Introduction and Application of a Lightweight Requirements Engineering Process Evaluation Method

Tony Gorschek
tony.gorschek@bth.se

Mikael Svahnberg
mikael.svahnberg@bth.se

Kaarina Tejle
kaarina.tejle@home.se

Department of Software Engineering & Computer Science,
Blekinge Institute of Technology, PO Box 520, S-372 25 Ronneby, Sweden
Phone: +46 457 385000

Abstract

The lack of an adequate requirements specification is often blamed for the failure of many IT investments. Naturally, the requirements specification is the product of a requirements engineering process.

Methods are required to evaluate the current requirements engineering process and identify where improvements are necessary making it possible to produce requirement specifications of high quality. Existing requirements engineering evaluation methods are often large, costly and time-consuming to use. Therefore we introduce a lightweight evaluation method, which we use to evaluate four industry projects. In this paper we outline the evaluation method, describe four industrial applications of the method and present an analysis of the findings.

The results suggest that the proposed evaluation method is useful and the studied cases to a large extent have adequate requirements engineering processes although many important aspects are missing from their respective processes.

1. Introduction

According to certain sources the failure rate of IT investments is over 60% [1]. In addition problems introduced through the requirements engineering of a project accounts for something like 50% of the total debugging costs [2]. One of the major causes for this is said to be the lack of a complete and/or adequate requirements specification [2] [3] [4]. As the requirements specification is a direct result of the requirements engineering process it stands to reason that an inadequate specification is a result of a requirements engineering process with a low maturity level [5].

Although there exist several methods for assessing software development processes, (e.g. CMM [6] and ISO9000 [7]), few models focus on requirements engineering, and those that do to some extent (e.g. Sommerville & Sawyer [3] [8], CMMI [9] and SPICE [10]) are large and demand a fair amount of resources in order to be used. This is primarily due to the fact that they are exhaustive and often aimed at large scale evaluations of entire processes, e.g. the whole of a development process. This may not be a problem for large business enterprises, but small and medium size enterprises (SME) often have a limited budget for process evaluation and improvement.

Hence there is no simple and fast way to assess whether or not the requirements engineering processes in a company is inadequate today, or whether other causes are responsible for the aforementioned lack of a complete and adequate requirements specification.

To address this we need a fast and cost effective way to study the status of a requirements engineering process. This initial investigation into the status of requirements engineering in a company need not necessarily be faultless or even exhaustive, instead it should be good enough to give an indication to whether or not a problem exists, and to some extent where the problem areas reside. For this purpose a process evaluation model is introduced, the lightweight model of requirements engineering practices – the *REPM model* [11][1].

In this paper we describe the results from evaluating the requirements engineering process in four companies, using the REPM model. The contribution of this paper is thus as a pilot study into requirements engineering practices in industry as well as the introduction and industrial application of the REPM model. This application is described in detail to illustrate (i) *how* the REPM model was used during these evaluations, (ii) *what* results were obtained, and (iii) *how* the results may be interpreted.

The remainder of the paper is organized as follows. In Section 2 we describe the planning for the case studies conducted and the REPM model, and in Section 3 we describe the execution of the case studies. The results from the study is presented and discussed in Section 4, and the paper is concluded in Section 5.

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[1] The REPM model can be downloaded at http://194.47.142.27

2. Planning

In this section we describe the context in which we conduct the study and the subjects involved, and present the design of the study as well as address validity issues. Furthermore the section holds a brief introduction to the REPM model itself.

2.1. Context and Subjects

The case studies are conducted in industry through in-person interviews by graduate students. The projects evaluated were concluded at the time of the study. This ensures that all of the stages in the RE process are completed at the time of the study.

The case studies involve a total of four companies. We chose to use two medium sized companies, i.e. under 500 employees, and two smaller ones (<150 employees). This to ascertain that the model was tested on both small and medium sized enterprises. The only criterion demanded from the companies selected was that they had projects featuring a customer-developer relationship. Two of the companies are situated in Sweden, and two in Ireland.

These companies were selected because we, or our local contact person on Ireland, had previous relationships with them and because they fit our criteria of large and small companies.

The subjects being interviewed were in senior positions in the projects being evaluated and had knowledge about requirements engineering, and more importantly extensive knowledge about the projects selected for evaluation. The projects' main responsible for requirements engineering was designated "project responsible" for each project evaluation session, but we did not put any limitations on the number of people that were present, as the positive effects of having a discussion with more than a single person in a senior position outweigh any risks that may be involved.

Each of the projects being evaluated was selected by the interview subjects. This made it possible for the companies to avoid questions dealing with projects very sensitive to being exposed to outside parties and also made it possible for them to choose a project that was concluded, of the right sort (customer-developer) and of interest to get evaluated. It is important to realize that the companies participating wanted the evaluation to take place in order to get an evaluation of their requirements engineering process. This alleviated the threat that a "good" project was chosen, i.e. it was in the companies own interest to get a accurate evaluation.

However this way of choosing projects introduces several threats to the study. The sampling is very much tainted by the person choosing the project and it may not be representative for the company at hand - it is a case of convenience sampling. In addition the choosing party can be biased, i.e. trying to portray the company in a positive way. We believe these risks to be small as the project responsible have nothing to loose in being honest and portraying the situation correctly – we informed them at a very early stage that the results of the evaluation would be treated as confidential. In addition the data gathered during the evaluations would have been less usable for the companies themselves if the evaluation was corrupted.

2.2. Study design

The study is based around a series of structured interviews (each interview represents one of the four cases). These structured interviews follow a model of requirements engineering practices that has been constructed by the authors, the REPM model [11]. In this section we briefly describe this model and how to interpret the results from it.

2.2.1. Requirements Engineering Process Maturity Model

To assess the state of the requirements engineering processes in the companies we have constructed a model of good requirements engineering practices. This model, the REPM model, is further presented in A Method for Assessing Requirements Engineering Process Maturity in Software Projects [11]. The model is inspired mainly by the work done by Somerville et. al. in the REAIMS project [12] but also other existing work, such as Sommerville & Sawyer [3] [8] CMM [6], ISO9000 [7], Jirotka & Goguen [2] and Kotonya & Sommerville [5]. The REPM model was constructed by combining these sources with personal experiences and including additional experts from academia and industry in the construction process. All of these sources were thus used to determine what should be included in the model and at what maturity level.

For reasons of brevity it is impractical to include the entire REPM model in this paper. Instead, we describe it briefly below and a summary of the actions included in the REPM model is presented in Table 1. This is mainly intended to give a brief overview so that an opinion of the usefulness of the REPM model can be formed. For detailed information about the model and the contents please contact the authors.

The REPM model mirrors what should be done to obtain a consistent requirements engineering process. The individual tasks of which the model is comprised are called *actions*. Actions are the smallest constituents of the model and are in turn mapped to one of three main categories (called Main Process Areas or *MPAs* in the model). The MPAs are: *Elicitation*, *Analysis & Negotiation* and *Management*.

Every action resides on a certain *Requirement Engineering Process Maturity level* (REPM level) spanning from 1 to 5, where level 1 represents a rudimentary requirements engineering process and level 5 represents a highly mature process. The

actions on each level ensure a consistent and coherent requirements engineering process for the particular maturity level.

The maturity levels enable us to evaluate companies with respect to requirements engineering with a better accuracy than if we simply assume that all actions are equally important. By "base-lining" the actions into maturity levels we can assess that a particular company has potential for a certain maturity in its requirements engineering processes and it enables us to see what actions should be focused on to achieve the particular maturity level.

In Table 1 we see the different REPM levels, the goals associated with each maturity level and the actions presented under the relevant level. The actions are divided into groups by the MPAs of Elicitation, Analysis & Negotiation and Management. It is important to notice that achieving REPM level 1 means completing all the actions under REPM level 1, achieving REPM level 2 involves completing all actions under REPM level 1 and all actions under REPM level 2. Thus in order to achieve REPM level 5 one has to complete all actions presented in Table 1.

Table 1. Action summary, REPM model

REPM Level 1
Goals: 1. Basic requirements specification

	Action Name
Requirements Elicitation	
	Ask Executive Stakeholders
	Technical Domain Consideration
	Executive Stakeholders
	In-house Scenario Creation
Analysis and Negotiation	
	Analysis Through Checklists
Management	
	Document Summary
	Term Definition
	Unambiguous Requirement Description
	Information Interchange Through CARE
	Information handling Through CARE

REPM Level 2
Goals: 1. Introduction of traceability 2. Introduction of validation of requirements 3. Introduction of a standardized structure for the documentation produced as a result of the requirements engineering process, i.e. the Requirements Document 4. Stakeholder identification

	Action Name
Requirements Elicitation	
	Research Stakeholders
	In-house Stakeholders
	Scenario Elicitation - Executive Stakeholders
Analysis and Negotiation	
	Requirements Classification

REPM Level 2
Management

	Requirements Origin Specification
	Document Usage Description
	Requirements Description Template
	Quantitative Requirements Description
	Prototyping
	User Manual Draft
	Requirements Test Cases
	Requirements Identification
	Backward-from traceability
	Backward-to traceability

REPM Level 3
Goals: 1. Application domain and processes are studied and taken into consideration 2. All stakeholders are consulted 3. Dependencies, interactions and conflicts between requirements are taken into consideration 4. Requirement categorization and prioritization 5. Requirements re-prioritization 6. Peer-reviews 7. Risk assessment

Requirements Elicitation	
	System Domain Consideration
	Operational Domain Consideration
	General Stakeholders
Analysis and Negotiation	
	Interaction Matrices
	Boundary definition through categorization
	Prioritizing Requirements
	Re-prioritization – New Requirements
	Re-prioritization – New Releases
	Risk Assessment – selected **OG1.03**
Management	
	Global System Requirements Identification
	Record Requirements Rationale
	Business Case
	Descriptive Diagrams usage - **Opt**
	System Models
	Requirements Review
	Forward-from traceability
	Volatile Requirements Identification
	User documentation
	System documentation

Actions REPM Level 4
Goals: 1. Human domain consideration 2. Business domain consideration 3. Advanced risk assessment 4. Advanced traceability

Requirements Elicitation	
	Human Domain Consideration
	Business Domain Consideration
	Scenario Elicitation - General Stakeholders
Analysis and Negotiation	
	Ambiguous Requirements refinement **Opt**
	Re-prioritization due to Change
	Risk Assessment – individual - **OG1.01**
	Risk Assessment - sets - **OG1.02**
Management	
	Environmental Models
	Requirements Inspection
	Forward-to traceability
	Management documentation

Table 1. Action summary, REPM model

Actions REPM Level 5
Goals:
1. Requirements reuse
2. Rejected requirements documentation
3. Architectural modeling
4. Advanced validation
5. Advanced requirements re-prioritization
Requirements Elicitation
Requirements Reuse
Analysis and Negotiation
Re-prioritization with Regularity
Management
Rejected Requirements Documentation
Architectural Models
System Model Paraphrasing
Version traceability

2.2.2. Structured Interview Design

Based on the REPM model a checklist is constructed, which we use to guide the structured interviews. This checklist takes each action and formulates it as a question which can be answered with one of the three answers: *completed*, *uncompleted* and *satisfied-explained*.

The purpose of the satisfied-explained category is to take model compatibility into consideration. Companies carrying out projects in special environments unlike the traditional customer-developer environment may deem certain actions unnecessary and have compelling reasons for this opinion.

An example can be a company where the developer and the customer both are specialists in a certain domain and hence "speak the same language". The need for extended clarification and validation of requirements may not be needed, e.g. the construction of prototypes can be omitted. Satisfied-explained thus denotes an action that is not completed but the organization doing the evaluation deems the action not applicable to their project.

The organization doing the evaluation makes the distinction when an action is to be considered satisfied-explained. It is important to notice that an action should not be deemed satisfied-explained for reasons like lack of time, lack of money, lack of know-how or just "did not think of it".

2.2.3. Results from Interviews

The results of a project evaluation are presented as four tables, one for each MPA and one summarizing all of the results. An example of such a table is found in Table 2. This table is an example of a summary table for all three MPAs for one project evaluation. We see that the actions for each REPM level are listed separately, and that e.g. REPM level 2 contains a total of 14 actions, of which 9 are completed and 4 are satisfied-explained $(14 - (9+4) = 1$ is uncompleted$)$.

Table 2. Example of Project Evaluation result

REPM level	*Total Actions*	*Completed*	*Satisfied-Explained*
1	10	8	2
2	14	9	4
3	19	11	4
4	11	4	2
5	6	1	4

To assist in the interpretation of the results, we suggest that the results are also presented as graphs, as the example in Figure 1. The graphs represent a simple overview of the results and it is recommended that all results be presented in this way as well. However, due to lack of space, we are unfortunately unable to do this in this paper. The absence of the diagrams should thus not be interpreted as a statement against their worth. A complete list of diagrams can be viewed in [11].

In the graph, the solid gray line represents the total number of actions, the solid black line represents a summary of all actions that are completed and satisfied-explained. The dashed line represents the actions that are actually completed. The area between the dashed line and the solid black line denotes to what extent the REPM model is inapplicable to the project being evaluated (called *model lag*), the area between the solid black line and the gray line represents the area of possible improvement of the RE process.
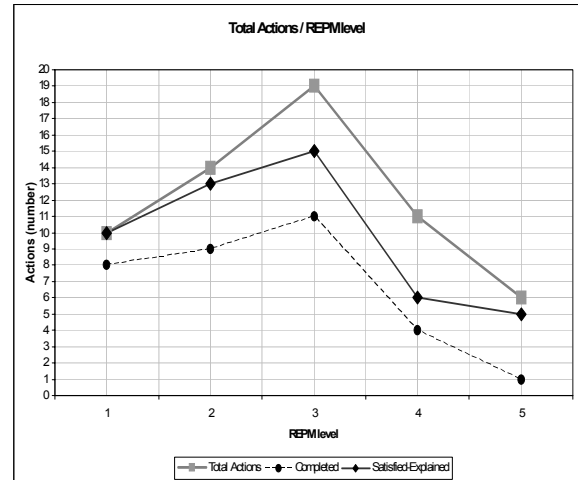
Figure 1. Example of result diagram

The tables and graphs are interpreted as follows. Starting with the first REPM level, if all actions are completed or satisfied-explained, i.e. the solid black line overlays the solid gray line, this level of maturity is achieved. This would mean, if no more REPM levels are achieved, that the company has a consistent and complete requirements engineering process of a low maturity level. This is then repeated for each of the REPM levels. Note that all lower REPM levels

must also be completed before a certain REPM level is achieved.

In Table 2 and Figure 1, for example, we see that REPM level one is achieved and only one action more is required to achieve REPM level two, whereas four more are required to achieve level three. Strictly speaking, this project would be considered to be on REPM level 1, but as only one action is necessary to get it up to level two this is the level that we think this company should aim for in a first step. This would ensure a consistent requirements engineering process that is fairly basic but may be sufficient for this company's needs.

2.3. Validity evaluation

In this section we discuss the threats to this investigation. We base this on the discussion of validity and threats to research projects presented in Wohlin et al. [13].

2.3.1. Conclusion validity

Four cases are inadequate for statistically sound generalization purposes. However, this is not the main intention of this study. The main intention of this study is to serve as a pilot project to see whether it is possible to assess the state of requirements engineering practice using the REPM model, and to possibly provide some early results as to what areas within requirements engineering are subject to most problems.

The checklist used for the case studies (structured interviews) was validated through preliminary testing and proofreading by several independent parties, this to avoid factors like poor question wording and erroneous formulation.

Each case study interview was conducted without any break. Thus the answers were not influenced by internal discussions about the questions during e.g. coffee breaks.

The sampling technique used, i.e. convenience sampling, can pose a threat to the validity of the investigation. The companies selected are not necessarily representative of the general population of software development companies, on the other hand there is no evidence that they are not.

2.3.2. Internal validity

Prior to the interviews the subjects had access to the REPM model so that they could acquaint themselves with the model (see Section 2.2.1) In addition the REPM evaluation checklist was explained before it was used. These steps were taken to avoid problems with maturity, i.e. that the first questions would act like a learning process and thus be answered with a different presupposition than the remaining questions. The preparation described was executed in an identical manner for each of the four case studies. We did not encounter any problems with this due to the fact that the subjects being interviewed had similar backgrounds, i.e. experience in the field of requirements engineering and software development.

2.3.3. Construct validity

The REPM model itself can be a threat to the investigation. If the model is unsatisfactory when it comes to content and/or structure it follows that the result of each case study (and thus the investigation) may be threatened to the same extent. Another important point is the usage of the model by the investigators and by the interview subjects. Using the REPM model as a tool in a manner not consistent with the initial intent may diminish the result obtained through the usage.

To reduce these risks the REPM model and the checklist were validated before the case studies were conducted. The validation was two-fold. First the model was scrutinized by the creators and an independent expert from academia. The second round of validation was conducted by an independent expert from industry. During the validation process the models structure and contents was modified when appropriate.

3. Operation

Having prepared the model, the checklist and a way to present the results, the next step consists of contacting companies and actually conducting the study. In this section we describe this, starting with the preparations and continuing with experiences from the actual execution.

3.1. Preparation

A copy of the REPM Model was sent to the interview subjects in advance. This to give all people involved a chance to study the model and its constituents in order to prepare them for the work during the project evaluations and to note any questions they wished to address.

In addition to this the participating companies were asked to choose a project to be evaluated and instructed that the project should be of a customer-developer type, i.e. not an internal development project but featuring an external customer. This due to the fact that the REPM model at this stage of its development is adapted primarily for these types of projects. In addition we asked the person(s) mainly responsible for the requirements engineering process for the projects selected to be present as the interview subjects at the project evaluation session.

The interviews in Ireland were preceded by personal contact and emails to prepare for the evaluation.

3.2. Execution

At the initial stage of the interview the basic layout of the evaluation was explained. Information about how the Project Evaluation Checklist version 1.4 (can be obtained from the authors) is structured, and how it is connected to the REPM model was provided. In addition we asked the people evaluating the project to "think-aloud" when answering the questions. An important thing we clarified was the concept of satisfied-explained actions, i.e. that the model may not suit all projects and that this concept was introduced to compensate for that fact.

All interviews were made on-site and in person. We find in-person interviews beneficial in several ways. It is often possible to extract more information as well as avoiding misunderstandings. However there can also be negative aspects like the interviewer influencing the interviewees [14] [15]. By strictly adhering to the pre-planned structure of the interview and only deviating when further explanations were necessary, we believe that the risk that this has occurred is low.

Each case study interview was estimated to take between 1.5 to 2 hours. This was based on an earlier test interview conducted using a software engineering post graduate student. The time spent on the interviews mirrored our estimation.

During the interviews we were somewhat surprised by the tendency for the subjects to engage in discussions related to the topic of requirements engineering in general and more specific topics as the questions reflected certain actions. We tried to steer the interview towards completing the checklist but did not categorically refuse to discuss matters. More often than not the discussions helped to clarify different points, and often the discussions were more or less one sided, i.e. the interview subjects discussed matters to clarify their own trail of thought to themselves before answering a question. We only got involved in the discussion when necessary, trying not to influence the answers by adding information not already present in the model and/or in the checklist. We took this decision to ensure that each interview subject received the same amount of information, so as not to change the conditions of any one interview in comparison with another.

3.3. Data validation

During the interview the subjects discussed their answers aloud as the questions were answered. This helped us catch misunderstandings, and if necessary we clarified the relevant questions in an effort to elicit a relevant answer to the question at hand.

All of the answers are included in this investigation. Our goal is to ascertain the status of the requirements engineering process in companies today, therefore all answers are relevant. Four case studies, and thus four interviews, were conducted. They are all presented in the study, no case studies were disqualified due to reasons such as lack of conformity.

4. Analysis and interpretation

In this section we present the results from the case studies (each case study is represented by one project). We do this in four tables, one for each project/case study. As mentioned earlier, it is easier to analyse the data if the results are presented as graphs in the same form as the examples in Figure 1. Due to lack of space, we are unfortunately not able to do this here, and instead refer you to [11], where these graphs are available.

We refer to the different projects as project alpha, beta, gamma and delta respectively. Projects gamma and delta are from what we consider small companies.

4.1. Presentation of results

In this section we present the results from the case studies (each case study is represented by one project). We do this in four tables, one for each project/case study. We refer to the different projects as project alpha, beta, gamma and delta respectively. Projects gamma and delta are from what we consider small companies.

In Table 3 we see the data from project alpha, and in Table 4, 5 and 6 we see the data from project beta, gamma and delta, respectively.

These tables are read as follows. There are four groups of data, each containing three columns. These columns list the total number of actions on each REPM level, the number of actions completed and the last column lists the number of actions satisfied-explained for the REPM level. The first group of three columns is a summary of the following three groups, which are the actions within the MPAs Elicitation, Analysis and Negotiation and Management, respectively.

We see that no project fulfils even REPM level 1. However, if we count those where only one or two actions are missing, we see that project alpha is close to REPM level 1, project beta close to level 2, project gamma close to level 1, and project delta close to level 2. We also see that project beta has potential for being on level 5, and that the others probably would benefit from completing the remaining actions for their respective REPM level and aim for REPM level 3. Level 3 represents a requirement engineering process that is fairly advanced and not just the bare basics, while still being streamlined and suitable for many software organizations.

Table 3. Project alpha

REPM level	Action Summary			Elicitation			Analysis & Negotiation			Management		
	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained
1	10	8	0	4	3	0	1	0	0	5	5	0
2	14	8	2	3	1	1	1	1	0	10	6	1
3	19	12	2	3	2	1	6	4	0	10	7	0
4	11	6	1	3	1	1	4	2	0	4	3	0
5	6	2	0	1	0	0	1	0	0	4	2	0

Table 4. Project beta

REPM level	Action Summary			Elicitation			Analysis & Negotiation			Management		
	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained
1	10	8	1	4	4	0	1	1	0	5	3	1
2	14	10	2	3	2	1	1	1	0	10	7	1
3	19	15	1	3	3	0	6	5	1	10	7	0
4	11	9	1	3	2	1	4	3	0	4	4	0
5	6	4	0	1	1	0	1	1	0	4	2	0

Table 5. Project gamma

REPM level	Action Summary			Elicitation			Analysis & Negotiation			Management		
	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained
1	10	8	0	4	3	0	1	0	0	5	5	0
2	14	7	0	3	2	0	1	1	0	10	4	0
3	19	13	1	3	3	0	6	3	0	10	7	1
4	11	3	2	3	0	1	4	2	0	4	1	1
5	6	1	1	1	0	1	1	0	0	4	1	0

Table 6. Project delta

REPM level	Action Summary			Elicitation			Analysis & Negotiation			Management		
	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained	Total Actions	Completed	Satisfied-Explained
1	10	9	0	4	4	0	1	0	0	5	5	0
2	14	9	4	3	2	1	1	1	0	10	6	3
3	19	11	4	3	3	0	6	1	3	10	7	1
4	11	5	3	3	3	0	4	0	1	4	2	2
5	6	3	1	1	1	0	1	0	1	4	2	0

4.2. Analysis of Results

First, we always recommend a homogenous REPM level across the three MPAs. The reason for this being mainly dependencies. If a project's requirements

engineering process resides on REPM level five when it comes to the MPA of *Requirements Elicitation* but only on level two in the other two MPAs this would not be a consistent and coherent requirements engineering process. Moreover, in many cases actions under one MPA are dependent on other actions being completed under another MPA.

In this respect, none of the projects succeed. The process area where all of the projects fail is that of *Requirements Management*. There are several reasons for this. Requirements Management is the largest MPA, i.e. housing the largest number of actions, and thus there is more to complete for this area. Moreover, this area contains actions which are notoriously difficult to accomplish in an efficient way, such as traceability and change policies. We are also quite stringent in how we think a requirements document should be structured and the individual requirements written which is reflected in the REPM model under requirements management where the actions for requirements documentation are included.

Assuming that all organizations should strive for at least REPM level 3 there are several actions that two or more projects need to complete. These are:

- In *Elicitation*, the action *In-house Scenario Creation (REPM level 1)*. This action is concerned with creating scenarios for elicitation purposes but to only consult the developers in the projects. As there are other actions where stakeholders are consulted and none of the projects fail to do this, the companies may think that if stakeholders are consulted it is not necessary to consult the developers.

- In *Elicitation*, the action *Research Stakeholders (REPM level 2)*. Who the stakeholders are is researched during this action. This can help identify groups that are affected by the requirement, and thus the basis for gathering information about a requirement is wider if the action is performed. That this action is not done may stem from a trust that the customer provides information regarding all stakeholder groups as this is in the best interest of the product and hence the customer. The development companies may forget who it is in the customer-developer relationship that has experience with requirements engineering.

- In *Analysis and Negotiation*, the actions *Analysis through Checklists (REPM level 1)* and *Interaction Matrices (REPM level 3)*. Analysis through checklists refers to having standardized checklists that are used to ensure certain standardized qualities of each requirement. Interaction matrices are constructs that can help catch requirements dependencies, conflicts or other interactions between requirements. These are very simple tools that can help catch problems with

requirements at an early stage, and we are surprised that this is not done in all companies.

- In *Analysis and Negotiation*, the action *Risk Assessment – Selected (REPM level 3)*. This action is part of a group of actions, of which one, but only one, must be completed. The remaining actions in this group are on REPM level 4, so this is the least possible amount of risk management that should be done with respect to requirements analysis and negotiation. What it means is simply that certain requirements are, based on intuition, identified as being extra prone to risk and then a risk assessment is performed for these requirements.

- In *Management*, the action *Quantitative Requirements Description (REPM level 2)*. With this action we mean that all requirements – especially quality requirements – should be specified such that they can be measured. Quality requirements are a notoriously difficult subject that is still the subject of much research. It is thus not surprising that the companies reflect the amount of uncertainty in the research community regarding quality requirements and their quantifiability.

- In *Management*, the actions *Requirements Review (REPM level 3)* and *User Manual Draft (REPM level 2)*. These two actions are concerned with validating the requirements. The second of these two actions suggests that an initial user manual is written based on the requirements, which serves as an informal walkthrough of the requirements. That this action is not completed in two of the companies may simply be that they have not thought of it.

- In *Management*, the action *Document Usage Description (REPM level 2)*. Different user groups often use the requirements document in different ways. A document usage description is a manual aimed at aiding different users of the document, helping them use and navigate the document. This may often be forgotten as it seems obvious to those writing the document how to read it.

- In *Management*, the action *Backward-to Traceability (REPM level 2)*. This action links the design and implementation back to the requirements. That this is not done may be a result of waterfall-inspired development methods. If previous development steps such as requirements engineering is never re-visited, what is the point in tracing the requirements backwards. Moreover, many companies may not update the requirements specification if the design and implementation deviates from what is specified.

4.3. Summary and Interpretation of results

Only 9 of the 43 actions up to REPM level 3 are not completed by two or more projects. However, many of the uncompleted actions are quite severe, and we are surprised that they are not done in all companies. For example, risk assessment seems to be a neglected area, and interactions between requirements do not appear to be mapped, which of course can cause severe problems if there are in fact conflicting or volatile requirements. Also, we are surprised that companies still spend time and effort on stating requirements without providing a measurement, as there is no way of telling when the requirement is fulfilled if this is not done. As mentioned quality requirements, where this is most often missed and required the most, is a subject with much research focus and methods are still needed for quantifying these quality aspects of software systems.

The size of a company does not seem to have a direct correlation to the maturity of the requirements engineering process to the extent believed initially. If we look at project alpha and beta approximately 68% (for project alpha) and approximately 85% (for project beta) of all the actions are fulfilled. The numbers for gamma and delta (the smaller companies) are 60% and 81%, respectively. At an initial glance the numbers seem very much comparable, even if the larger companies have a small advantage. To see the whole picture however one has to take the amount of actions deemed satisfied-explained under consideration. In project alpha, beta and gamma the number of actions in this category seem to be a fairly constant 8%, whereas in the case of delta the number of satisfied-explained actions is 20%. It is vital to understand whether the latter figure is the result of model inapplicability (See Section 2.2.1) or not, in order to find out whether project delta is representative as a small company project or not.

If the number has another reason than model inapplicability this may indicate a distinct line between medium sized and smaller companies when it comes to requirements engineering. The projects in this study were chosen with the same criteria in mind, and thus should be generally compatible when it comes to model applicability. A widened study, involving more companies is necessary to understand whether this distinction between medium sized and smaller companies exist.

The MPA of *Requirements Management* is generally the one needing most improvements, i.e. the MPA with most actions not completed. There are several reasons for this. As mentioned Requirements Management is the largest MPA, i.e. housing the largest number of actions, and thus there is more to be completed. Another reason may be that the actions under this particular MPA are fairly advanced, i.e. on

a higher REPM level relative to the total number of actions. An example of this is that there are more actions under the MPA of *Requirements Management* on REPM level 5 than there are under the other MPAs in total.

5. Conclusions

The main purpose of the investigation presented above was to (1) to give an idea of the problem scope pertaining to requirements engineering practices in industry, and (2) test a method for quickly ascertaining the status of requirements engineering in companies. This was done through the design of the REPM model, which in turn was used for the investigation.

Firstly, if we look at results gathered from the four cases they may of may not be generalizable to a larger set of companies, i.e. if replications of this study show similar results, there are several ways to react to this, depending on what audience one belongs to.

For researchers, the question seems to be to find effective and attractive methods for risk assessment and for requirements management. For development companies, the reaction should be to first assess whether the very simple actions are done, as we believe this would vastly enhance the quality of the resulting products and, above all, reduce the risks involved.

For companies participating in an evaluation such as the ones presented above, the results should be analyzed to decide whether or not there is an indication of a problem. The second step is then to study the evaluation, examine the improvement suggestions and the conclusions drawn for inaccuracies and/or neglected parts. It is also important to scrutinize the actions deemed to be under the category of Satisfied-Explained to ensure that they are put there for the right reason. After the evaluation review a plan should be constructed based on the improvement suggestions and improvement consequences. This plan should state what measures should be taken. One way proceed is to order a more comprehensive and exhaustive examination of the requirements engineering process using the results from the REPM model evaluation as a first insight to where the problems may reside. Another way to go is to use the REPM results purely as a basis for deciding on a more thorough investigation. In the latter case the results from the two investigations could be validated through a subsequent comparison.

Secondly, if we look at the REPM model itself and the use of it in the four cases there are two main parts, namely the gathering of the data using the Project Evaluation Checklist (see section 0), and the evaluation and interpretations of the results (see section 4).

The main point in constructing the REPM model was to get a fast, easy and cost effective evaluation of a requirements engineering process. During the industrial application of the model the gathering of the data took no more than eight person-hours per project. The subsequent analysis of the data took approximately 30 to 40 person-hours per project. This gave us at most 48 person-hours in cost for the REPM evaluation of a project, which can be considered to be fast.

In this paper a fairly detailed description was presented of how the industry cases (projects) were evaluated. During the gathering of data the actions were deemed as belonging to one of three categories, i.e. Completed, Uncompleted or Satisfied-Explained (see section 0). The diagram example presented in section 2.2.3 gives information of how result diagrams could be constructed to give an overview of the process (as well as parts of the process), and how the data could be evaluated and interpreted is presented in sections 4.2 and 4.3. One could go so far as to claim that the collection of the data is fairly easy using the Project Evaluation Checklist. The analysis and interpretation of the results on the other hand does demand some expertise in the area of requirements engineering, although the complete REPM model offers some insights into the area.

Whether usage of the REPM model is cost effective or not is of course dependent on how accurate and exhaustive the gathered results are. As mentioned before emphasis was put on speed and ease, not exhaustiveness. If we look at the results from the case studies quite a few indications point to areas of possible improvements. However this does not give any information about things potentially missed. In our experience the REPM model provides an indication of problem areas that should be scrutinized further. An REPM evaluation could be used to develop a plan for what steps to take in order to improve a requirements engineering process, though it is important to realize that the REPM model is lightweight, and an evaluation taking 48 person-hours is bound to overlook issues.

It is also important to notice that the REPM evaluation is project based. If a company has a "generic" (typical) project to evaluate one instance may suffice. On the other hand most companies may need to evaluate more than one project in order to get an accurate (and more exhaustive) picture of their RE process, this is especially true for companies without a standardized and repeatable process.

As the results from the cases were presented to each of the companies the general view was that some of the results gathered were already more of less known, but for the most part the REPM evaluation results were seen as valuable insights in the respective company's process offering an indication that further study was warranted.

5.1. Future work

This study serves as a pilot study as far as ascertaining (1) the problem scope pertaining to requirements engineering practices in industry, which is the reason why only four companies have participated. In order to gain real understanding of what is done and what is not done in industry today, an extended study involving a larger set of companies needs to be performed. We also need to further understand the relation between what is considered an inadequate requirements specification and the connection between this and the maturity of the requirements engineering process at large.

We encourage others to design and execute similar investigations on their own, as there is a clear and present need for knowledge about the status of requirements engineering in industry today.

(2) If we look at the REPM model there is a need for further evaluation, refinement and validation. There is also a need to validate results gathered with the REPM model by using another approach (other model/method). This would provide further information on of how accurate and cost effective the REPM model is, as well as how the REPM model can be improved upon.

(3) A study of how the results from a REPM evaluation can be used in further and more detailed RE process evaluation is also warranted. I.e. how to use the REPM results obtained to take the next step, either towards further evaluation or maybe even a the creation of an adequate improvement plan.

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