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Research Report 1

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A State-of-the-Practice Survey on Requirements Engineering in Small- and Medium-Sized Enterprises

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ABSTRACT

Technology transfer to small- and medium-sized enterprises has failed to achieve its full potential in the requirements engineering (RE) field. Most companies do not know how to start their RE improvement efforts even if they are aware of the problems in this field. The state-of-the-practice survey presented in this paper gives a realistic view of how marginal technology transfer from the research community to the industry has been. It also reveals that the key development needs in industry are (1) development of own RE process adaptations, (2) RE process improvement, and (3) automation of RE practices. Directing efforts to these areas would substantially improve the chances of successful technology transfer and process improvement efforts in industry.

Keywords: Requirements engineering, software engineering, software process improvement, technology transfer

1. INTRODUCTION

Discussions with industry representatives about software engineering (SE) and process improvement often lead to questions about applicable “best practices”. It is clear, though, that best practices in the research community and industry are quite different. But what keeps industry from adopting the best practices in academia?

Practically all textbooks on SE present software development paradigms which include the generic phases of requirements, design, implementation, and testing. Most of them (e.g. (Pfleeger 1998; Sommerville 1995)) also contain a proper treatment of requirements engineering (RE). In addition to general SE textbooks there is also a lot of RE specific literature available (e.g. (Gause and Weinberg 1989; Jackson 1995; Kovitz 1999; Robertson and Robertson 1999a; Sommerville and Sawyer 1997)). Thus there is lots of information available on solid RE practices but anecdotal evidence still indicates poor practices.

The situation in the whole SE field has been similar: even though a lot of literature is available, transfer of that knowledge into practice has been problematic. However, after the process improvement topic was introduced in the form of a software capability maturity model (CMM) (Humphrey 1989) over a decade ago some tangible improvement has been recorded. The Software Engineering Institute has published the

CMM maturity profile (SEI 1999) since the early 90's and the trend for the maturity levels during the past decade looks promising. The number of companies at the initial level has decreased from 80% to 53% while the companies in repeatable and defined levels have roughly doubled to 28% and 15% respectively. Based on these experiences in the general SE field, the RE field can also hope for noticeable improvement in industrial practices in the long run. The key issues in accelerating this improvement are to first identify the areas that need most improvement and then find the best ways to support industry in developing these areas.

To study current RE practices, development needs, and preferred ways of technology transfer, we interviewed twelve software companies. The questions addressed basic issues of RE knowledge to further prepare for future technology transfer efforts. Since only twelve companies were interviewed the results are not suitable for statistical analysis. The survey was, however, based on a structured questionnaire to collect objective and measurable information to complement the current state-of-the-practice surveys in RE that report only little statistical data. Even if the sample size of our survey does not allow us to utilize the numerical data to its full potential, we feel that it helps to assess the current state-of-the-practice in a more objective way than merely qualitative studies. Thus we would also like to encourage quantitative studies in the RE field in the future.

The rest of the paper is structured as follows. Section 2 discusses the related research on this topic. Section 3 describes the research methods used and Section 4 the results of the survey. Section 5 includes the discussion and Section 6 the conclusions with the key findings of the survey.

2. RELATED RESEARCH

The first field study of the software design process for large system development projects was published in 1988 by Curtis, Krasner, and Iscoe. The study was initiated from the software engineering viewpoint but it "focused on how requirements and decisions were made, represented, communicated, and changed, as well as how these decisions impacted subsequent development process." As a conclusion the authors state that knowledge sharing and integration, change facilitation, and broad communications and coordination were the three key issues impacting the project success. Lubars, Potts, and Richter (1993) interviewed ten organizations to find out how they defined, interpreted, analyzed, and used requirements. Their results concluded that organizational solutions were preferred over technological ones and general-purpose tools were more common than special purpose tools in RE. El Emam and Madhavji (1995) studied RE processes and found seven key issues that must be addressed in a successful RE process improvement effort: package consideration, managing the level of detail of functional process models, examining the current system, user participation, managing uncertainty, benefits of CASE tools, and project management capability.

One of the larger projects in the RE field was the REAIMS project in the mid 90's. One of the project achievements was a RE process maturity model definition that can be used to assess current RE processes. This model has been published (Sommerville and Sawyer 1997) and it is one of the main starting points for our survey. The REAIMS model provides a ready template for doing RE practice assessments. However, so far no papers have been published using the model as a reference model.

Recent studies in RE and technology transfer have been published by Morris, Masera, and Wilikens (1998), Kamsties, Hörmann, and Schlich (1998), and Fowler et al. (1998). Morris et al. used a workshop setting for their studies of RE and industrial uptake and report that the key problems are training, inherent complexity, internal business integration, and business culture. Their main recommendations to improve the situation were support for the discipline, project flexibility, proposal acceptance, and project relevance. Kamsties et al. also used a workshop environment in their study of the RE practices in small- and medium-sized enterprises (SMEs). At the end of the workshop participants were asked to rank six different topics in order of relevance and priority to their own environment and development plans. The most relevant topics were modeling, improvement of requirements document, inspections, and tools. The first priority was clearly given to modeling while requirements document, inspections, and tools were considered equally important. It was also noticed that most SMEs do not have extensive requirements documents – a fact that was also recorded by Lubars et al. The Fowler et al. study concerned technology transfer with a "transition package" in the requirements management (RM) area. The authors developed a prototype web site containing RM related materials that the companies could access and utilize for their own process development tasks. Most of the people utilizing the site did not have a defined RE process and seemed also in many other ways to be quite in the initial stages of their development efforts. General information on RM was the most accessed type of documents and many participants expressed a need for a primer for RM – where to start and how to proceed in different organizational settings.

Other related research in RE practices include the studies by Regnell, Beremark, and Eklundh (1998), Tvete (1999), and Weidenhaupt et al. (1998). Regnell et al. describe a process improvement effort in one company, their positive results, and the new challenges confronted after the deployment of the process. Tvete describes experiences in defining the RE process, selecting and introducing RM in a company, and related problems during the project. Weidenhaupt et al., on the other hand, did an extensive state-of-the-practice survey on scenarios and their usage in RE.

3. RESEARCH METHODS

The companies for our survey were selected so that they represent different application areas, sizes, ages, etc. Thus the survey gives a general overview of different kinds of companies and their attitudes to RE. Even if this approach leads to a situation were the companies are not fully comparable, it was selected since it gives an idea of the development path from a start-up to a large software company.

The questions for the survey were selected mainly from the RE literature (IEEE 1998; Jackson 1995; Sommerville and Sawyer 1997). Background information about the companies, projects, and products played an important role in the survey. The survey was completed with questions about the ways the companies would like to improve they current practices. All these questions were compiled to a four-page questionnaire form and it was used to guide all the interviews. Most of the questions were multiple selection ones or could be answered with few words but few open questions were also included to provide the interviewees with the possibility of expressing their own viewpoints. Since the survey was quite extensive, not many interviewees utilized this opportunity, however.

All the interviews were conducted by the first author of this paper. The interviews consisted of an introduction to the topic lasting from 15 to 30 minutes and the question and answer part of the interview which lasted from 1 to 4 hours with an average of about 1.5 hours. All the interviews took place on company premises. Since the goal was to get an overview of current practices and development needs, interviewees with a company-wide role and knowledge of high level practices were sought.

The interviews were documented on a structured questionnaire form and tape recorded. The discussions were lead by the interviewer and all the topics were explained in more detail when necessary. In most cases the form was filled in by the interviewer.

4. RESULTS

Section 4 explains the findings of the survey. Section 4.1 describes the companies that participated in the survey, 4.2 the projects they did, and 4.3 the products they were producing. Section 4.4 describes the current RE Practices and 4.5 the development needs. Section 4.6 explains the expectations of RE research in academia and finally 4.7 closes the section with miscellaneous questions.

4.1. Companies

The companies (*n*=12) were located in six different cities in Finland. Three of the companies were 1 to 5 years old, six were 6 to 11 years old, and three were over 12 years old. The number of employees in 1998 varied from four to over one thousand. Three companies had 4 to 10 employees, five had 11 to 50, and four had over 150 employees.

All the interviewees (*n*=15) had company wide roles. Four were development directors or managers, three chief executive officers, three quality directors or managers, one process developer, and one solution manager. All the interviews were done with the key person but in three cases other people supported the interviews with detailed or background information on specific topics.

The software business was the only business field for eight of the companies. The other four companies had some related business (related hardware, services, and/or consultation), which formed in two cases a smaller part of the business (15% and 40%) while in two cases they formed the majority of the business (67%). Seven companies had net sales of software from 0.3 to 1.7 MEUR, three had 1.7 to 17 MEUR, and two had over 17 MEUR. Only two of the companies did not measure as a SME according to the EU definition (250 employees and 40 MEUR).

The companies operated in seven application domains that were not exclusive. Three companies indicated that their application domain was *industrial systems or applications* and for two of them more specifically *control software*. Three companies were in the *telecommunications* field, two in *data security*, and one in both the *software engineering tools* and *digital media* fields. Seven companies developed *business information systems*.

The most common operating environment was *international sales*, which was indicated by eight companies. The second biggest group was *international development* with three companies. The smallest group was *domestic only* –operation with only one company.

Nine companies used *internally accepted* processes. Two companies had *informal internal processes* and only one company had an *audited quality system.* Most of the companies did not recognize the capability maturity model at all and none had had their maturity assessed by an outside party. Three companies gave their own assessment of their maturity: two in level 1 and one in level 3.

4.2. Projects

The second set of background questions concerned the projects the companies were involved in. The options provided were not exclusive.

The project type referred to the kind of software the company developed. Ten companies did *custom software projects*, seven produced *commercial products* (commercial off the shelf or COTS), and five did *components based projects*. The project starting point was in eleven cases customer requirements (requirements driven) and in five cases technical possibility (architecture driven).

The project sizes varied a lot for the selected companies, both as the effort in man months (MM) and duration in calendar months. Nine companies gave both minimum and maximum estimates and nine companies gave only typical values. The minimum efforts for a project with a project plan were 1 MM (four companies) and 2 MM (three). The most common maximum efforts were between 20 and 50 MM (four) and the typical effort was 12 to 36 MM (six). Less common estimates included a minimum effort of 30 MM and maximum of 1200 MM, while three companies had over 100 MM maximum efforts. However, all the typical estimates were in the range from 3 to 120 MM.

The typical project duration was from 6 to 12 months (six). The minimum duration was 1 to 2 months for six companies and the maximum varied from 6 to 24 months (seven). Less common values were a minimum duration of 6 months and maximum of 2 or 60 months. All the typical projects lasted 2 to 24 months.

Only nine companies named their software development paradigms. The most common one was the *object-oriented* approach with six companies, while four used the *evolutionary* and two *function driven* approaches. Four companies selected the *other* option and no company in this group subscribed to the *data-driven* approaches.

The lifecycle models were specified by eight companies only. The most common lifecycle model was the *evolutionary approaches* with five companies. Four companies used the *waterfall model* and two had *spiral or incremental* models in use. Five companies chose the *other* option.

The most common specialist role for team members was *designer for user interface, database, or alike* that was present in seven companies. The next most common specialist groups were the *technical writers* and *systems analysts*, both found in six companies. Three companies had *testers* and five did not have any such specialists but *all developers* was true for them. Figure 1 shows the team member roles graphically.

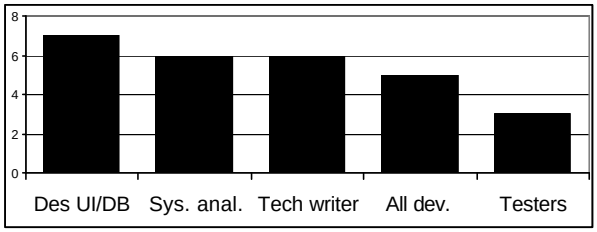

Figure 1. Team member roles in the companies.

The most commonly used tool in the interviewed companies was a *configuration management* tool with ten companies. Eight companies used some special *testing* tools and four had *CASE* tools in use. No company had *requirements management* (*RM*) tools in use. Figure 2 shows the tool usage in graphical format.

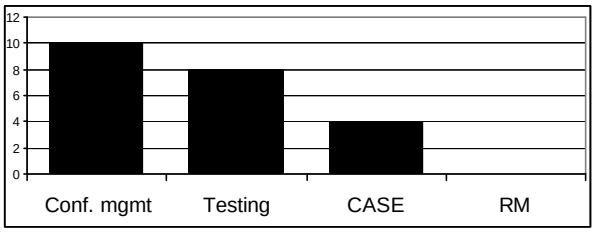

Figure 2. Tool usage in the companies.

4.3. Products

The third set of background questions concerned the software the companies developed. The lifetime of the software was recorded both for a release and for the whole product. With the evolutionary changes the whole product was considered changed when most of the code had been changed. Six companies estimated the lifetime for a release to be 6 months, three from 12 to 24 months, two from 1 to 1.5 months, and one did not provide any estimate. The product lifetimes can be categorized in three groups with four companies in each group: 1.5–2 years, 5–7 years, and over 10 years.

Few companies (*n*=9) had a clear idea of the number of people that used their software. The biggest group with four companies expected hundreds of users (100-500) and three expected thousands (1000-5000). Single companies estimated millions of users and 60 users.

The amount of code was recorded in lines of code. The code line counts varied from ten thousand to one million lines with seven estimates between 10 and 60 thousand lines. C, C++, and Java were used in multiple companies (three each) and the following languages were each used by one company only: Delphi, SmallTalk, SQL Windows, and TSQL. Two companies did not specify any language since it depended on the project; three companies specified two languages.

The price estimates varied a lot. This is only natural since the companies were involved both with project and product businesses and the projects and products varied a lot. To manage these differences each company was asked a typical price and a reasonable range for the prices. Four companies did not give estimates for minimum and maximum prices and three companies left the typical price open. Three companies gave a typical price for their software products and they were from 100 EUR to 17 KEUR. The minimum price for the projects was 3.3 KEUR for two companies and 20 to 580

KEUR for three companies. The maximum prices for the projects were all different with values from 0.8 KEUR to 1 MEUR. The typical price for the project was different for all and the values ranged from 2.3 to 830 KEUR.

The number of variants was divided into two parts: the number of different operating systems (*n*=11) and other supported variants (different languages, customer specific versions, etc.) (*n*=11). Four companies supported only one operating system, another four had three supported operating systems, and single companies had 4, 5, or 10 operating systems each. For other variants the most common answer was 0 with seven companies, two companies had 2 variants, and single companies had 10 and 11 supported variants. In one case the number of both supported operating systems and other variants was so case dependent that it was not estimated. In eight cases only a single source code existed and four of them supported more than one operating system.

4.4. Current Requirements Engineering Practices

The current requirements engineering practices in the companies were determined with 35 multiple-choice questions and three other questions. The multiple-choice questions had the same four options as in the REAIMS maturity model (Sommerville and Sawyer 1997): never applied, applied at the discretion of the project manager, normally applied, and applied as a standard practice in the company.

The first question was the number of requirements. Since there is no standard definition for such a number the question was "if all the things that a developer must consider when she starts to design/code the software were written in one list, how many items would it contain?" Since none of the companies had a definite answer to this question three categories were used: tens, hundreds, and thousands. Seven companies estimated the requirements count to be in tens, four in hundreds, and one in thousands. The two open questions offered a possibility to define the used requirements document format and RM method in more detail. Only three companies used this option: one used only a database as their requirements document format, another used their change management and tracking system, and the third one used email as the RM method.

The questionnaire contained also the 13 fields from the Volere requirement template (e.g. description, rational, fit criterion, customer satisfaction, etc.) (Robertson and Robertson 1999b). However, only two companies used requirements templates in a standard manner and two at the discretion of the project manager. Thus only the use of requirements templates and the use of unique identifiers for the requirements are shown in these results.

Figures 3-5 show the results of the current RE practices in the interviewed companies. Figure 3 shows the results related to the requirements document style and contents, Figure 4 the use of different RM methods, and Figure 5 the general guidelines for RE practices. As can be seen the standard application of various practices is quite rare. Only natural language was used in a standard manner in more than one third of the companies and no company used formal methods, did the requirements document in hypertext format, or used commercial tools for managing requirements.

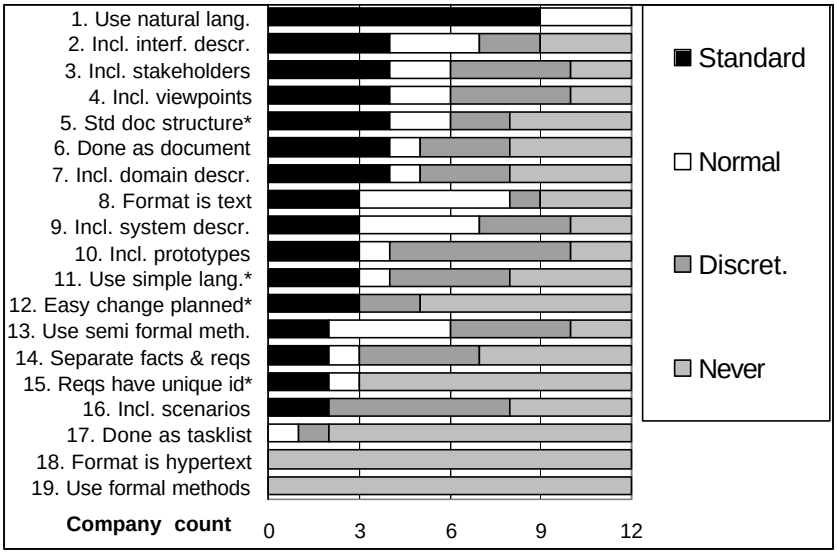

Figure 3. Requirements document style and contents questions in Pareto order. The items with an asterisk are the REAIMS Top Ten practices.

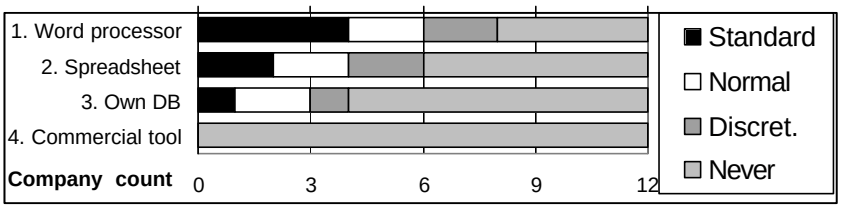

Figure 4. Use of different RM methods in Pareto order.

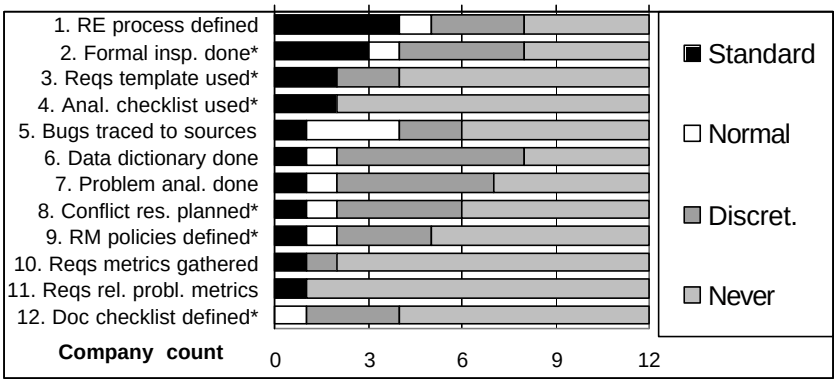

Figure 5. General RE guidelines in Pareto order. The items with an asterisk are the REAIMS Top Ten practices.

Figures 3 and 5 include an asterisk in ten items. These are the REAIMS Top Ten practices that were embedded in the questions. The full REAIMS maturity assessment includes 66 different questions and from the outset these questions seemed too advanced for our assessment. Thus we decided to explore the REAIMS model with only the top ten practices. These practices are shown in Figures 3 and 5 that show how common the practices are. The sums of the REAIMS Top Ten points for the interviewed companies are shown in Figure 6.

The point gains were calculated as follows. First the selected options were scored according to the REAIMS instructions: standard use was scored with 3, normal with 2, discretion with 1, and never used with 0 points (Sommerville and Sawyer 1997). The full REAIMS model divides the practices into basic, intermediate, and advanced ones

and calculates the maturity using also this division. On the other hand, though, the REAIMS authors say that the top ten practices should be applied by all companies irrespective of their maturity level. Thus we decided to do a quick assessment just by summing up the top ten practice points and use it as an indication of the maturity. Figure 6 shows the total points for the companies in this survey; clearly most of them still have a lot of room for improvement.

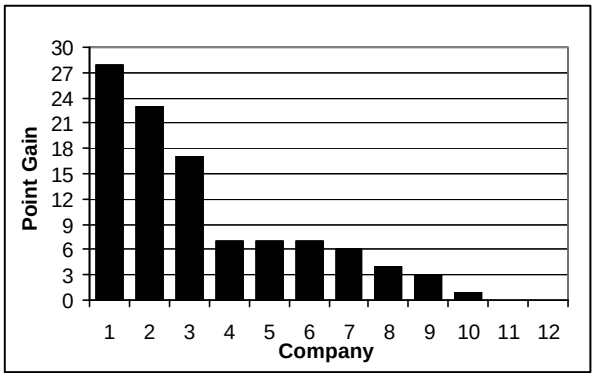

Figure 6. REAIMS Top Ten -point gains for the companies. The maximum number of points was 30; the best result was 28 points and two companies did not get any points.

4.5. Development Needs

Development needs in the RE area were sought with 37 multiple-choice questions. The options for each question were *definitely not needed*, *not needed*, *currently OK*, *development needed*, and *definitely needed*. The *currently OK* –option generally means that the given topic has not been observed as problematic or needing improvement. The *not needed* answers indicate that the topic is not relevant for the given company or that an improvement effort has been made in that area and no further actions are needed there. The *needed* answers indicate an acknowledged need for improvement or problems in the given area.

It was requested that the evaluations were made fairly quickly. A detailed analysis would probably lead to somewhat different results but with a quick assessment the general feeling about the most important and acute development needs was identified. However, many of the topics and terms were new to the interviewees so explanations were often required.

Figure 7 shows the requirement development needs and Figure 8 the general RE development needs. The requirement development had more *definitely needed* –marks while the general RE development had the three topics with the most *needed* and *definitely needed* –marks together. These three most needed topics were *own RE adaptations* (all companies), *RE process improvement* (eleven), and *RM tool introduction* (ten companies). At the other extreme were *more technical requirements* and *prototypes* for which half of the companies said *development not needed*.

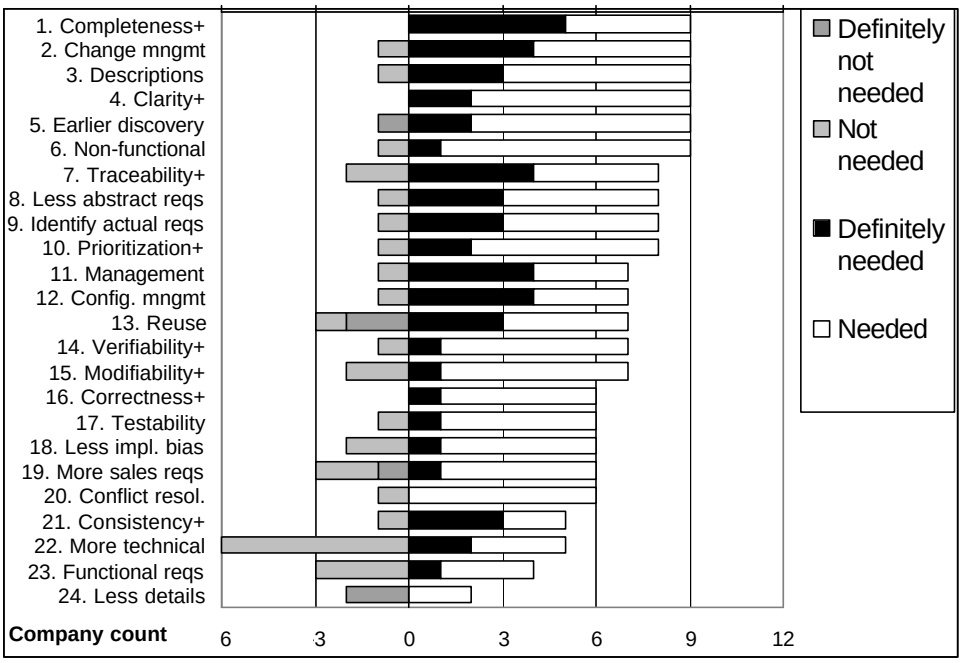

Figure 7. Requirement development needs in Pareto order. The items with the character '+' are the IEEE Std 830 characteristics.

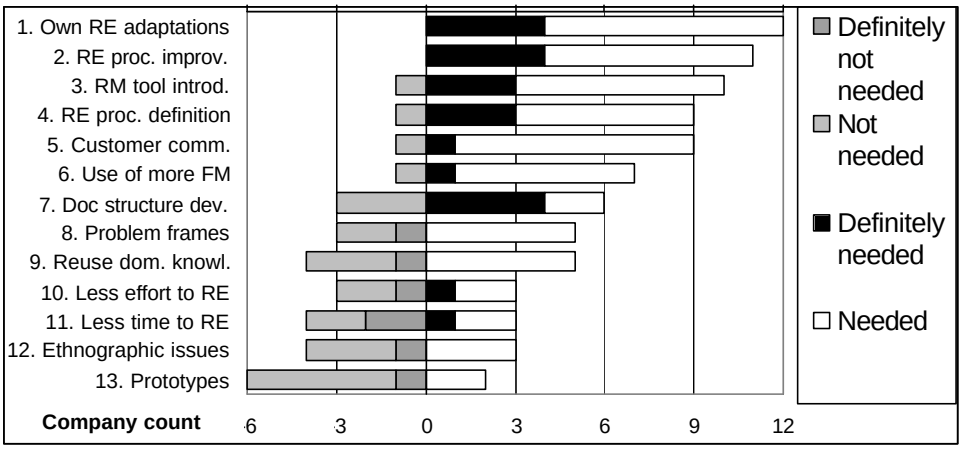

Figure 8. General RE development needs in Pareto order.

The IEEE Recommended Practice for Software Requirements Specifications (IEEE Std 830-1998) includes, among others, eight characteristics of a good software requirements specification (IEEE 1998). These characteristics were included in the list of development needs to see how the companies felt about them. The results are shown in Figure 7 as the topics with a +-sign. The requirement development need most indicated was *completeness*, which is also an IEEE Std 830 characteristic. Note also that none of these characteristics was *definitely not needed*.

4.6. Expectations of RE Research in Academia

One of the goals for this survey was to document the expectations industry has of academic research in software engineering and especially in RE. Thus four options were proposed and an open question given to elicit the industry representatives' ideas. None of the options were exclusive so some interviewees selected all the options while others selected only a few main options.

All the companies (*n*=12) considered *education* to be one of the most important goals of academic RE research and only one company did not expect the academic world to participate in *technology transfer* of existing RE knowledge. On the other hand, two companies expected research to *create new methods and techniques* and another two expected the *development of new tools* in the field. Figure 9 shows these results in a graphical format.

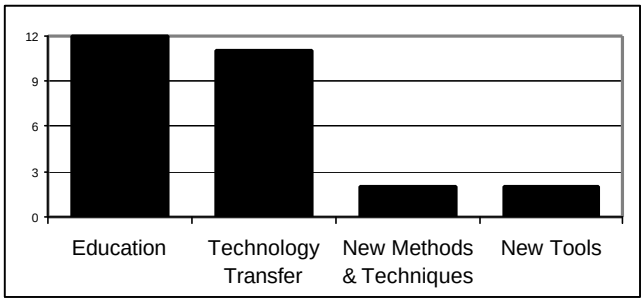

Figure 9. Expectations of academic RE research.

The level of education could be specified further and six of the companies (*n*=7) expected people with a Master's degree. Four companies considered a Bachelor's degree to be the right level and only two expected doctoral level people in the RE field.

Technology transfer also had more specific options and nine companies (*n*=10) considered training for practitioners suit their purposes best. Eight companies considered templates and examples to work best. Six companies wanted consultation and two would have liked to see new technology transfer methods created and used. See Figure 10 for a graphical presentation.

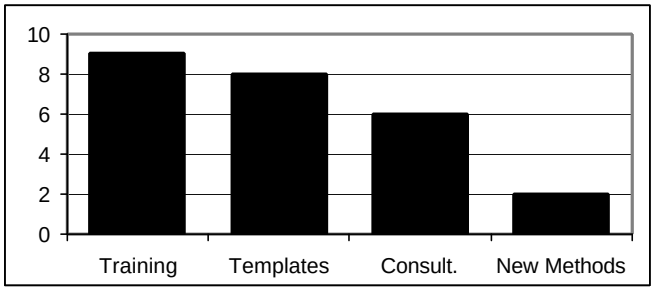

Figure 10. Preferred ways of technology transfer.

In tool development (*n*=2) one company expected prototype level tools. Another company considered both prototype and production level tools to be appropriate.

4.7. Miscellaneous Questions

Each interview was closed with general questions related to familiarity with RE books and tools, attitudes to RE, and RE improvement efforts. An open question asking about any other relevant issues was also asked.

Familiarity with RE books and tools was clarified with two lists from which the interviewees were requested to indicate familiar titles. The book list consisted of the references (Davis 1993; Gause and Weinberg 1989; Jackson 1995; Kovitz 1999; Robertson and Robertson 1999a; Sommerville and Sawyer 1997; Thayer and Dorfman 1998) and the tool list of the 13 RM tools in the INCOSE survey (INCOSE 1999). The

question about these books and tools was whether the name was known; no reading of a book or usage of a tool was required.

Four interviewees (*n*=15) recognized one book and one person two books while ten interviewees did not recognize any book. The best-known book was the book by Davis (1993) that was recognized by two interviewees. The books by Gause and Weinberg (1989), Jackson (1995), Sommerville and Sawyer (1997), Kovitz (1999), and Thayer and Dorfman (1998) were all recognized by one person. The Robertson and Robertson book (1999a) was the only one that was not recognized by anybody but, on the other hand, it was published only a few months before the survey.

Seven interviewees (*n*=15) recognized from 1 to 3 tools in the tool list and eight did not recognize any of them. The best recognized tool was RequisitePro with four interviewees, DOORS with three, CORE and QSSrequireit with two interviewees each. Caliber RM, Cradle, RDT, RTM, and SLATE were each recognized by one person.

The attitude to RE was clarified with questions whether RE is of strategic importance to the company, what is the importance of RE improvement activities, what is the best way to improve the practices, and whether the company has had prior RE development projects. In this context the term “strategic area” meant that RE is considered essential for the company’s business; however, it was not considered as part of the key business areas in the sense that the RE practices would be confidential information in the company.

Presented in this way, ten companies (*n*=12) considered RE to be strategically important. Five companies also considered their RE process improvement activities to have high-importance. Six considered them to be of medium importance and one rated them as being of low importance.

The best ways of improving the current level of RE practices were considered to be training and internal projects, both with eight companies. Five companies wanted to start a project with an appropriate partner and three were ready to hire people in this area.

Prior projects (*n*=5) on RE practice development were done as a part of systems development (one) or general software process improvement projects (two) but two companies had also had special RE development projects. The goals of these projects were for two companies a common process description while one company wanted to create a data dictionary and utilize it with help-files etc. One company wanted to define common headings for their requirements documents and also a database structure for storing the requirements. In one case students did the project as a course work and another company had started an improvement project only to realize that a real software development project took precedence.

Eleven of the companies were interested in starting a RE development project with an academic partner. The preferred goal of this co-operation was for ten companies training a new specialist in the RE area, while eight companies wanted to get help in developing their own processes. Six companies considered receiving information about research activities and results as an appropriate form of co-operation. Eleven of the interviewed companies had had prior projects with academic partners.

5. DISCUSSION

Section 5 includes the discussion of the survey findings. Section 5.1 explains the proposals and comments presented during the interviews and 5.2 explains the role of RE as part of the software development process. Section 5.3 discusses the current RE practices, 5.4 the common development needs in RE, and 5.5 the status of technology transfer from academia to industry.

5.1. Proposals and Comments

There were two open questions in the questionnaire where the interviewees could propose new topics for academic research and development in the RE area or give comments related to the survey or related areas. Since the survey was quite extensive already these questions did not create much conversation. However, some good ideas were received for future research topics.

Three companies had two clear proposals for research topics: problems of small companies, and subcontracting. The focus on small companies is based on the fact that their problems differ from those of large companies (Kamsties, Hörmann, and Schlich 1998). Subcontracting was proposed from two viewpoints. One company wanted to concentrate on developing software and would have liked international partners to develop the software requirements with international customers. In this way the company could concentrate on software development. The other company wanted to be the one with the customer contacts and subcontract software development to partner companies. Both these proposals address topics that are open but less studied areas in RE.

Three companies had specific problems that they would like to be clarified: linking the software development phases to each other, RM tools, and the Software Quality Function Deployment (SQFD) –method's applicability. The linkage between different development phases is often explained in theory in software engineering literature. However, practical implementation with real size projects is seldom easy so this request is easy to understand. The second topic, RM tool survey, is also a common practical problem after realizing the diversity of the tools in the market; at first sight there seems to be no tools at all but then there are a dozen of them. Selecting "the right one" thus easily becomes quite a big task and a survey of tools and their applicability could help a lot. The third proposal was SQFD and specifically its applicability to product and project software development. SQFD is an adaptation of the Quality Function Deployment (QFD) method that has been used in the production industry for some decades now (Haag, Raja, and Schkade 1996). Thus the method has proved its strength in some areas already but the software domain is still considered untried.

Four companies had a more fundamental need that can be considered as a framework or a guide to the best practices in RE. The basic need was to understand how to apply existing methods and tools in practice, how to select the best method or tool for each task, and to what extent to use them. The same topic was proposed from different viewpoints. For example, real examples, case studies on method usage, and longitudinal studies on how practices have developed in industry were requested. This kind of information was considered necessary to justify company investments in RE and also to direct development efforts in the right direction. This need also supports Fowler et al.'s notion that companies need a primer for RM (RE) that can be used to guide the initial steps in improvement efforts (1998).

5.2. RE as Part of Software Development Process

The companies interviewed were not very specialized in their software development processes. The result is the same whether we look at the use of special purpose tools or at the team member's roles. Configuration management tools were used in 80% of the companies, testing tools in 67%, CASE tools in 33% of the companies, and nobody used RM tools. From these results we could conclude that software process improvement is started from the development phase, followed by the testing, and finally it may also reach the design phase. The improvement path looks a little different if we consider the employee roles: 58% of the companies had special designers for user interfaces, databases or similar tasks, 50% had system analysts as well as technical writers, 25% had testers while, on the other hand, 42% of the companies called all their employees developers. It should also be noted that only half of the system analysts work only in the RE area while the other half also work as project managers or developers. Of course, special purpose tools and roles are not a guarantee of better results but their absence is also not without consequences.

The low specialization rate generally has two consequences: there are no real specialists in the companies and only general-purpose tools are used. As long as the software developers are happy with general-purpose tools and the fact that they do not support real automation, this situation is acceptable. But automation of processes generally requires good domain knowledge, well-defined processes, and also the support of special-purpose tools. The problem is further complicated with the supposed ease of use that is often promised by salespeople of the tools. Even if the basic usage of a tool is easy, they generally must be configured to each project and this is often far from easy with the many options that the tools include.

Software development as a process has two further implications for RE. The process-approach implies that all the phases should make their own contributions to the software development effort and also integrate with each other. Thus RE as a stand-alone phase should document the reasons for developing the software together with priorities etc. so that the design, implementation, and testing phases become easier and the end product satisfies customer needs. If RE fails to fulfill these expectations, it is of no use to the software development effort. However, if any other phase fails to utilize the documented knowledge, the end result can also be a failure. Therefore a successful RE improvement effort should consider the whole software development process and its capability to utilize the documented information. As RE is the first phase in software development, problems with the integration and maturity of the whole process create an extra risk to the success of the RE phase.

5.3. Current RE Practices

Based on the REAIMS Top Ten points, the current RE practices of the interviewed companies are not too advanced. The three companies with 17 to 28 points from 30 stand out in this survey and indicate that they have made some serious efforts in improving their practices. As can be expected, the company having an audited quality system and the CMM level 3 company are both among the top three, even if neither one of them got the best points. All the top three companies are from software business, while the two companies with 0 points both had their origin in the application area. The smaller one of these had only 5 people and the survey questions were clearly inappropriate. In the discussions it became clear that the practices applied by the company in analysis and specification were actually very detailed and reminiscent of

methods found in textbooks. Thus the REAIMS Top Ten assessment did not suit this company and it could have been excluded from the survey. However, since the Top Ten was only one part of the survey this was not done. The majority of the companies got from 1 to 7 points meaning that they had some practices established but were still in the initial stages in their improvement efforts. In this group, analysis of the requirements documents as instructed by the REAIMS evaluation process (Sommerville and Sawyer 1997) might have increased the point gain to some extent.

The creation of requirements document is not self-evident, as has also been observed by Kamsties, Hörmann, and Schlich (1998) and Lubars, Potts, and Richter (1993). In this survey no common factor could be identified predicting document creation. For example, even within the biggest companies having more than 150 employees, one company made the document only at the discretion of the project manager and, on the other hand, two of the companies with less than ten people did it in a standard or normal manner. Thus the decision whether the requirements document is created or not depends on many factors and is probably mostly dependent on the company attitude towards RE. Similarly, general guidelines in RE practices were applied quite sparingly. This may be due to the fact that establishing generally applicable guidelines is hard and they are substituted by the discretion of project manager. The guidelines for requirements document style and contents were generally better defined. A standard document structure was defined at the same level as the requirements document was done for all except two companies. The actual documents were constructed from basic items like natural language. Semiformal methods like diagrams were used mostly on a discretionary basis only. No company used hypertext, formal methods, or RM tools and even tools like templates, checklists, and metrics were in standard use in one or two companies only.

The lack of RM tool users in the survey was somewhat surprising, even if Lubars, Potts, and Richter also noted that general-purpose tools were more common than special tools in RE (1993). One of our companies had actually had a pilot project with one tool and since they had similar problems as reported by Tvete (1999) they decided to reject it. Many companies also expressed their concern about the costs and problems associated with tool adoption. The use of general-purpose text processing and spreadsheet software together with a few company specific database solutions is thus quite understandable.

In general the terminology contained in the survey was new to most interviewees. Combined with the fact that only one third knew any book on RE it can be concluded that general knowledge of RE was quite weak and this alone rises the threshold for starting any development efforts in the RE field.

5.4. Development Needs in RE

The three most important development needs were among the general RE topics. The top two needs, own RE adaptations and RE process improvement, indicate that most companies have already seen many methods and techniques that do not quite fit their needs and that a domain specific approach seems to be the only feasible solution. Most companies are also aware of their process maturity and consider it to need some improvement. RM tool adoption was the third most commonly desired development topic. This is probably due to the fact that most companies have made requirements documents with general-purpose tools and realized the many problems associated with them. The fact that no company had a commercial RM tool in use is also reflected in

the scarce knowledge of existing tools – only one third of the interviewees recognized more than one tool, less than one fourth one, and half did not recognize any tool. So in most cases the adoption of a RM tool has not been a realistic option since even the tool names are not known.

The topic that was most often considered as *definitely needed* was requirements completeness. Other important topics were requirements and change management. All these problems indicate the lack of a systematic approach to RE using standard practices, templates, and RM tools that are normally used to solve these kinds of problems. Altogether these companies resemble the ones in the Fowler et al. (1998) study where the companies usually did not have a defined RE process and in general seemed to be in the initial stages of their improvement efforts.

With the ever increasing need to shorten the time to market, it was interesting to hear that only one company had a definite need to reduce the time and effort on RE. One third of the companies even thought that the time or effort for RE could and should be increased.

5.5. Technology Transfer

The level of successful technology transfer is hard to estimate but the calculated REAIMS Top Ten points give an indication of it. At first sight there seems to be a lot of diversity in the companies but actually two groups can be identified with 17 to 28 points and 0 to 7 points. The first group with more than half of the maximum points would probably have benefited from the full REAIMS assessment since they already have most of the key practices in place. On the other hand, the benefit of the full assessment for the group with seven points or less would probably have been quite marginal since even this top ten reveals that RE lacks systematic approaches. Further assessment would hardly bring out any real benefit so efforts are probably best directed to improvement.

The three companies with 17 or more REAIMS Top Ten points had diverse backgrounds. These companies included both the ones with the least and the most employees; the company ages varied from 6 to 30 years; and two companies were mainly in the product business while the third one was in the project business. As can be expected, this group included both the companies with an audited quality system and the CMM level 3. Thus well-established processes can be found in very different organizations and the key factor is probably the desire to excel. It is interesting to note, though, that none of the properties named above (except for the product-business) is true for the company with the most points. To sum this up, the two smaller ones of these top three companies could probably be classified as innovators with their products and the third one as an early adopter with its well-established quality system (Rogers 1995).

The rest of the companies got 0 to 7 points in the REAIMS Top Ten. The two companies with zero points did not know any of the proposed books and had their origin in the application domain. However, no definite reason for the low points could be identified in this survey. These companies could probably be classified as laggards (Rogers 1995) in the RE or software engineering fields but in their own application area they are more likely innovators since they have both started from technological innovations. On the other hand, the 1 to 7 points indicate some degree of activity in developing common practices but it also indicates it is in the quite early stages. Thus

these companies probably belong to the early or late majority of technology adaptors that expect commercial grade materials that can either be tailored for their needs or have a low price and are easy to use (Fowler et al. 1998).

The expectations for RE research clearly indicate that all companies would like new graduates to know about basic issues in RE. The next most important expectation of academia was technology transfer to industry and the best ways were considered to be training, examples and templates, and consultation. These results support well the results of Kamsties, Hörmann, and Schlich (1998) who found that SMEs are "rather price sensitive" and "require well-packed and mature results being transferred in short time periods". The Fowler et al. (1998) result that "[organizations] hoped to find standard products and services to provide prepackaged solutions for use with minimal adoption or as is" is also supported by this survey except for the fact that our companies acknowledged that their organization, product, and process form a unique combination and any general solution is hardly applicable to them without adoption. The Morris, Masera, and Wilikens (1998) result that training is one of the biggest problems for companies is also supported by our study.

The key recommendation of Morris, Masera, and Wilikens (1998) was support to the discipline. This is in line with our results since 92% of the companies were interested in cooperation with an academic partner. The training of new RE specialist was considered desirable by 83% of the companies and 67% of them wanted help in developing their own processes. So clearly support for the discipline and development efforts is desired. An academic partner is probably considered a cheaper option than commercial consultants and, on the other hand, it also offers a natural way to hire new graduates.

As can be expected, doctoral level people were desired by the two biggest companies with fairly mature processes. The other companies were happy with lower level education in RE.

6. CONCLUSIONS

This state of the practice survey affirms the low level of technology transfer in the RE field. Even standard topics in RE research are new and unfamiliar to many companies and companies do not know how to actually start practical RE process improvement efforts. Nevertheless, most of the companies have a need to improve their RE practices and they have very similar high-level development needs:

1. development of own RE process adaptations,

2. RE process improvement, and

3. automation of RE practices.

Most of the industry representatives also had similar hopes about the ways of transferring knowledge from the research community to industry: technology transfer in the form of training, examples and templates. Thus clear technology transfer packages and support for adopting them to company specific domains is needed in present-day software companies.

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Survey of the RE Practices in Industry

Place:_____

Time:_____

Participants:_____

1. COMPANY

- size
  - number of workers_____
  - net sales 1998_____
  - software business size_____
- year established_____
- interviewee job title/role_____
  - ❑ company wide role
  - ❑ project manager/specific role
- application domain
  - ❑ business information systems
  - ❑ control software
  - ❑ telecommunications
  - ❑ software engineering tools
  - ❑ office automation
  - ❑ embedded software
  - ❑ life critical applications (ATC, train control, hospital, etc.)
  - ❑ other_____
- operating environment
  - ❑ domestic only
  - ❑ international sales/development
- general process assessment
  - ❑ audited quality system
  - ❑ internally accepted processes
  - ❑ informal processes based on the people
  - ❑ CMM level_____

2. PROJECTS OR RELEASE FOR PRODUCTS (SELECT ONE AS THE REFERENCE CASE)

_____

- project types
  - ❑ custom software development projects
  - ❑ component based software projects
  - ❑ COTS software products (**C**ommercial-**O**ff-**T**he-**S**helf)
- project starting point
  - ❑ customer requests (requirements driven)
  - ❑ technology facilitates (architecture driven)
- size in person months/years, typical and range _____
- duration in months/years, typical and range_____
- overall systems development paradigm
  - ❑ object-oriented (e.g. UML/RUP, OMT, OOA/D)
  - ❑ function-driven/structured (e.g. SA)
  - ❑ data-driven
  - ❑ evolutionary, iterative (e.g. RAD)
  - ❑ other
- life-cycle model
  - ❑ waterfall
  - ❑ spiral, incremental
  - ❑ evolutionary, iterative, prototyping
  - ❑ other_____
- development team structure, specialized people in
  - ❑ system analysis, requirements engineering

- ❑ UI/DB/… design
- ❑ testing
- ❑ technical writing
- ❑ no specialists, all are developers

- development tools used
  - ❑ test support tools
  - ❑ design/CASE tools
  - ❑ configuration management tools
  - ❑ requirements management tools

3. COMPLETED SOFTWARE (SELECT ONE AS THE REFERENCE CASE)_____

- lifetime for release/software_____
- expected end user count_____
- software size in lines of code (language)_____
- price for a single copy of software/for project, typical and range_____
- number of supported operating systems_____
- number of other variants_____

4. REQUIREMENTS

4.1. number of requirements per release/project, typical and range_____

	never	discr.	normal	stand.
4.2. requirements document				
4.2.1. created for every project/release				
a. as a requirements document	❑	❑	❑	❑
b. as a task list	❑	❑	❑	❑
4.2.2. standard document structure defined	❑	❑	❑	❑
4.2.3. planned to be easy to change	❑	❑	❑	❑
4.2.4. simple, consistent, and concise use of language	❑	❑	❑	❑
4.2.5. formal inspections performed	❑	❑	❑	❑
4.3. document format				
4.3.1. text document	❑	❑	❑	❑
4.3.2. hypertext (e.g. HTML, XML)	❑	❑	❑	❑
4.3.3. other_____				
4.4. requirements management method				
4.4.1. word processor	❑	❑	❑	❑
4.4.2. spreadsheet program	❑	❑	❑	❑
4.4.3. database, own solution	❑	❑	❑	❑
4.4.4. commercial requirements management tool	❑	❑	❑	❑
4.4.5. other_____				
4.5. general guidelines				
4.5.1. requirements management policies defined	❑	❑	❑	❑
4.5.2. document validation checklists defined	❑	❑	❑	❑
4.5.3. requirements analysis checklists used	❑	❑	❑	❑
4.5.4. planned for conflicts and conflict resolution	❑	❑	❑	❑
4.5.5. process defined	❑	❑	❑	❑
4.5.6. problems/bugs traced to sources	❑	❑	❑	❑
4.5.7. problems analysis performed	❑	❑	❑	❑
4.5.8. metrics gathered of requirements	❑	❑	❑	❑
4.5.9. metrics gathered of reqs related problems	❑	❑	❑	❑
4.6. methods used				
4.6.1. natural language	❑	❑	❑	❑
4.6.2. semi-formal (diagrams, pseudo-code, etc.)	❑	❑	❑	❑
4.6.3. formal methods (Z, B, VDM, …)	❑	❑	❑	❑
4.7. contents include/define				
4.7.1. stakeholders	❑	❑	❑	❑
4.7.2. viewpoints	❑	❑	❑	❑
4.7.3. use cases, scenarios	❑	❑	❑	❑
4.7.4. prototypes	❑	❑	❑	❑
4.7.5. description of environment/domain	❑	❑	❑	❑

4.7.6.	description of machine/system	❑	❑	❑	❑
4.7.7.	descr. of interf. betw. environment and system	❑	❑	❑	❑
4.7.8.	separation of facts and reqs statements	❑	❑	❑	❑
4.7.9.	data dictionary				
a.	as a separate document	❑	❑	❑	❑
b.	as a glossary	❑	❑	❑	❑
4.8.	requirement descriptions (Volere-template)				
4.8.1.	template(s) for reqs/tasks exist, contains	❑	❑	❑	❑
a.	requirement id	❑	❑	❑	❑
b.	requirement type	❑	❑	❑	❑
c.	event/use case id	❑	❑	❑	❑
d.	description	❑	❑	❑	❑
e.	rationale	❑	❑	❑	❑
f.	source	❑	❑	❑	❑
g.	fit criterion	❑	❑	❑	❑
h.	customer satisfaction	❑	❑	❑	❑
i.	customer dissatisfaction	❑	❑	❑	❑
j.	dependencies	❑	❑	❑	❑
k.	conflicts	❑	❑	❑	❑
l.	supporting materials	❑	❑	❑	❑
m.	history	❑	❑	❑	❑

5. CURRENT KEY ISSUES IN RE RELATED TOPICS, DEVELOPMENT NEEDS

		Def not	Not	OK	Yes	Def yes
5.1	correctness of requirements	❑	❑	❑	❑	❑
5.2	clarity of requirements	❑	❑	❑	❑	❑
5.3	completeness of requirements	❑	❑	❑	❑	❑
5.4	consistency of requirements	❑	❑	❑	❑	❑
5.5	prioritization, ranking for importance and/or stability	❑	❑	❑	❑	❑
5.6	verifiability of requirements	❑	❑	❑	❑	❑
5.7	modifiability of requirements	❑	❑	❑	❑	❑
5.8	traceability of requirements	❑	❑	❑	❑	❑
5.9	conflict resolution, conflicting requirements	❑	❑	❑	❑	❑
5.10	less abstract requirements needed	❑	❑	❑	❑	❑
5.11	less detailed requirements needed	❑	❑	❑	❑	❑
5.12	high-level goals missing, sales reqs needed	❑	❑	❑	❑	❑
5.13	technical constraints missing, more technical reqs needed	❑	❑	❑	❑	❑
5.14	less implementation bias needed, requirements vs. design	❑	❑	❑	❑	❑
5.15	testability, metrics for requirements needed	❑	❑	❑	❑	❑
5.16	functional requirements	❑	❑	❑	❑	❑
5.17	non-functional (quality) requirements	❑	❑	❑	❑	❑
5.18	requirements document structure development	❑	❑	❑	❑	❑
5.19	requirement description development	❑	❑	❑	❑	❑
5.20	management of individual requirements	❑	❑	❑	❑	❑
5.21	requirements configuration management	❑	❑	❑	❑	❑
5.22	change management	❑	❑	❑	❑	❑
5.23	communicating with customer about the reqs	❑	❑	❑	❑	❑
5.24	identifying the actual requirements	❑	❑	❑	❑	❑
5.25	earlier discovery of requirements	❑	❑	❑	❑	❑
5.26	prototypes and the knowledge they contain	❑	❑	❑	❑	❑
5.27	identifying problem frames/patterns	❑	❑	❑	❑	❑
5.28	reuse of domain knowledge	❑	❑	❑	❑	❑
5.29	reuse of requirements	❑	❑	❑	❑	❑
5.30	own adaptations of RE methods	❑	❑	❑	❑	❑
5.31	sociological/ethnographic issues	❑	❑	❑	❑	❑
5.32	RE process definition	❑	❑	❑	❑	❑
5.33	RE process improvement	❑	❑	❑	❑	❑
5.34	reducing the development time used for RE	❑	❑	❑	❑	❑
5.35	reducing the effort spend on RE	❑	❑	❑	❑	❑
5.36	introduction of requirements management tool	❑	❑	❑	❑	❑

5.37 introduction of more formal specific. methods ❑ ❑ ❑ ❑ ❑

6. EXPECTATIONS FROM RE RESEARCH IN ACADEMIA

- ❑ new methods and techniques
- ❑ new tools
  - ❑ ready to use tools
  - ❑ tool prototypes
- ❑ technology transfer
  - ❑ templates, examples
  - ❑ new methods
  - ❑ consultation
  - ❑ training for practitioners
- ❑ educated people, with the degree of
  - ❑ bachelor
  - ❑ master
  - ❑ doctor
- ❑ proposals for RE R&D in academia_____

7. CLOSING REMARKS

- do you know any of the books in List 1
  - ❑ yes_____
  - ❑ no
- do you know any of the requirements management tools in List 2
  - ❑ yes_____
  - ❑ no
- is RE strategic area of your business
  - ❑ yes
  - ❑ no
- have you had any RE development projects before in your company
  - ❑ yes_____
  - ❑ no
- importance of your requirements engineering process/practice improvement activities
  - ❑ high
  - ❑ medium
  - ❑ low
  - ❑ none
- how would you like to improve your current requirements engineering state
  - ❑ train people
  - ❑ hire trained people
  - ❑ start an internal development project
  - ❑ start a project with an appropriate partner
- would you be interested in participating in RE development projects with academia
  - ❑ yes
    - ❑ receive information from research directions and results
    - ❑ get help in developing own processes
    - ❑ train new RE specialist (e.g. thesis works)
  - ❑ no
- have you participated in R&D projects with academia before
  - ❑ yes
  - ❑ no
- any other comments

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List 1. Books

1. **Exploring Requirements: Quality Before Design**, Donald C. Gause and Gerald M. Weinberg, Dorset House, 1989.

2. **Software Requirements: Objects, Functions, and States**, Alan M. Davis, Prentice Hall, 521 pages, Revised edition 1993.

3. **Software Requirements & Specifications: A Lexicon of Practice, Principles and Prejudices**, Michael Jackson, Addison-Wesley Pub Co, 228 pages, 1995.

4. **Requirements Engineering: A Good Practice Guide**, Ian Sommerville and Pete Sawyer, John Wiley & Sons, 404 pages, 1997.

5. **Practical Software Requirements: A Manual of Content and Style**, Benjamin L. Kovitz, Manning Publications Company, 444 pages, 1999.

6. **Software Requirements Engineering**, Richard H. Thayer and M. Dorfman (Eds), IEEE Computer Society, 500 pages, 2nd edition revised in '99.

7. **Mastering the Requirements Process**, Suzanne Robertson and James Robertson, Addison-Wesley Pub Co, 352 pages, 1999.

List 2. Requirements Management Tools

1. Caliber RM 2.0, Technology Builders, Inc.
2. CORE 2.0, Vitech Corporation
3. Cradle/SEE 3.2, 3SL Inc.
4. DOORS 4.0, Quality Systems & Software
5. QSSrequireit 1.0, Quality Systems and Software
6. RDD-100 4.1.1, Ascent Logic Corporation
7. RDT 2.0, GEC Marconi Systems Pty Limited
8. RequisitePro 4.0, RATIONAL SOFTWARE
9. RTM 4.x, Integrated Chipware
10. SLATE 4.1, TD Technologies
11. Tofs 98, Tofs
12. Vital Link, Compliance Automation Inc.
13. XTie-RT, Teledyne Brown Engineering

A survey of these tools can be found at http://www.incose.org/tools/tooltax.html.