE), Confidentiality (CO), Configuration (CN), Documentation (DO), Interoperability (IN), Legal (LG), Performance (PS), Security (SE)	**Success**	NFR Confidentiality was found both in the associated Figure/image (NFRM) and the requirement sentence. NFRs Accessibility, Availability, Compliance, Configuration, Documentation, Interoperability, Legal and Security were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
for unrestricted and full direct access to the selected Economic Operators) eProcurement system - Report proof documents integrity and authenticity. Report data/locking infringements and violation of any confidentiality rules						
23.2 Hence, authorized Procurement Officers may be provided with the possibility to produce DPS reports, not only reporting details of its establishment (i.e. when it was established, who created it, information of the Contract Notice, etc.), but also information about specific contracts procured within it (i.e. the list of tenderers admitted to the DPS, number of specific contracts procured through the DPS, etc.) Fig 2-6 Activity Diagram for Dynamic Purchasing System ,Establishment of DPS –DPS Reporting	authorized, officer, reporting, establishment, created, information, contract, list, user, prepare, documents, contract, establish	Confidentiality, Security	Auditability, Confidentiality, Documentation, Interoperability, Security, Legal	Accessibility (AC), Auditability (AU), Configuration (CN), Confidentiality (CO), Documentation (DO), Legal (LG), Security (SE), Usability (US), User Interface (UI)	**Success**	NFRs Auditability, Documentation and Legal were found both in the associated Figure/image (NFRM) and the requirement sentence. NFRs Usability and User Interface were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
User Login Prepare PIN (Optional) Prepare Contract Documents Dispatch Contract Notice to OJEU Establish DPS Workspace Prepare Contract Notice						
24.1 An eProcurement system can allow the creation of as many specific contract workspaces within the DPS workspace as required by the contracting authority. Fig 2-6 Activity Diagram for Dynamic Purchasing System, Dispatch Contract Notice to OJEU Visualize or Request Additional Documents for Specific Contract Open Tender after Tender submission deadline Dispatch Contract Award Notice to OJEU Provide Additional Documents for Specific Contract Receive and store Tenders before the Tender submission deadline	system, contract, workspace, contracting, add, documents, submission, store, compliance, submit, operator, time, period, days, submit	Scalability	Availability, Auditability, Configurability Documentation, Interoperability	Auditability (AU), Accuracy (AR), Accessibility (AC), Auditability (AU), Availability (AV), Compliance (CE), Documentation (DO), Interoperability (IN), Performance (PS), Scalability (SC)	**Success**	NFRs Auditability and Performance were both found in the associated Figure/image (NFRM) and requirement sentence.

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
Invite all Economic Operators admitted to the DPS to submit Tenders for the Specific Contract Note: The time period from the date the simplified Contract Notice was compliance EOs to submit tenders for the Specific Contract can be no less than 15 days						
24.4 It can permit Procurement Officers to store all contract specific information within the workspace, while all Tenders submitted for the specific contract can also be securely stored in this virtual area. Fig 2-6 Activity Diagram for Dynamic Purchasing System Dispatch Contract Notice to OJEU Visualize or Request Additional Documents for Specific Contract Open Tender after Tender submission deadline Dispatch Contract Award Notice to OJEU Provide Additional Documents for Specific Contract Receive and store Tenders before the Tender submission deadline	officer, store, contract, information, workspace, submit, contract, securely, stored, add, documents, submission, store, compliance, submit, operator, time, period, days, submit,	Security	Auditability, Confidentiality, Documentation, Security	Auditability (AU), Accessibility (AC), Accuracy (AR), Availability (AV), Compliance (CE), Documentation (DO), Interoperability (IN), Performance (PS), Security (SE), Usability (US)	**Success**	NFRs Accessibility, Auditability, Compliance, and Documentation were found in both associated Figure/image (NFRM) and requirement sentence. NFRs Auditability, Availability, Interoperability and Usability were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
Invite all Economic Operators admitted to the DPS to submit Tenders for the Specific Contract Note: The time period from the date the simplified Contract Notice was compliance EOs to submit tenders for the Specific Contract can be no less than 15 days						
24.5 Furthermore, an eProcurement system supporting DPS must ensure the confidentiality of all information stored within a specific contract workspace, for example with regard to authorized users of another specific contract. Fig 2-6 Activity Diagram for Dynamic Purchasing System Dispatch Contract Notice to OJEU Visualize or Request Additional Documents for Specific Contract Open Tender after Tender submission deadline Dispatch Contract Award Notice to OJEU Provide Additional Documents for Specific Contract Receive and store Tenders before the	system, supporting, confidentiality, information stored, contract, workspace, authorized, users, contract, add, documents, submission, store, compliance, submit, operator, time, period, days, submit,	Confidentiality, Security	Auditability, Availability, Confidentiality, Configurability, Documentation, Interoperability, Legal, Security, User Interface	Accessibility (AC), Accuracy (AR), Auditability (AU), Availability (AV), Compliance (CE), Confidentiality (CN), Documentation (DO), Interoperability (IN), Legal (LG), Multilingual (ML), Performance (PS), Security (SE), Scalability (SC) Usability (US), User Interface (UI),	**Success**	NFRs Auditability, Availability, and Documentation were found in both the associated Figure/image (NFRM) and requirement sentence. NFRs Accessibility, Accuracy, Compliance and Performance were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
Tender submission deadline Invite all Economic Operators admitted to the DPS to submit Tenders for the Specific Contract Note: The time period from the date the simplified Contract Notice was compliance EOs to submit tenders for the Specific Contract can be no less than 15 days						
25.3 An eProcurement system may assist contracting authorities in defining the format of an electronic catalogue. Fig 2-6 Activity Diagram for Dynamic Purchasing System Visualize or Request Additional Documents for Specific Contract User Login Visualize DPS public information (Notices, Contract Documents, Additional Documents) Provide Additional Documents for DPS	contracting, authorities, add, contract, documents, user, public, information,	Configuration	Availability, Configuration, Documentation, Interoperability, User Interface	Accessibility (AC), Availability (AV), Auditability (AU), Configuration (CN), Confidentiality (CO), Scalability (SC), Documentation (DO), User Interface (UI)	**Success**	NFR Auditability was found both in the associated Figure/image (NFRM) and requirement sentence. NFRs Accessibility, Availability, Confidentiality, Documentation and User Interface were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
25.4 Furthermore, the system may provide the necessary support for allowing Economic Operators to create their Indicative Tenders in the required format, and/or allow Procurement Officers to visualize eCatalogues in a user-friendly format. Fig 2-6 Activity Diagram for Dynamic Purchasing System Visualize or Request Additional Documents for Specific Contract User Login Visualize DPS public information (Notices, Contract Documents, Additional Documents) Provide Additional Documents for DPS	system, support, create, officers, eCatalogues, user-friendly, add, documents, submission, store, compliance, submit, operator, time, period, days, submit,	Usability, User Interface	Availability, Configurability, Documentation, Interoperability, Multilingual, Usability, User Interface	Accessibility (AC), Availability (AV), Auditability (AU), Configuration (CN), Confidentiality (CO), Documentation (DO), Multilingual (ML), Scalability (SC), Usability (US), User Interface (UI)	**Success**	NFRs Documentation, Usability, and User Interface were both found in the associated Figure/image (NFRM) and requirement sentence. NFRs Accessibility, Availability, and Auditability were found in the associated Figure/image (NFRM).
25.7 Nevertheless, the eCatalogue needs to conform to the specifications of the Call for Tender. Fig 2-6 Activity Diagram for Dynamic Purchasing System Visualize or Request Additional Documents for Specific Contract User Login	eCatalogue, conform, add, documents, submission, store, compliance, submit, operator, time, period, days, submit,	Compliance	Compliance	Accessibility (AC), Availability (AV), Auditability (AU), Compliance (CE), Confidentiality (CO), Documentation (DO), Usability (US), User Interface (UI)	**Success**	NFR Auditability was both in the associated Figure/image (NFRM) and requirement text. NFRs Accessibility, Availability, Confidentiality and Documentation were from the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
Visualize DPS public information (Notices, Contract Documents, Additional Documents) Provide Additional Documents for DPS						
26.2 This virtual workspace should only be accessible to authorized users; eAuction parameters should be established and fixed within it. Functional Requirement 26 eAuction workspace Figure 2-10 - Activity Diagram for eAuction Workspace Full initial evaluation following open, restricted or negotiated procedure, or procedure for a specific contract within a Framework Agreement or a Dynamic Purchasing System Insert full initial evaluation results in eAuction workspace	workspace, accessible, authorized users, established, restricted, contract, full, open, framework, information, display, predefined	Accessibility, Security	Accessibility, Availability, Legal, Security	Accessibility (AC), Accuracy (AR), Auditability (AU), Availability (AV), Confidentiality (CO), Documentation (DO), Interoperability (IN), Legal (LG), Performance (PS), Security (SE), Usability (US), User Interface (UI)	**Success**	NFRs Availability and User Interface were found in both the associated Figure/ image (NFRM) and requirement sentence. NFRs Accuracy, Auditability, Confidentiality, Documentation and Interoperability were found in the associated Figure/image (NFRM).

Req. ID sentence Fig. ID sentence	Keywords & Phrases	NORMAP (Baseline)	NERV on Base.	CEP on Base.	Results	Comment
Display anonymous ranking and other relevant, non-sensitive information Note: Repeat until eAuction is closed according to predefined parameters Award contract according to lowest price or MEAT, as set in Contract Notice FullInitialEvaluation						

Appendix M

Weight of Requirement based on NFR

Requirement	CEP	NERV	NORMAP	Weighted Sum Value
	0.33	0.33	0.33	
R 1.2	8	5	2	4.95
R 2.4	7	5	1	4.29
R 2.5	6	3	2	3.63
R 3.1	10	4	1	4.95
R 3.2	11	5	1	5.61
R 4.3	9	3	1	4.29
R 4.4	9	4	2	4.95
R 5.1	9	5	1	4.95
R 5.2	11	3	1	4.95
R 5.4	9	4	2	4.95
R 6.1	7	3	0	3.3
R 7.1	10	11	1	7.26
R 7.3	7	2	1	3.3
R 7.4	9	4	2	4.95
R 7.5	13	5	2	6.6
R 8.1	7	3	0	3.3
R 9.3	11	4	2	5.61
R 9.4	9	6	2	5.61

Requirement	CEP	NERV	NORMAP	Weighted
	0.33	0.33	0.33	Sum Value
R 10.3	9	4	1	4.62
R 10.5	9	3	1	4.29
R 10.6	7	3	1	3.63
R 10.8	9	3	1	3.63
R 10.9	7	1	1	2.97
R 10.10	10	6	1	5.61
R 11.1	9	2	2	4.29
R 12.3	16	12	4	10.56
R 12.4	7	5	2	4.62
R 12.5	10	4	1	4.95
R 12.6	9	4	3	5.28
R 13.1	10	4	1	4.95
R 13.2	8	2	0	3.3
R 14.1	11	5	2	5.94
R 14.2	9	4	1	4.62
R 14.3	12	5	2	6.27
R 15.3	13	8	3	7.92
R 15.4	7	1	1	2.97
R 16.3	11	3	2	5.28
R 17.1	9	5	3	5.61
R 17.2	5	2	1	2.64

Requirement	CEP	NERV	NORMAP	Weighted Sum Value
	0.33	0.33	0.33	
R 17.4	10	8	2	6.6
R 17.5	7	3	2	3.96
R 17.6	10	5	3	5.94
R 17.7	9	7	1	5.61
R 18.1	8	7	2	5.61
R 18.2	10	4	2	5.28
R 19.1	8	4	1	4.29
R 20.2	10	3	1	4.62
R 21.1	6	5	2	4.29
R 22.4	10	2	1	4.29
R 23.2	9	5	2	5.28
R 24.1	11	5	1	5.61
R 24.4	11	4	1	5.28
R 24.5	15	10	2	8.91
R 25.3	9	5	1	4.95
R 25.4	10	7	2	6.27
R 25.7	8	1	1	3.3
R 26.2	12	4	2	5.94

Appendix N

Priority Rank of Requirement based on NFR

Requirement	A	B	γ	Req. Rank
R 1.2	800	4.95	1	40
R 2.4	700	4.29	1	47
R 2.5	600	3.63	1	57
R 3.1	1000	4.95	1	23
R 3.2	1100	5.61	1	11
R 4.3	900	4.29	1	41
R 4.4	900	4.95	1	30
R 5.1	900	4.95	1	31
R 5.2	1100	4.95	1	18
R 5.4	900	4.95	1	32
R 6.1	700	3.3	1	54
R 7.1	1000	7.26	2	5
R 7.3	700	3.3	1	55
R 7.4	900	4.95	1	33
R 7.5	1300	6.6	2	4
R 8.1	700	3.3	1	56
R 9.3	1100	5.61	1	12
R 9.4	900	5.61	1	20
R 10.3	900	4.62	1	36

Requirement	A	B	γ	Req. Rank
R 10.5	900	4.29	1	42
R 10.6	700	3.63	1	53
R 10.8	900	3.63	1	45
R 10.9	700	2.97	2	37
R 10.10	1000	5.61	1	17
R 11.1	900	4.29	1	43
R 12.3	1600	10.56	5	1
R 12.4	700	4.62	1	46
R 12.5	1000	4.95	1	24
R 12.6	900	5.28	1	26
R 13.1	1000	4.95	1	25
R 13.2	800	3.3	1	49
R 14.1	1100	5.94	1	10
R 14.2	900	4.62	1	38
R 14.3	1200	6.27	1	7
R 15.3	1300	7.92	2	3
R 15.4	700	2.97	2	39
R 16.3	1100	5.28	1	15
R 17.1	900	5.61	1	21
R 17.2	500	2.64	2	50
R 17.4	1000	6.6	1	9
R 17.5	700	3.96	1	48

Requirement	A	B	γ	Req. Rank
R 17.6	1000	5.94	1	14
R 17.7	900	5.61	1	22
R 18.1	800	5.61	1	29
R 18.2	1000	5.28	1	19
R 19.1	800	4.29	1	44
R 20.2	1000	4.62	1	28
R 21.1	600	4.29	1	52
R 22.4	1000	4.29	1	35
R 23.2	900	5.28	1	27
R 24.1	1100	5.61	1	13
R 24.4	1100	5.28	1	16
R 24.5	1500	8.91	3	2
R 25.3	900	4.95	1	34
R 25.4	1000	6.27	2	6
R 25.7	800	3.3	1	51
R 26.2	1200	5.94	1	8

Appendix O

FR (Functional Requirement) for EU eProcurement System

FR 1: User Registration

This functional requirement allows for the user registration of new Procurement Officers and Tenderers/Economic Operators to the eProcurement system. The registration process must ensure the confidential transfer and storage of all personal information of users. Furthermore, mechanisms may be put in place for the validation of the information provided by new users of the system. Hence, the registration process may be performed in two phases. One phase can allow new users to apply for registration to the system, and another phase can allow authorised personnel to validate the submitted information and approve or reject a registration application.

FR 2: User Profiling

This functional requirement relates to the ability of the eProcurement system to store personal information of its registered users. Users can update their personal information if required. This personal information can be used for several other functionalities of the system, including reporting, automated notifications, etc. Also, each user is associated to a unique identifier, which can be used by the audit trailing facility of the system, in order to record all user activities, and to identify the initiator/actor of each activity. Moreover, user profiling can allow users to setup their preferences when using the system, in terms of how data is searched, displayed, etc.

FR 3: User Authentication

This functional requirement allows users to identify themselves to the eProcurement system. This is necessary for the system to display the appropriate data to users, as well as, to make available the appropriate activities to be executed according to a user's role in the system.

FR 4: User Authorization

Each user in the system is commonly associated with a certain role. As presented in more detail in section 5.2, users can undertake and perform different roles, like Call administrators, Tender opening staff, Tender evaluating staff, etc. User authorization can enable the eProcurement system to be aware of the role of a user. Depending on the user rights for each user, the system can control which activities a user can perform, as well as, what data a user should have access to.

FR 5: Tender workspace creation

When creating a Call for Tenders, the eProcurement system can make available to the Procurement Officers a virtual workspace for storing all Call-related information. This virtual workspace allows authorized users to provide core information about the Call, like its name, description, estimated value, etc., and provides the functionality for uploading documents, like Notices, Contract Documents, Additional Documents, etc.

Moreover, the Tender workspace can be used as the area for storing Tenders submitted by Tenderers, and all logically related data of a Call. A Tender workspace needs to be well integrated with the User authorization of the system (Functional Req. 4: "User authorization"), as information stored in a Tender workspace should be accessed and/or manipulated by authorized users only. Furthermore, some activities should only be possible when certain events have already taken place (e.g. accessing the details of a Tender should only be possible for authorized personnel after Tenders are securely opened, following the four-eye principle).

FR 6: Preparation of a Prior Information Notice

Procurement Officers may be assisted in creating a PIN by using an application for the preparation of the Notice to be published in the Official Journal. Such an application, commonly known as "Form Filling Tool", can be a part of the eProcurement system itself, or an external application integrated to the eProcurement system.

Document templates or electronic standard forms shall be used to prepare a PIN.

Procurement Officers can be further assisted in preparing a PIN by automatically utilizing Call information already provided to the system within the Tender workspace, during STEP 1 of the procedure. The Form Filling Tool may obtain all pre-defined Call information from the eProcurement system, and automatically prefill as many fields in the PIN template as possible.

FR 7: Use of the Common Procurement Vocabulary (CPV) classification standard

The new Public Procurement Directives require contracting authorities to use the CPV to advertise their procurement needs. The CPV constitutes a European classification standard specifically tailored to describe goods, services or works purchased by public authorities by numerical codes. The CPV exists in the 20 official languages of the EU. Thanks to this classification, Economic Operators can easily identify the goods/services/works a contracting authority wishes to procure, irrespective of the language of the PIN and to perform specific searches on the TED database.

An eProcurement system can prompt Procurement Officers to make use of the CPV classification standard when creating a PIN.

FR 8: Publication of a Prior Information Notice

Once the PIN is created, Procurement Officers can be assisted to dispatch an appropriate electronic message to the OJEU, containing all information of the PIN, to request for its publication. The eProcurement system should be in position to store the dispatch date of the PIN to the OJEU.

FR 9: Nomenclature of Territorial Units for Statistics (NUTS) classification standard

The Contract Notice may specify the NUTS codes for the contract to be procured. NUTS is a classification standard for geographic regions, which uses numerical codes to define the location of the goods/services/works to be procured. Similarly to the CPV, the inclusion of NUTS codes in a Contract Notice allows Economic Operators to easily identify the locations to which they will be required to deliver the goods/services/works of the contract irrespective of the language of the Contract Notice.

An eProcurement system can prompt Procurement Officers to make use of the NUTS classification standard when creating a Contract Notice. This functional requirement is not legislated by the EU public procurement legal framework, nevertheless can significantly increase the services that can be offered by an eProcurement system (e.g, searching, reporting, system integration, etc.)

FR 10: Tender Evaluation Mechanism

Contracting authorities shall conclude a competition by performing the full evaluation of Tenders received, and the awarding of a contract. The evaluation of Tenders is based on one of the following two Tender evaluation models: either lowest price or Most Economically Advantageous Tender (MEAT). In both cases, the evaluation model to be used must be specified in the Contract Notice or the Contract Documents. In the latter case, this fact must be stated in the Contract notice. If the evaluation is based on the Most Economically Advantageous Tender, contracting authorities are required to define the exact evaluation criteria to be used, as well as to indicate their weightings either in the Contract Notice or in the Contract Documents. In the latter case this reference to the Contract Documents must be stated in the Contract Notice. In duly justified cases where the weighting cannot be established, contracting authorities must be able to give reasons, and indicate the descending order of importance of all criteria.

When the evaluation parameters of a Call based on MEAT can be established with precision, a contracting authority may decide that the award of the contract shall be preceded by an electronic auction. The intention of using an electronic auction as part of the awarding procedure needs to be mentioned in the Contract Notice of the Call.

To accommodate the above, an eProcurement system can prompt Procurement Officers to

define the evaluation mechanism to be used, as well as automatically include the details of the evaluation mechanism in the Contract Notice and/or Contract Documents.

FR: 11 Interface with the OJEU

Once the Contract Notice of a Call for Tenders is completed, it needs to be made publicly available. For contracts above the EU thresholds, as defined in the EU public procurement directives, the Contract Notice needs to be published to the Official Journal of the European Union (OJEU).

The EU Publications Office, responsible for the daily publication of the Official Journal, offers several methods by which a notice can be published on the OJEU. An eProcurement system can offer the functionality for automating or semi-automating the publication of notices in the OJEU. This does not only simplify the processes a Procurement Officer needs to follow, but also allows to shorten the time-limit for the submission of Tenders.

FR: 12 Publication of Contract Documents

The preparation of Contract Documents involves an "approval" lifecycle for documents (and possible notices), comprising their creation, validation, approval and publication. The "approval" lifecycle depends on the internal procedures of the contracting authority, and may involve multiple Procurement Officers. An eProcurement system can provide a functionality for modelling these internal workflows which can assist Procurement Officers to comply with the internal workflows of their contracting authority in a more efficient and time-effective manner. While a document is in "not-published" state, it is accessible only to the Procurement Officers associated with it.

The finalized Contract Documents approved by the contracting authority shall not be made publicly available until the Contract Notice is dispatched to the OJEU for publication. Once the Contract Notice has been published by the OJEU, it may also be published at the national level, and all interested parties should be given unrestricted and full access to the Contract Documents.

Once a Contract Document is made publicly available, it should not be possible for anyone to remove and/or modify this document.

FR 13: Search Calls mechanism

At this step, the Call for Tender is considered "open", as it is publicly available. An eProcurement system may provide a search Calls mechanism to any interested party, so that it can search through all publicly "open" Calls and locate interesting ones, for which s/he might wish to participate.

FR 14: Visualize/Download Call for Tenders specifications

Any interested party should be provided with the functionality to access all publicly available information of a Call, comprising PIN, Contract Notice, Contract Documents, Additional Documents, etc. An eProcurement system may require interested parties to provide some personal information, so that they are notified if and when new information about the Call is published (Additional Documents, new Contract Documents, etc.)

The eProcurement system should ensure that full and unrestricted access to all publicly available information is provided equally to all interested parties.

FR 15: Request for Additional Documents

Any interested party may be provided with the possibility to request Additional Documents about a Call (i.e. ask a question to the awarding authority). This may be provided only within a predefined time period (i.e. accept questions posted before a certain date). All requests for Additional Documents and the Additional Documents themselves need to be made publicly available to all interested parties, and in due time before the end of the time-limit for submission to ensure non-discrimination and equal treatment of Economic Operators. The identities of Economic Operators posting requests for Additional Documents should not be disclosed, neither to the general public nor to other Economic Operators.

FR 16: Automated Notifications

An eProcurement system may support an automated notification mechanism, which can automatically notify its users of interesting events. For instance, Economic Operators that requested an Additional Document (i.e. posted a question) may be automatically notified when an Additional Document is published by the contracting authority (i.e. the contracting authority has provided an answer to the posted question). As described in Functional Requirement 15, such a notification mechanism must ensure equal treatment of all Economic Operators and operate within the time limit for submission of tenders.

FR 17: Submission of Tenders

Submission of Tenders
Economic Operators interested in a Call shall have the possibility to submit electronically the Tenders that they have prepared through generally available, nondiscriminatory, and interoperable means of communication. Contracting authorities examine whether the Tenders received are compliant with the requirements defined in the Tender

specifications.

Economic Operators that have submitted a Tender should be provided with the possibility to update their Tender until the Tender submission deadline.

The eProcurement system must ensure that all Tenders for a Call are stored in a secure environment and cannot be accessed until authorized Procurement Officers authorize their opening following the four-eye principle. If access prohibition is infringed, it should be reasonably ensured that the infringement is clearly detectable.

Official time-stamping facility can ensure the exact submission date and time of a Tender is recorded, guaranteeing there are no misconceptions about the submission time of a Tender (see relevant non-functional requirements in section 4.3.3.2).

Security arrangements for all data transmitted to/from the eProcurement system and stored in the eProcurement system should ensure the integrity of the Tenders, as well as, the authenticity of the Economic Operators that have submitted them (see relevant non-functional requirements in section 4.5).

FR 18: Four-eye Principle

An eProcurement system needs to ensure that access to Tenders cannot be obtained by anyone, until authorized procurement officers proceed to the opening of Tenders following the four-eye principle. To “open” or “unlock” Tenders, two or more authorized procurement officers need to perform simultaneous actions. The opening of Tenders shall only be performed after the Tender submission deadline.

It is considered as best practice for the opening of Tenders to be performed in phases. Hence, for instance, proof documents are opened first, followed by the opening of technical document, and lastly the opening of financial offers. In all Tender opening phases, the Four-eye Principle can be applied.

FR 19: Tender Confidentiality

Once Tenders are opened, they can only be accessed by authorized personnel, ensuring that the confidentiality of Tenders is not violated.

FR 20: Tender Evaluation

An eProcurement system may assist procurement officers to perform the evaluation of Tenders, either in an automated or semi-automated manner. Initially, all Tenders should be evaluated in order to ensure that participating Tenderers satisfy the Conditions for Participation stated in the Contract Notice or Contract Documents of the Call.

This is followed by the full Tender evaluation according to the pre-defined evaluation mechanism stated in the Contract Notice or Contract Documents of the Call.

FR 21: Creation of Mandatory Reports regulated by the legislation

Another requirement of the legislation is related to the capability of the contracting authority to prepare regulatory reports, which provide information on all aspects of the competition. Such reports include information about the tenderers that participated in the competition, the successful tenderer(s), the reasons for their selection, etc. The contracting authority may be assisted in this process by an eProcurement system which, utilizing all information created/stored in it during the competition, can automatically or semi-automatically produce such reports.

FR 22: Invitation to Tender

Once all proof documents have been examined and, where applicable, candidates have been short-listed based on the objective criteria stated in the Contract Notice, the contracting authority invites all or some Economic Operators to submit their Tenders until a defined submission deadline. Rejected Economic Operators should be notified that they will not be invited.

This process can be simplified for contracting authorities by an eProcurement system which can automatically or semi-automatically calculate the deadline for submitting Tenders, as well as, prepare appropriate messages to all Economic Operators involved. The identity of all Economic Operators involved must remain confidential.

From this point onward, all Call related information (comprising Contract Documents and Additional Documents) can be disclosed only to the economic operators selected to submit a Tender.

FR 23: DPS reporting

The DPS workspace effectively constitutes an "umbrella" for the procurement of specific contracts within it. Hence, authorized Procurement Officers may be provided with the possibility to produce DPS reports, not only reporting details of its establishment (i.e. when it was established, who created it, information of the Contract Notice, etc.), but also information about specific contracts procured within it (i.e. the list of tenderers admitted to the DPS, number of specific contracts procured through the DPS, etc.)

FR 24: Creation of specific contract workspaces within DPS workspace

An eProcurement system can allow the creation of as many specific contract workspaces within the DPS workspace as required by the contracting authority. When creating a specific contract, certain properties of the specific contract must be pre-set as defined in the DPS workspace (like Contract Documents and Tender evaluation methodology). A workspace for a specific contract within the DPS may function in a similar way to the workspace of the open procedure (Functional Req. 5: "Tender workspace creation"). It can permit Procurement Officers to store all contract specific information within the workspace, while all Tenders submitted for the specific contract can also be securely stored in this virtual area. Furthermore, an eProcurement system supporting DPS must ensure the confidentiality of all information stored within a specific contract workspace, for example with regard to authorized users of another specific contract workspace of the same DPS.

FR 25: Indicative Tenders in the form of electronic catalogues (eCatalogues)

An Indicative Tender may take the form of an eCatalogue. The contracting authority may define the format an eCatalogue should have.

An eProcurement system may assist contracting authorities in defining the format of an electronic catalogue. Furthermore, the system may provide the necessary support for allowing Economic Operators to create their Indicative Tenders in the required format, and/or allow Procurement Officers to visualize eCatalogues in a user-friendly format. Advanced search capabilities, multimedia support (e.g. images, sounds, etc.) and/or tools for comparing eCatalogues from different Economic Operators may also be offered. An eCatalogue is possible to also be used for forming a Tender for an Individual Contract competition. Nevertheless, the eCatalogue needs to confirm to the specifications of the Call for Tender.

FR 26: Creation of eAuction workspace and establishing eAuction parameters

This functional requirement covers the creation of a virtual workspace, where all eAuction related information can be stored. This virtual workspace should only be accessible to authorised users; eAuction parameters should be established and fixed within it. Subsequent eAuction activities, such as tenderers' placing of Bids and displaying of the ranking of Tenders may be performed within this virtual eAuction workspace or using the services of an external eAuction provider.

eAuction parameters comprise the bidding fields, the eAuction opening and closing conditions, the type of the eAuction, etc. The parameters for the full initial evaluation and the features for auction and their evaluation mechanism should be defined prior to launching the procedure and be published in the eAuction specifications alongside with the Contract Notice.

Appendix P

Portions of the code to the CEP methodology

```
#!/usr/bin/ruby
# Ruby code to create the CEP NFRs tables in the MySQL database
# CEP utility code
# createCEPtablesMySQL.rb
require 'mysql'

begin

   con = Mysql.new 'localhost', '', '', 'NFRS'

   con.query("CREATE TABLE IF NOT EXISTS \
      IMAGE_METADATA(ID INT PRIMARY KEY AUTO_INCREMENT,
IMG_METADATA VARCHAR(500))")

   con.query("CREATE TABLE IF NOT EXISTS \
      DOC_METADATA(ID INT PRIMARY KEY AUTO_INCREMENT,
DOC_METADATA VARCHAR(500))")

   con.query("CREATE TABLE IF NOT EXISTS \
      NFRs_Metadata(Id INT PRIMARY KEY AUTO_INCREMENT, REQ_ID
VARCHAR(50), NFR_SENTENCE VARCHAR(500), NFR_PRIORITY INT(11),
NFR_TYPE VARCHAR(100)")


rescue Mysql::Error => e
   puts e.errno
   puts e.error

ensure
   con.close if con
end
```

```
#!/usr/bin/ruby
# Display the raw data for the IMAGE_METATADATA and DOC_METADATA tables
# CEP utility code
# filename: displayCEPimagedoc_raw.rb

require "mysql"

begin

   con = Mysql.new 'localhost', '', '', 'NFRS'

   rs = con.query("SELECT ID, IMG_METADATA FROM IMAGE_METADATA")
   number_rows = rs.num_rows

   puts "Result set contains #{number_rows} rows"

   number_rows.times do
      puts rs.fetch_row.join("\s")
   end

   rs2 = con.query("SELECT ID, DOC_METADATA FROM DOC_METADATA")
   number_rows2 = rs2.num_rows

   puts "Result set contains #{number_rows} rows"

   number_rows2.times do
      puts rs2.fetch_row.join("\s")
   end


rescue Mysql::Error => e
   puts e.errno
   puts e.error

ensure
   con.close if con
end
```

```
#!/usr/bin/ruby
# Display the NFRs_METADATA table
# CEP Utility code - NON GUI display
# filename: displayCEPNFRs_metadata.rb

require "mysql"

begin

   con = Mysql.new 'localhost', '', '', 'NFRS'

   rs = con.query("SELECT ID, REQ_ID, NFR_SENTENCE, NFR_PRIORITY,
NFR_TYPE  FROM NFRS_METADATA")
   number_rows = rs.num_rows

   puts "Result set contains #{number_rows} rows"

   number_rows.times do
      puts rs.fetch_row.join("\s")
   end


rescue Mysql::Error => e
   puts e.errno
   puts e.error

ensure
   con.close if con
end
```

```
#!/usr/bin/ruby
# Display the NFRs_METADATA table by top NFR Priority
# CEP Utility code - NON GUI display
# filename: displayCEPNFRS_metadatatoppriority.rb

require "mysql"

begin

   con = Mysql.new 'localhost', '', '', 'NFRS'

   rs = con.query("SELECT ID, REQ_ID, NFR_SENTENCE, NFR_PRIORITY,
NFR_TYPE  FROM NFRS_METADATA ORDER BY NFR_PRIORITY")
   number_rows = rs.num_rows

   puts "Result set contains #{number_rows} rows ordered by Top NFR Priority"

   number_rows.times do
      puts rs.fetch_row.join("\s")
   end


rescue Mysql::Error => e
   puts e.errno
   puts e.error

ensure
   con.close if con
end
```

```
# Ruby on Rails – NFR controller and Viewer

class NfrController < ApplicationController
  def index
     @nfrs = Nfr.all.sort_by {|a| (a.nfr_priority.to_i)}
end
end

<center><img src="nsu_logo.gif"></center>
<center><b><font size="5" color="blue">NFR Viewer - Non-Functional Requirements
sorted by top NFR Priority</font></b></center>

<table border = "1">
   <tr>
     <th>NFR ID</th>
     <th>NFR Sentence</th>
     <th>NFR Rank</th>
     <th>NFR Group</th>
 </tr>


 <% @nfrs.each do |nfr| %>
    <tr>
      <td><%= nfr.nfrid %></td>
      <td><%= nfr.nfr_sentence %></td>
      <td><%= nfr.nfr_priority %></td>
      <td><%= nfr.nfr_type %></td>
    </tr>
<% end %> </table>
```

```
// Updated attribute list to the NFR Locator – Baseline NFRs
// https://github.com/RealsearchGroup/NFRLocator
// Filename: classification_attributes.json

{
	"attributeList" : [
	{
		"name" : "accessibility",
		"type" : "boolean",
		"description" : "",
		"abbreviation" : "AC",
		"includeInEvaluation": false
	},
	{
		"name" : "accuracy",
		"type" : "boolean",
		"description" : "",
		"abbreviation" : "AR",
		"includeInEvaluation": false
	},
	{
		"name" : "auditability",
		"type" : "boolean",
		"description" : "",
		"abbreviation" : "AU",
		"includeInEvaluation": false
	},
	{
		"name" : "availability",
		"type" : "boolean",
		"description" : "",
		"abbreviation" : "AV",
		"includeInEvaluation": false
	},
	{
		"name" : "compliance",
		"type" : "boolean",
		"description" : "",
		"abbreviation" : "CE",
		"includeInEvaluation": false
	},
	{
		"name" : "confidentiality",
		"type" : "boolean",
		"description" : "",
		"abbreviation" : "CO",
```

```
            "includeInEvaluation": false
        },
        {
            "name" : "configuration",
            "type" : "boolean",
            "description" : "",
            "abbreviation" : "CN",
            "includeInEvaluation": false
        },
        {
            "name" : "documentation",
            "type" : "boolean",
            "description" : "",
            "abbreviation" : "DO",
            "includeInEvaluation": false
        },
        {
            "name" : "efficiency",
            "type" : "boolean",
            "description" : "",
            "abbreviation" : "EF",
            "includeInEvaluation": false
        },
        {
            "name" : "interoperability",
            "type" : "boolean",
            "description" : "",
            "abbreviation" : "IN",
            "includeInEvaluation": false
    },
        {
            "name" : "legal",
            "type" : "boolean",
            "description" : "",
            "abbreviation" : "LG",
            "includeInEvaluation": false
        },
        {
            "name" : "multilingual",
            "type" : "boolean",
            "description" : "",
            "abbreviation" : "ML",
            "includeInEvaluation": false
        },
        {
            "name" : "performance",
```

```
                "type" : "boolean",
                "description" : "",
                "abbreviation" : "PS",
                "includeInEvaluation": false
        },
        {
                "name" : "reliability",
                "type" : "boolean",
                "description" : "",
                "abbreviation" : "RE",
                "includeInEvaluation": false

        },
        {
                "name" : "scalability",
                "type" : "boolean",
                "description" : "",
                "abbreviation" : "SC",
                "includeInEvaluation": false
        },
        {
                "name" : "security",
                "type" : "boolean",
                "description" : "",
                "abbreviation" : "SE",
                "includeInEvaluation": false
        },
        {
                "name" : "usability",
                "type" : "boolean",
                "description" : "",
                 "abbreviation" : "US",
                "includeInEvaluation": false
        },
        {
                "name" : "user interface",
                "type" : "boolean",
                "description" : "",
                "abbreviation" : "UI",
                "includeInEvaluation": false
        }
        ]
}
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs AC
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: AC.rb
# NFR Accessibility (AC)

fname = ARGV[0]

system (" egrep --color --text -n -i
'(access|accessible|availability|accessibleness|accessibly|accessibility|approachable|reacha
ble|attainable|obtainable|procurable|available|inacessible|restricted|limited|unavailable|una
ttainable|unobtainable|omnipresent|prevalent|ubiquitous|widespread|unrestricted|comman
d|print|handy|accessible|available|convenience|suitable|suitableness|quality|attribute|abstra
ction|abstract entity|easily used|easily obtained|easily accessed|access code|memory
access|approach|reach|attain|obtain|handy|easily met|at
hand|choose|lhcp|hcp|visit|privilege|read|office|add|presentation|sort|name|administrator|p
ersonal|dlhcp|view|status|accessor|edit|role|list)'  " + fname);

print " Number of Occurrences of NFR AC: "
system (" egrep -c --text -n -i
'(access|accessible|availability|accessibleness|accessibly|accessibility|approachable|reacha
ble|attainable|obtainable|procurable|available|inacessible|restricted|limited|unavailable|una
ttainable|unobtainable|omnipresent|prevalent|ubiquitous|widespread|unrestricted|comman
d|print|handy|accessible|available|convenience|suitable|suitableness|quality|attribute|abstra
ction|abstract entity|easily used|easily obtained|easily accessed|access code|memory
access|approach|reach|attain|obtain|handy|easily met|at
hand|choose|lhcp|hcp|visit|privilege|read|office|add|presentation|sort|name|administrator|p
ersonal|dlhcp|view|status|accessor|edit|role|list)' " + fname);
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs AR
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: AR.rb
# NFR Accuracy(AR)

fname = ARGV[0]

system ("egrep --color --text -n -i
'(accurate|consistent|time|precise|correct|exact|definite|accuracy|certainty|correctness|defin
iteness|accurateness|closeness|exactness|fineness|perfection|preciseness|rigor|ultraprecisio
n|imprecise|inaccurate|inaccuracy|falseness|inconsistency|nonconformity|exactitude|minut
eness|preciseness|precision|trueness|fidelity|timely accurately|one on one
accuracy|property accuracy|value accuracy|consistency|external consistency|internal
consistency|near true value|error free|precise|correct|conform to a
standard|precision|magnitude of error|standard)' " + fname);

print " Number of Occurrences of NFR AR: "

system ("egrep -c --text -n -i
'(accurate|consistent|time|precise|correct|exact|definite|accuracy|certainty|correctness|defin
iteness|accurateness|closeness|exactness|fineness|perfection|preciseness|rigor|ultraprecisio
n|imprecise|inaccurate|inaccuracy|falseness|inconsistency|nonconformity|exactitude|minut
eness|preciseness|precision|trueness|fidelity|timely accurately|one on one
accuracy|property accuracy|value accuracy|consistency|external consistency|internal
consistency|near true value|error free|precise|correct|conform to a
standard|precision|magnitude of error|standard)' " + fname);
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs AU
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: AU.rb
# NFR Auditability(AU)

fname = ARGV[0]

system ("egrep --color --text -n -i
'(infringe|copyright|audit|examination|comply|compliance|analyze|analyse|scrutinize|contr
act|review|auditable|auditee|auditability|Inspection|check|examination|scan|see|review|go-
over|scrutiny|survey|view|study|examine|canvass|learn|read|take|train|prepare|drill|exercis
e|practice|functional configuration audit|physical configuration|comply with
standard|auditor|accounting audit|financial audit|methodical review and
examination|idependent examination|assess compliance with standards|contractual
agreement|authorship|trail|arise|worksheet|auditable|exclusion|reduction|deletion|examine|
editing|stamp|non-
repudiation|inclusion|alteration|finalize|finalise|disable|summarize|summarise|attestation|l
og)'  " + fname)


print " Number of Occurrences of NFR AU: "

system ("egrep -c --text -n -i
'(infringe|copyright|audit|examination|comply|compliance|analyze|analyse|scrutinize|contr
act|review|auditable|auditee|auditability|Inspection|check|examination|scan|see|review|go-
over|scrutiny|survey|view|study|examine|canvass|learn|read|take|train|prepare|drill|exercis
e|practice|functional configuration audit|physical configuration|comply with
standard|auditor|accounting audit|financial audit|methodical review and
examination|idependent examination|assess compliance with standards|contractual
agreement|authorship|trail|arise|worksheet|auditable|exclusion|reduction|deletion|examine|
editing|stamp|non-
repudiation|inclusion|alteration|finalize|finalise|disable|summarize|summarise|attestation|l
og)'  " + fname )
```

```
!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs AV
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: AV.rb
# NFR Availability(AV)

fname = ARGV[0]

system (" egrep --color --text -n -i
'(achieve|24|availability|98|addition|available|99|hour|day|online|schedule|confidentiality|r
esource|technical|year|transmit|integrity|maintenance|%|period|Handiness|acessibility|con
venience|dependability|maintainability|reliability|availableness|availably|accessible|acquir
able|attainable|obtainable|limited|restricted|procurable|inacessible|unattainable|unavailabl
e|unobtainable|suitable|suitability|convenient|partial|continuous|full|intermittent|tolerance|
probablility|error tolerance|ready for immediate use|use|service|service interruption
tolerance|system|system degradation toleration|business continuity|operational and
accessible when needed for use|probability)'  “ + fname)

print " Number of Occurrences of NFR AV: "

system (" egrep -c --text -n -i
'(achieve|24|availability|98|addition|available|99|hour|day|online|schedule|confidentiality|r
esource|technical|year|transmit|integrity|maintenance|%|period|Handiness|acessibility|con
venience|dependability|maintainability|reliability|availableness|availably|accessible|acquir
able|attainable|obtainable|limited|restricted|procurable|inacessible|unattainable|unavailabl
e|unobtainable|suitable|suitability|convenient|partial|continuous|full|intermittent|tolerance|
probablility|error tolerance|ready for immediate use|use|service|service interruption
tolerance|system|system degradation toleration|business continuity|operational and
accessible when needed for use|probability)'  “ + fname)
```

```
!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs CE
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: CE.rb
# NFR Compliance(CE)

fname = ARGV[0]

system ("egrep --color --text -n -i
'(require|compliantly|compliant|compliance|conformity|conformation|abidance|comply|su
bmit|submission|accede|bow|put|forth|nonconformity|noncompliance|acquiescence|biddab
ility|compliancy|deference|obedience|abidance|adherence|conformance|conformity|submis
sion|subord|ination|keeping|obedience|observation|submissiveness|formality|line|honoring
|cooperation|collaboration|teamwork|prostration|adjust|adapt|custom|get used to|legal
standards|conform to requirements|follow rule|act in accord with accepted
standards|conform to official requirements|satsify government regulations|official)' “ +
fname)

print " Number of Occurrences of NFR CE: "

system ("egrep -c --text -n -i
'(require|compliantly|compliant|compliance|conformity|conformation|abidance|comply|su
bmit|submission|accede|bow|put|forth|nonconformity|noncompliance|acquiescence|biddab
ility|compliancy|deference|obedience|abidance|adherence|conformance|conformity|submis
sion|subord|ination|keeping|obedience|observation|submissiveness|formality|line|honoring
|cooperation|collaboration|teamwork|prostration|adjust|adapt|custom|get used to|legal
standards|conform to requirements|follow rule|act in accord with accepted
standards|conform to official requirements|satsify government regulations|official)'  “ +
fname)
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs CO
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: CO.rb
# NFR Confidentiality(CO)

fname = ARGV[0]

system ("egrep --color --text -n -i '(confidential|confidentially|confidentiality|behind-the-
scenes|private|esoteric|hushed|intimate|privy|nonpublic|secret|common|open|public|shared
|well-
known|advertised|announced|blazed|broadcast|declared|disclosed|divulged|enunciated|her
alded|proclaimed|professed|promulgated|publicized|published|reporting|reported|spotlight
ed|widespread|privacy|private|privateness|secrecy|concealment|discretion|discreetness|circ
umspection|prudence|data|data protection|unauthorized
disclosure|information|information protection|information privacy|keep information
secret|unauthorized disclose of data and information|accidental or deliberate disclosure
protection|authority)' “ + fname)

print " Number of Occurrences of NFR CO: "

system ("egrep -c --text -n -i '(confidential|confidentially|confidentiality|behind-the-
scenes|private|esoteric|hushed|intimate|privy|nonpublic|secret|common|open|public|shared
|well-
known|advertised|announced|blazed|broadcast|declared|disclosed|divulged|enunciated|her
alded|proclaimed|professed|promulgated|publicized|published|reporting|reported|spotlight
ed|widespread|privacy|private|privateness|secrecy|concealment|discretion|discreetness|circ
umspection|prudence|data|data protection|unauthorized
disclosure|information|information protection|information privacy|keep information
secret|unauthorized disclose of data and information|accidental or deliberate disclosure
protection|authority)' “ + fname)
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs CN
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: CN.rb
# NFR Configuration (CN)

fname = ARGV[0]

system ( " egrep --color --text -n -i
'(conFigure|configuration|configurational|configurationally|configurative|configurability|a
rchitecture|armature
|cadre|frame|edifice|fabric|framework|framing|infrastructure|shell|skeleton|structure|comp
osition|material|matter|stuff|substance|assemble|piece|put together|set up|tack
together|make|create|connect|tie|link up |reassemble|computer configurability|hardware
configuration|software configuration|configuration management system|set up for specific
purpose|computer configuration of parts|interconnections of components)' + fname " )

print " Number of Occurrences of NFR CN: "

system ( " egrep -c --text -n -i
'(conFigure|configuration|configurational|configurationally|configurative|configurability|a
rchitecture|armature
|cadre|frame|edifice|fabric|framework|framing|infrastructure|shell|skeleton|structure|comp
osition|material|matter|stuff|substance|assemble|piece|put together|set up|tack
together|make|create|connect|tie|link up |reassemble|computer configurability|hardware
configuration|software configuration|configuration management system|set up for specific
purpose|computer configuration of parts|interconnections of components)' + fname " )
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs DO
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: DO.rb
# NFR Documentation (DO)

fname = ARGV[0]


system (" egrep --color --text -n -i
'(document|documentary|documentation|documentational|attestation|confirmation|corrobo
ration|proof|evidence|substantiation|testament|testimonial|testimony|validation|voucher|wi
tness|disproof|certificate|document|exhibit|demonstration|illustration|authentication|identif
ication|manifestation|verification|confirmation|information|info|message|content|subject
matter|substance|communication|reinforcement|reenforcement|corroborate|software
documentation|certification|corroboration|support|program listing|technical
manuals|program use and operation|software|software program|computer
software|system|software system|software package|package|document
validation|documents collection|describe|define|specify|report information|certify
activities|requirements|procedures and results|documents
management|identify|acquire|process|store|disseminate documents)' “ + fname)

print " Number of Occurrences of NFR DO: "

system (" egrep -c --text -n -i
'(document|documentary|documentation|documentational|attestation|confirmation|corrobo
ration|proof|evidence|substantiation|testament|testimonial|testimony|validation|voucher|wi
tness|disproof|certificate|document|exhibit|demonstration|illustration|authentication|identif
ication|manifestation|verification|confirmation|information|info|message|content|subject
matter|substance|communication|reinforcement|reenforcement|corroborate|software
documentation|certification|corroboration|support|program listing|technical
manuals|program use and operation|software|software program|computer
software|system|software system|software package|package|document
validation|documents collection|describe|define|specify|report information|certify
activities|requirements|procedures and results|documents
management|identify|acquire|process|store|disseminate documents)' “ + fname)
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs EF
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: EF.rb
# NFR Efficiency (EF)

fname = ARGV[0]


system ("  egrep --color --text -n -i
'(efficient|efficiently|efficiency|inefficiency|edge|effectiveness|effectualness|efficaciousne
ss|efficacity|efficacy|productiveness|ineffectiveness|ineffectuality|ineffectualness|Figure
of merit|ratio|economy|Storage efficiency|efficiency in use|ratio of output to
input|perform functions|minimum resources|ualness|Figure of merit|ratio|economy|storage
efficiency|efficiency in use|ratio of output to input|perform functions|minimum
resources)' “ + fname)

print " Number of Occurrences of NFR EF: "

system ("  egrep -c --text -n -i
'(efficient|efficiently|efficiency|inefficiency|edge|effectiveness|effectualness|efficaciousne
ss|efficacity|efficacy|productiveness|ineffectiveness|ineffectuality|ineffectualness|Figure
of merit|ratio|economy|Storage efficiency|efficiency in use|ratio of output to
input|perform functions|minimum resources|ualness|Figure of merit|ratio|economy|storage
efficiency|efficiency in use|ratio of output to input|perform functions|minimum
resources)' “ + fname)
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs IN
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: IN.rb
# NFR Interoperability (IN)

fname = ARGV[0]


system (" egrep --color --text -n -i
'(operable|operably|operability|interoperable|interoperability|available|employable|exploit
able|fit|functional|operable|practicable|service|serviceable|useful|impracticable|inoperable|
nonfunctional|unavailable|unemployable|unusable|ability|quality|adaptability|compatibilit
y|working together|two or more systems|exchange and use information|operate
harmoniously|system)' “ + fname)

print " Number of Occurrences of NFR IN: "

system (" egrep -c --text -n -i
'(operable|operably|operability|interoperable|interoperability|available|employable|exploit
able|fit|functional|operable|practicable|service|serviceable|useful|impracticable|inoperable|
nonfunctional|unavailable|unemployable|unusable|ability|quality|adaptability|compatibilit
y|working together|two or more systems|exchange and use information|operate
harmoniously|system)' “ + fname)
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs LG
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: LG.rb
# NFR Legal (LG)

fname = ARGV[0]


system (" egrep --color --text -n -i
'(legality|legally|legal|courtordered|jural|ratified|sanctioned
judicial|juristic|statutory|legislative|legislature|legislation|illegal|valid|invalid|lawful|legiti
mate|licit|allowable|authorized|noncriminal|permissible|justifiable|warrantable|constitutio
nal|dejure|regulation|statutory|good|innocent|just|proper|right|illegitimate|illicit|lawless|unl
awful|wrongful|establish|accepted founded on law|Official|official rules|accepted
rules|infeasible|custodian|hipaa|breach|dua|discovery|iihus|publication|iihi|recipient|delay|
secretary|definition|harm|scope|jurisdictional|affect|derive|vocabulary|reuse)' “ + fname)


print " Number of Occurrences of NFR LG: "

system (" egrep -c --text -n -i '(legality|legally|legal|courtordered|jural|ratified|sanctioned
judicial|juristic|statutory|legislative|legislature|legislation|illegal|valid|invalid|lawful|legiti
mate|licit|allowable|authorized|noncriminal|permissible|justifiable|warrantable|constitutio
nal|dejure|regulation|statutory|good|innocent|just|proper|right|illegitimate|illicit|lawless|unl
awful|wrongful|establish|accepted founded on law|Official|official rules|accepted
rules|infeasible|custodian|hipaa|breach|dua|discovery|iihus|publication|iihi|recipient|delay|
secretary|definition|harm|scope|jurisdictional|affect|derive|vocabulary|reuse)' “ + fname)
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs ML
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: ML.rb
# NFR Multilingual (ML)

fname = ARGV[0]


system ("  egrep --color --text -n -i '(multilingual|multi
languages|support|multiple|language|support|more than one language|multiple
languages|express in several languages|multi-lingual format)' + fname ")

print " Number of Occurrences of NFR ML: "

system ("  egrep -c --text -n -i '(multilingual|multi
languages|support|multiple|language|support|more than one language|multiple
languages|express in several languages|multi-lingual format)' + fname ")
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs PS
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: PS.rb
# NFR Performance (PS)

fname = ARGV[0]


system (" egrep --color --text -n -i
'(perform|interpretation|account|reading|rendition|version|nonfulfillment|nonperformance|
space|time|main|memory|response|time|throughput|off-peak throughput|peak
throughput|peak mean throughput|peak uniform throughput|Time behavior|resource
utilization|second|minutes|hour|day|week|month|year|byte|kilobyte|megabyte|gigabyte|exe
cution|instruction|execution|perform|efficiently|manner of
operating|functioning|functional|function|operate|operational|fast|simultaneous|scale|capa
ble|increase|peark|longer|average|acceptable|lead|handle|flow|response|capacity|maximum
|cycle|distribution)' “ + fname)

print " Number of Occurrences of NFR PS: "

system (" egrep -c --text -n -i
'(perform|interpretation|account|reading|rendition|version|nonfulfillment|nonperformance|
space|time|main|memory|response|time|throughput|off-peak throughput|peak
throughput|peak mean throughput|peak uniform throughput|Time behavior|resource
utilization|second|minutes|hour|day|week|month|year|byte|kilobyte|megabyte|gigabyte|exe
cution|instruction|execution|perform|efficiently|manner of
operating|functioning|functional|function|operate|operational|fast|simultaneous|scale|capa
ble|increase|peark|longer|average|acceptable|lead|handle|flow|response|capacity|maximum
|cycle|distribution)' “ + fname)
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs RE
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: RE.rb
# NFR Reliability (RE)

fname = ARGV[0]


system (" egrep --color --text -n -i
'(reliably|reliability|undependableness|unreliability|unreliable|dependability|dependablene
ss|reliableness|responsibility|solidity|solidness|sureness|trustability|infallibility|reproducib
ility|duplicability|responsibleness|trustworthiness|trustiness|accountability|answerability|a
vailability|fault tolerance|recoverability|MTBF|probability of availability|continual
operation|perform required functions|under specific conditions|specific period of
time|maintain specific performance under specific
conditions|dependent|validate|validation|input|query|accept|loss|failure|operate|alert|labora
tory|prevent|database|product|appropriate|event|application|capability|ability)' “ + fname);

print " Number of Occurrences of NFR RE: "

system (" egrep -c --text -n -i
'(reliably|reliability|undependableness|unreliability|unreliable|dependability|dependablene
ss|reliableness|responsibility|solidity|solidness|sureness|trustability|infallibility|reproducib
ility|duplicability|responsibleness|trustworthiness|trustiness|accountability|answerability|a
vailability|fault tolerance|recoverability|MTBF|probability of availability|continual
operation|perform required functions|under specific conditions|specific period of
time|maintain specific performance under specific
conditions|dependent|validate|validation|input|query|accept|loss|failure|operate|alert|labora
tory|prevent|database|product|appropriate|event|application|capability|ability)' “ + fname);
```

```
# Ruby/unix utility code to verify NFRs SC
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: SC.rb
# NFR Scalability (SC)

fname = ARGV[0]


system ("  egrep --color --text -n -i
'(scalable|scalability|able|capable|equal|fit|good|qualified|suitable|incompetent|inept|poor|u
nfit|unfitted|unqualified|quantifiability|measurability|ratability|capable to scale|ease to
expand|upgrade on
demand|fast|simultaneous|second|scale|capable|increase|peark|longer|average|acceptable|l
ead|handle|flow|response|capacity|maximum|cycle|distribution)' “ + fname);

print " Number of Occurrences of NFR SC: "


system ("  egrep -c --text -n -i
'(scalable|scalability|able|capable|equal|fit|good|qualified|suitable|incompetent|inept|poor|u
nfit|unfitted|unqualified|quantifiability|measurability|ratability|capable to scale|ease to
expand|upgrade on
demand|fast|simultaneous|second|scale|capable|increase|peark|longer|average|acceptable|l
ead|handle|flow|response|capacity|maximum|cycle|distribution)' “ + fname);
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs SE
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: SE.rb
# NFR Security (SE)

fname = ARGV[0]


system (" egrep --color --text -n -i
'(security|secure|securely|unsecure|insecurity|assurance|invulnerable|impregnable|inviolab
le|secure|strong|unassailable|unattackble|vulnerable|hazard|risk|threat|instability|precariou
sness|harms
way|exposure|liability|openness|violability|vulnerability|susceptibility|susceptibleness|dan
ger|distress|endangerment|imperilment|jeopardy|peril|trouble|secureness|protection|shelter|
safety|availability|integrity|confidentiality|operational
security|completeness|accuracy|internal consistency|external consistency|external
confidentiality|internal confidentiality|operational internal confidentiality|protection from
accidental|malicious access|unauthorized use|modification
destruction|disclosure|unauthorized access|confidentiality|integrity|non
repudiation|accountability|accountable|authenticity|authenticate|identify|authorize|authori
zed|authorization|immunity|survivability|cookie|encrypted|ephi|http|predetermined|strong|
username|inactivity|portal|ssl|deficiency|uc3|authenticate|certificate|session|path|string|pas
sword|incentive)' “ + fname);

print " Number of Occurrences of NFR SE: "


system (" egrep -c --text -n -i
'(security|secure|securely|unsecure|insecurity|assurance|invulnerable|impregnable|inviolab
le|secure|strong|unassailable|unattackble|vulnerable|hazard|risk|threat|instability|precariou
sness|harms
way|exposure|liability|openness|violability|vulnerability|susceptibility|susceptibleness|dan
ger|distress|endangerment|imperilment|jeopardy|peril|trouble|secureness|protection|shelter|
safety|availability|integrity|confidentiality|operational
security|completeness|accuracy|internal consistency|external consistency|external
confidentiality|internal confidentiality|operational internal confidentiality|protection from
accidental|malicious access|unauthorized use|modification
destruction|disclosure|unauthorized access|confidentiality|integrity|non
repudiation|accountability|accountable|authenticity|authenticate|identify|authorize|authori
zed|authorization|immunity|survivability|cookie|encrypted|ephi|http|predetermined|strong|
username|inactivity|portal|ssl|deficiency|uc3|authenticate|certificate|session|path|string|pas
sword|incentive)' “ + fname);
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs US
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: US.rb
# NFR Usability (US)

fname = ARGV[0]

system (" egrep --color --text -n -i
'(usable|usableness|usability|usably|use|user|available|employable|exploitable|fit|functiona
l|operable|serviceable|useful|actionable|applicable|applicative|applied|functional|practical
ble|serviceable|ultrapractical|usable|useable|useful|workable|working|impracticable|inoper
able|nonfunctional|unavailable|unemployable|unusable|impracticable|impractical|inapplic
able|nonpractical|unusable|unworkable|useless|utility|usefulness|function|purpose|role|hel
pfulness|use|instrumentality|practicality|practicability|usable|useable|serviceable|user-
friendly|operability|serviceability|serviceableness|usableness|useableness|learn to
operate|use efficiently|use with satisfaction|use effectively|easy to learn|use and
operate|prepare inputs|interpret
outputs|easy|enterer|wrong|learn|word|community|drop|realtor|help|symbol|voice|collision|
training|conference|easily|successfully|let|map|estimator|intuitive)' “ + fname);

print " Number of Occurrences of NFR US: "


system (" egrep -c --text -n -i
'(usable|usableness|usability|usably|use|user|available|employable|exploitable|fit|functiona
l|operable|serviceable|useful|actionable|applicable|applicative|applied|functional|practical
ble|serviceable|ultrapractical|usable|useable|useful|workable|working|impracticable|inoper
able|nonfunctional|unavailable|unemployable|unusable|impracticable|impractical|inapplic
able|nonpractical|unusable|unworkable|useless|utility|usefulness|function|purpose|role|hel
pfulness|use|instrumentality|practicality|practicability|usable|useable|serviceable|user-
friendly|operability|serviceability|serviceableness|usableness|useableness|learn to
operate|use efficiently|use with satisfaction|use effectively|easy to learn|use and
operate|prepare inputs|interpret
outputs|easy|enterer|wrong|learn|word|community|drop|realtor|help|symbol|voice|collision|
training|conference|easily|successfully|let|map|estimator|intuitive)' “ + fname);
```

```
#!/usr/bin/ruby
# Ruby/unix utility code to verify NFRs UI
# utility code uses UNIX grep to locate NFRs highlighting the words
# Filename: UI.rb
# NFR User Interface (UI)

fname = ARGV[0]

system (" egrep --color --text -n -i '(user
interface|user|interface|interfacial|interfaced|interfacing|command line|graphical user
interface|program|programme|computer program|computer programme|GUI|display|user
friendly|human computer interface|control display|user interaction with
system|system|interact|coordinate harmoniously|usability|use)' “ + fname)

print " Number of Occurrences of NFR UI: "

system (" egrep -c --text -n -i '(user
interface|user|interface|interfacial|interfaced|interfacing|command line|graphical user
interface|program|programme|computer program|computer programme|GUI|display|user
friendly|human computer interface|control display|user interaction with
system|system|interact|coordinate harmoniously|usability|use)' “ + fname)
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