B. Regnell, B. Paech, A. Aurum, C. Wohlin, A. Dutoit and J. Natt och Dag, "Requirements Mean Decisions! - Research Issues for Understanding and Supporting Decision-Making in Requirements Engineering", Proceedings First Swedish Conference on Software Engineering Research and Practise, pp. 49-52, Ronneby, Sweden, 2001.

Requirements Mean Decisions! – Research issues for understanding and supporting decision-making in Requirements Engineering

Björn Regnell[1], Barbara Paech[2], Aybüke Aurum[3], Claes Wohlin[4],
Allen Dutoit[5] and Johan Natt och Dag[1]

[1]Dept. of Communication Systems, Lund Univ., Sweden
[2]Fraunhofer Inst. for Experimental Software Eng., Germany
[3]Sch. of Information Systems, Techn. & Mgmt, Univ. of New South Wales, Australia,
[4]Dept. of Software Eng. and Computer Sci., Blekinge Inst. of Techn., Sweden
[5]Inst. für Informatik, Techn. Univ. München, Germany

bjorn.regnell@telecom.lth.se; paech@iese.fhg.de; aybuke@unsw.edu.au;
claes.wohlin@bth.se; dutoit@in.tum.de; johan.nattochdag@telecom.lth.se

Abstract

Requirements result from stakeholders' decisions. These decisions are governed by hard issues such as the balance between cost and functionality, and soft issues such as social processes and organisational politics. The quality of the decision-making process is crucial as good-enough requirements is the foundation for a successful focusing of the available development resources. In this paper it is argued that research should focus more on Requirements Engineering (RE) as a decision-making process with focus on describing and understanding it, and on providing and evaluating methods to improve and support RE decision-making. There are many opportunities of fruitful interdisciplinary research when combining RE with areas such as decision theory, decision support systems, operations research and management science. A number of research issues are identified and several aspects of RE decision-making are described, with the aim of promoting research on methods which can better support requirements engineers in their decision-making.

1 Introduction

Requirements can be viewed as the results of stakeholders' decisions regarding the functionality and quality of the software product to be constructed. Furthermore, the Requirements Engineering (RE) process needs staffing, planning, control, and organisation; all these issues are related to decision-making.

There are already existing theories and methods for decision-making in research areas such as decision theory, decision support systems, operations research and management science. The previously established large base of research results in these areas is a great resource for RE researchers to take advantage of when conducting interdisciplinary research. The objective of the presented work is to identify both descriptive research issues for *understanding* (Section 2) and prescriptive research issues for *supporting* (Section 3) RE decision-making.

2 Understanding the RE decision-making process

Although certain aspects of RE decision-making may be specific to RE, there are also many aspects which are general. Hence, RE decision-making may in part be explained using frameworks from classical decision-making theory [1, 2]. By taking existing frameworks, and relate them to decision-making in RE, a number of descriptive research issues can be identified. A number of such issues are discussed subsequently.

The RE process is communication intensive. The requirements are interpreted and decisions are made in a so called *mutual knowledge exchange process* [3]. Many stakeholders who are involved in the process make a variety of decisions that ultimately affect the effectiveness and efficiency of the software product. This process is a typical *group problem solving process*. A major challenge for RE research is thus to understand this group process and, based on this understanding, find efficient ways of supporting groups of stakeholders in solving the problem of deciding what to build.

From a management perspective, each 'requirement' takes the place of a 'decision' [4]. The decision process is both an evolutionary process and a problem solving activity, and it involves many decisions that are continuous with several levels and review points with iterations. Classical theo-

ries of decision-making in an organizational context involve three main activities: *strategic planning*, *management control* and *operational control* [5]. The strategic planning deals with decisions that are related to policy setting, choosing objectives and identifying resources. Management control deals with decisions related to assuring efficiency and effectiveness in the use of resources. Operational control deals with assuring effectiveness in performing operations.

Fig. 1 describes RE decision-making in an organizational context [5]. Strategic planning and management control in RE may include decisions such as:

(1) *scope decisions* dealing with whether a requirement is consistent with the product strategy,

(2) *resource decisions* regarding for example if more effort should be put on RE, and

(3) *responsibility decisions* where it is decided who is responsible for what in the RE process. The requirements are designed at the operational level.

Operational control may include decisions such as:

(4) *quality assessment decisions* where it is decided if a requirement is of good-enough quality,

(5) *classification decisions* where it is decided that a requirement is of a certain type, which in turn may imply specific actions, and

(6) *property decisions* where it is decided that a requirement has a certain property or value (e.g., req. X has implementation cost Y and depends on req. Z).

These decisions are made in various, inter-related and overlapping contexts such as:

(a) customer-specific systems,

(b) off-the-shelf systems,

(c) embedded systems,

(d) safety-critical systems,

(e) data-base centric systems.

A number of important research issues are related to the investigation of the nature of decision types (such as 1-6) in various contexts (such as a-e). Empirical studies of real projects with real requirements can give us a thorough understanding of types and qualities of decisions, with the benefit of providing insight into what types of decisions need what type of support in what context.

Each requirement can be viewed as an information element that is elevated in terms of quality throughout development. This view of RE as a continuous process of asynchronous information refinement is especially salient in market-driven RE [6]. The "salmon ladder" metaphor in Fig. 2 can be used to describe the life-cycle of each individual requirement in such a process. Each transition in the salmon ladder implies an operational or strategic decision. Consequently, RE research should investigate the nature of these decisions. In order to find ways of supporting decision-making in RE we need to understand issues such as: How many requirements are discarded either too early or too late? How often are requirements specified which are never released? What is the adequate quality of a requirement before it is allowed to enter the process?

3 Supporting RE decision-making

Why does RE sometimes fail? One reason may be that bad decisions are made by requirements engineers and managers during system definition. In turn, these decisions may lead to wrong or poor requirements, which subsequently may lead to a software product not fit for purpose, which eventually is rejected by the market. Consequently, a major issue for RE research is to prescribe methods and tools that can support better decision-making. This includes providing comprehensive information and stable grounds for timely decisions. For a complex system with many stakeholders, the amount of information to be handled by requirements engineers is immense. Providing structure and overview in this confusion is a central quest in order to pave the way for better decisions. Hence, *support for measurements on requirements* both for decision making in the RE proc-

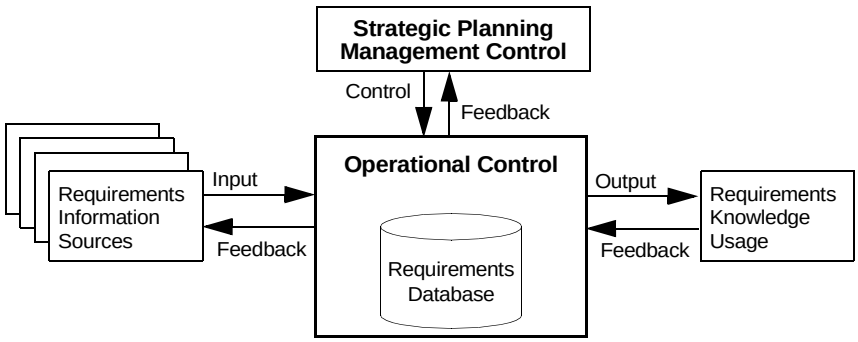

Fig. 1. Decision-making in RE at different levels, shown in an organizational context.

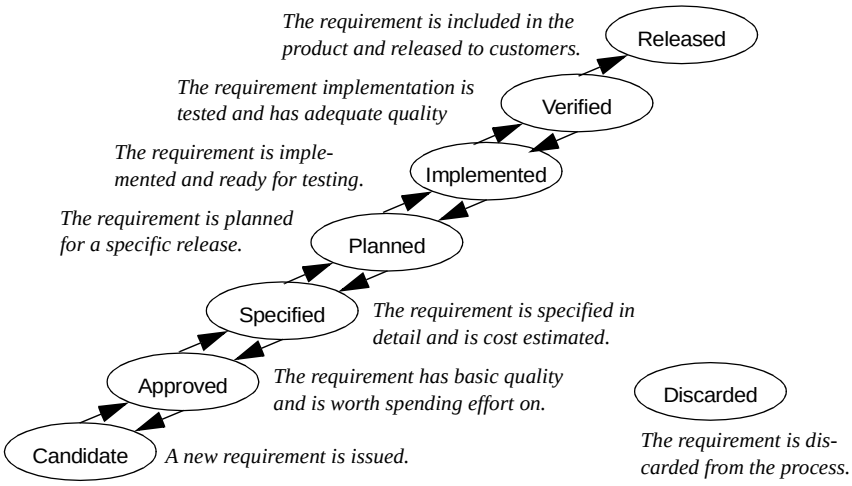

Fig. 2. An example of a "salmon ladder" where requirements are decided to be elevated or downgraded individually in a continous, asynchronous refinement process.

ess and in related processes, such as release planning and architectural design, is of great interest. Strong support for visualizing metrics allows requirements engineers to continuously answer questions such as: How much of the available construction effort is currently planned for the next software release? Which customer category will be most satisfied with the current set of planned requirements? How long does it on average take for a requirement to go from approved to specified?

The research on requirements prioritisation [7] is a striking example of how an old technique from decision theory - Analytical Hierarchy Process (AHP) [8] - after adaptation to RE, can support and improve decision-making in a new context. When adopting existing decision support methods to the special case of software requirements, it is important to investigate the underlying assumption of the methods in relation to the RE context. For example, AHP assumes that decision objects (requirements) can be treated independently, although we know that requirements depend on each other in various complex ways. Hence, research is needed on *support for management of requirements dependencies* in a cost-efficient way [6]. A related issue is *support for impact analysis*, in connection with changed decisions.

During the proposal of candidate requirements, and their subsequent approval or discarding (see Fig. 2), the decision process is characterized by intensive negotiation among multiple stakeholders. Thus, decisions made during this process are the result of the evaluation and refinement of different options. However, often only the selected option is documented in the requirements specification and the discarded options are lost. This information loss leads to costly misunderstandings about the options between the different stakeholders and a lack of *support when revising decisions*. Rationale methods [9, 10] are used to explicitly capture and manage options, decisions, and their justifications [11]. *Support for negotiation* is needed to make sure all relevant positions are represented and respected. Providing rationale-based tools to make decision steps explicit can do this. While such tools have been successful during the elaboration of complex decisions [12], several issues remain to be solved, such as training stakeholders and decreasing overhead.

Support for decision recording is needed once consensus has been achieved. When going up and down the salmon ladder, many decisions will be re-opened, sometimes without all stakeholders being available. Restructuring of the model produced during negotiation can be used for recording decisions. However, the restructuring process (e.g. identification of missing steps or obsolete decisions) using current techniques is not cost effective. The issue of cost-effectiveness in decision recording is hence a key challenge for research.

Supporting traceability between requirement decisions and their corresponding rationale is needed to assess the consistency and the impact of change to existing decisions based on the existing rationale. While this sounds straightforward, maintaining traceability is also an added cost and may not be useful at all granularity levels.

The available solutions for the issues above have had little acceptance so far, due to their lack of integration with processes and tools [13]. Thus, a major issue is to bridge the gap between group decisions support, recording decisions, and traceability. For an integrated approach to be accepted by a software development organisation, a systematic, incremental, and experimental approach should be adopted. We need to identify the applicability of solutions and evaluate the cost benefit trade-offs, reinforcing the issue of measurement on RE products and processes.

4 Conclusions

Previous research in requirements engineering has to a large extent been focused on the creation of a specification document in a contract-driven development situation. We argue that interdisciplinary research using empirical methods is needed in order to describe and understand RE as a *decision-making process* in a product development context. The major motivation from an engineering perspective for such research is to provide the basis for prescribing effective and efficient decision support. Methods and tools are needed to support areas such as: decision information management and retrieval, requirements metrics, requirements dependencies, revising decisions, and negotiation.

In summary, the following research areas have been identified and motivated:

- decisions on strategic level
- decisions on operational level
- decision contexts
- product and process metrics
- management of dependencies
- impact analysis
- decision revisioning
- negotiation
- decision recording
- traceability

These areas should be treated both descriptively and prescriptively. Research questions of a descriptive nature can provide a deeper understanding of the RE process from a decision-makers point of view. Many different kinds of empirical studies are needed in order to gain such a deep understanding. Ultimately, prescriptive research may provide empirically grounded guidelines on what methods and tools to use in what contexts, with a quantified expectancy on benefits and costs.

Acknowledgements

The presented work is a result of a research co-operation including Lund University, Fraunhofer Institute for Experimental Software Engineering, University of New South Wales and Blekinge Institute of Technology. The authors would like to express their gratitude for financing made available from each organisation. Travel funds have also been given from the Ericsson Research Exchange Scholarship.

References

[1] Vliegen, H. J. W. and Van Mal, H. H. “Rational Decision Making: Structuring Design Meetings”, IEEE Engineering Management, Vol. 37(3), pp. 185-190, 1990.

[2] Aurum, A. and Martin, E. “Managing both Individual and Collective participation in Software Requirement Elicitation Process”. Proc. 14th Int. Symposium on Computer and Information Sciences (ISCIS'99), pp. 124-131, 1990.

[3] Mallick, S. and Krishna, S. “Requirements Engineering: Problem Domain Knowledge Capture and the Deliberation Process Support”, Proc. 10th Int. Workshop on Database & Expert Systems Applications, pp. 392-397, 1990.

[4] Evans, R., Park, S. and Alberts, H. “Decisions not Requirements: Decision-Centered Engineering of Computer-Based Systems”. Proc IEEE Int. Conference and Workshop on Engineering of Computer-Based Systems, pp. 435-442, 1997.

[5] Anthony, R. N. *Planning and Control Systems: A Framework for Analysis*. Harward University, Boston, USA, 1965

[6] Carlshamre, P. and Regnell, B. “Requirements Lifecycle Management and Release Planning in Market-Driven Requirements Engineering Processes”, Proc. IEEE Int. Workshop on the Requirements Engineering Process (REP’2000), 6th-8th of September 2000, Greenwich UK.

[7] Karlsson, J. and Ryan, K. “A Cost-Value Approach for Prioritizing Requirements”, *IEEE Software*, September/October 1997.

[8] Saaty, T. L. *The Analytical Hierarchy Process*, McGraw-Hill, 1980.

[9] Moran, P. and Carroll J.M. *Design Rationale: Concepts, Techniques, and Use*, Lawrence Erlbaum Associates, Mahwah, NJ, 1996.

[10] Toulmin, S. *The Uses of Argument*, Cambridge University Press, 1958.

[11] Dutoit, A. H. and Paech, B. “Rationale Management in Software Engineering”, *Handbook on Software Engineering and Knowledge Engineerin*g, World Scientific, December 2001.

[12] Boehm, B., Egyed, A., Kwan, J., Port, D., Shah, A., and Madachy, R.”Using the WinWin Spiral Model: A Case Study”, *IEEE Computer*, Vol.31(7), pp. 33-44, July, 1998.

[13] Balasubramaniam, R. and Kannan, M. “Integrating Group Decision and Negotiation Support Systems with Work Processes”, Proc. 34th Int. Conference on System Sciences, Hawaii, January 2001.