Decision-making in the Requirements Engineering Process:
A Human-centred Approach

by

Beatrice Alenljung

Submitted to Linköping Institute of Technology at Linköping University in partial
fulfilment of the requirements for the degree of Licentiate of Philosophy

Department of Computer and Information Science
Linköpings universitet
SE-581 83 Linköping, Sweden

Linköping 2005
Decision-making in the Requirements Engineering Process: A Human-centred Approach

by

Beatrice Alenljung

December 2005
ISBN 91-85457-55-8
Linköping Studies in Science and Technology
Thesis No. 1204
ISSN 0280-7971
LiU-Tek-Lic-2005:59

ABSTRACT

Complex decision-making is a prominent aspect of requirements engineering and the need for improved decision support for requirements engineers has been identified by a number of authors. A first step toward better decision support in requirements engineering is to understand decision-makers’ complex decision situations. To gain a holistic perspective of the decision situation from a decision-makers perspective, a decision situation framework has been created. The framework evolved through a literature analysis of decision support systems and decision-making theories. The decision situation of requirements engineers has been studied at Ericsson Microwave Systems and is described in this thesis. Aspects of decision situations are decision matters, decision-making activities, and decision processes. Another aspect of decision situations is the factors that affect the decision-maker. A number of interrelated factors have been identified. Each factor consists of problems and these are related to decision-making theories. The consequences of this for requirements engineering decision support, represented as a list that consists of desirable high-level characteristics, are also discussed.

This work has been supported by The University of Skövde and The Swedish Knowledge Foundation.
Acknowledgements

First of all I want to thank my supervisor Dr. Anne Persson for all support and encouragement. You haven always given me valuable up-front advice in great things as in small.

I want to express my gratitude to my supervisor Prof. Sture Hägglund and co-supervisor Dr. Pär Carlshamre. You have given me insightful comments on research ideas, been supportive, and asked necessary questions. Furthermore, I want to thank Dr. Mattias Strand who thoroughly reviewed and discussed this thesis. You gave me a lot of helpful comments.

I also wish to thank my colleagues especially in the Information Systems Research Group and my teaching colleagues in human-computer interaction and cognitive science. None mentioned, none forgotten.

Last but not least, I want thank my family, my husband Mattias and my sons Sebastian and Zackarias. You are my everything. Ni är det bästa som finns!
## Contents

1   Introduction .......................................................................................................................... 1
   1.1  Problem domain ............................................................................................................. 2
   1.2  Research problem ......................................................................................................... 2
   1.3  Research method .......................................................................................................... 4
   1.4  Main contributions ....................................................................................................... 4
   1.5  Future work .................................................................................................................. 5
   1.6  Thesis outline ............................................................................................................... 5

2   Requirements Engineering and Requirements Engineering Decision Support ................. 7
   2.1  Goals, process, and requirements ............................................................................... 7
   2.2  Requirements engineers .............................................................................................. 9
       2.2.1  Skills and knowledge ......................................................................................... 9
       2.2.2  Tasks .................................................................................................................. 9
       2.2.3  Social context ................................................................................................... 10
   2.3  Requirements engineering as decision-making ........................................................... 10
   2.4  Requirements engineering decision support .............................................................. 11

3   Decision-making – an analysis of theories in use ............................................................... 15
   3.1  Decisions ..................................................................................................................... 15
   3.2  Decision-makers ......................................................................................................... 20
       3.2.1  Classes of Decision-makers ............................................................................ 20
       3.2.2  Psychological types and decision styles ......................................................... 21
   3.3  Decision-making ......................................................................................................... 23
       3.3.1  Problem solving ............................................................................................... 24
       3.3.2  Models of decision processes ......................................................................... 25
       3.3.3  Individual, behavioural decision-making ....................................................... 31
       3.3.4  Group decision-making .................................................................................. 37
       3.3.5  Organisational decision-making ..................................................................... 38

4   Decision Support Systems .................................................................................................. 45
   4.1  Definitions .................................................................................................................... 45
4.2 Characteristics ........................................................................................................ 46
4.3 Types of DSS ........................................................................................................... 47
4.4 The use of DSS ........................................................................................................ 48
  4.4.1 Supporting decision-making .............................................................................. 49
  4.4.2 Benefits ............................................................................................................. 50

5 Method ....................................................................................................................... 53
  5.1 Methodological considerations ........................................................................... 53
  5.2 Research process .................................................................................................. 54
    5.2.1 Literature analysis ............................................................................................ 56
    5.2.2 Case study ....................................................................................................... 56
    5.2.3 Synthesis ......................................................................................................... 61
  5.3 Reflections of the research process ...................................................................... 62

6 Results ....................................................................................................................... 65
  6.1 A decision situation framework .......................................................................... 65
  6.2 The decision situation of requirements engineers .............................................. 67
    6.2.1 Decision matters, decision-making activities and decision processes in RE .... 67
    6.2.2 Characteristics of decision matter and decision outcome ......................... 73
    6.2.3 Input used by requirements engineers ............................................................ 74
  6.3 Factors that affect the decision-making requirements engineer .................... 76
    6.3.1 Attitudes towards requirements work ............................................................. 76
    6.3.2 Communication and coordination ................................................................. 78
    6.3.3 Resource ......................................................................................................... 79
    6.3.4 Pressure ......................................................................................................... 79
    6.3.5 Cognitive load ............................................................................................... 80
    6.3.6 Knowledge ...................................................................................................... 81
    6.3.7 Other ............................................................................................................... 82
  6.4 Desirable characteristics of RE decision support ............................................ 83
    6.4.1 The requirements engineer as a single user .................................................. 84
    6.4.2 The nature of RE decision-making tasks ....................................................... 86
6.4.3 The requirements engineer in the social context.............................................................. 88

7 Discussion......................................................................................................................................... 91
7.1 Contributions and limitations........................................................................................................ 91
7.2 The decision situation framework.................................................................................................. 93
7.3 Future work ...................................................................................................................................... 94

8 Research Plan .................................................................................................................................... 97

9 References ......................................................................................................................................... 101
1 Introduction

Researchers and practitioners have for a number of years agreed that requirements engineering (RE) is a critical activity for the success of systems development. The complexity of RE and the large extent of decision-making involved in the RE process have also been recognised. One would then assume that the computerised tools used to support RE are purposeful. However, the limitations of and dissatisfaction with RE tools (Lang & Duggan, 2001; Alenljung & Persson, 2005c) as well as the low adoption of RE tools in organisations (Matulevičius, 2005) paints a different picture.

The aim of our research project is to enhance the ability of RE tools to effectively support RE decision-making. The tools can be considerably improved if their development is governed by a human-centred perspective, using theories of human decision-making and taking into account the experiences of requirements engineers as decision-makers. The consequence of such improvement should primarily be apparent on an individual level and on a project level. Requirements engineers should experience that their decision-making activities substantially have been facilitated. In a development project it should be possible to state that for instance error reports stemming from bad RE decisions have been reduced.

As can be seen in Figure 1, this thesis consists of the first part of a larger research project. This means that we will not develop complete RE decision support, but rather to take the first steps towards it.

![Figure 1](image_url)

**Figure 1, The relation between the research project and this thesis**

One of many challenges when developing decision support is to properly understand the actual decision situation in which the decision-maker acts, so that decision-making can be supported from the decision-maker’s perspective. Properly
means that attention has to be paid to the very nature of the decision-making situation. Otherwise we risk supporting what does not need to be supported or we risk providing support in an inappropriate way. A support system is only useful in relation to the characteristics of its target users, the tasks that are supposed to be carried out, and the context in which the system is going to be used (e.g. Maguire, 2001). This means that adopting a user-centred design approach to obtaining successful decision support is reasonable (Parker and Sinclair, 2001). The target users in the case of RE decision-making are the requirements engineers.

1.1 Problem domain

Requirements engineering (RE) is the process in software systems development concerned with the transformation of vague ideas about a software system, informal knowledge, and personal views into complete system specification, formal representation, and agreement (Pohl, 1996). The RE process consists of related activities that are concerned with deriving, validating and maintaining a systems requirements document (Sommerville & Sawyer, 1997). Requirements are statements of a system, which are used by different actors in the development process (Sommerville, 1995). Requirements serve as verbalisation of decisions concerning the functionality and qualities of a system. Thus, the RE process can be viewed as a decision process and requirements can be viewed as decisions (Aurum & Wholin, 2003; Evans et al. 1997). The requirements engineers can then be viewed as decision-makers. RE decision-making is complex and of vital importance for both the development process and the system. Therefore, requirements engineering decision support can increase the effectiveness and efficiency of RE decision-making.

1.2 Research problem

Decisions are made at all steps in information systems development, for example with regard to requirements, architecture, components, project planning, validation etc. (Kotonya & Sommerville, 1998; Ruhe, 2003). In the same way the requirements engineering (RE) process can be viewed as a decision-making process (Aurum & Wholin, 2003; Regnell et al., 2001). Decision-making in the RE process is far from straightforward. It involves the difficulties that characterise decision-making in natural settings, e.g. uncertain and dynamic environment; shifting, ill-defined, or competing goals or values; time stress; and multiple players (Orasanu & Connolly, 1993). The decision situation of the requirements engineer can be both complex and difficult to manage, due to for example lack of supportive resources, high cognitive load, and pressure. Lacking resources are for instance usability problem of requirements management tools and lack of resource personnel. High cognitive load stems from for example the difficulty of obtaining a general view of the system and subsystems, and their relationships and interdependencies. Pressure emerges from e.g. lack of time and related actors with different needs (Alenljung & Persson, 2005c). This implies that decision-makers in the RE process need decision support, for example requirements management tools that are adapted to the actual decision-making activities.
In order to be able to purposefully improve RE decision support it is essential to gain a comprehensive understanding of the requirements engineers’ decision situation, e.g. in terms of which decisions are actually made; which factors affect RE decision-makers; what decision-making activities are carried out; and which decision processes exist? This understanding enables a definition of what kind of decision support requirements engineers need and how such support should be constituted.

As a consequence, the research questions of this thesis are:

1. How can the decision situation of a decision-maker be described?
2. Which are the decision situations of requirements engineers?
3. Which problems and difficulties face the requirements engineers in their decision situations?
4. What kind of decision support do requirements engineers need and how should such a decision support be constituted?

The relationship between the research questions is presented in Figure 2. The first research question has a wider scope than the second and third questions. These questions form the basis for the forth research question. This, in turn, directs the plans for further research.

![Figure 2, Relationship between research questions and research plan](image)

The focus is on requirements engineers in a contract development context, where both the projects and systems to be developed are large and complex.
1.3 Research method

In order to answer the research questions a qualitative and human-centred approach has been used. The research process consists of three stages: a) a literature analysis, b) a case study, and c) a synthesis of theories and empirical findings.

The literature analysis was used to answer the first research question. It embraced different kinds of decision-making theories and literature from decision support systems. This stage resulted in a decision situation framework that was used during stage two.

To answer the second and third research questions, a case study was conducted. The case study took place at a software development company, Ericsson Microwave Systems, which develops military radar systems. The first step in the case study was open-ended interviews with requirements engineers. Then a focus group session was held at the company. In the first part of the session the preliminary results from the first round of interviews were presented and in the second part the results were discussed by the participants. The third step was open-ended interviews with actors in the development process related to the requirements engineers. This stage resulted in descriptions of decision matters; decision-making activities; decision processes; inputs; and factors that affect the decision-making requirements engineer.

The fourth research question was answered with a synthesis of the results from the case study and theories about decision-making as well as decision support systems. This stage resulted in a number of high-level characteristics that are desirable of requirements engineering decision support.

1.4 Main contributions

The main contributions of this thesis are:

- A decision situation framework that provides a holistic perspective of decision-making in general and which places the human decision-maker at the centre.

This contribution has resulted in the following publications:


- A comprehensive description of the decision situation of requirements engineers, which includes descriptions of RE decision processes; RE decision-
making activities; RE decision matters and their characteristics; as well as input used by the requirements engineer.

This contribution has resulted in the following publication:


- A model of factors that directly or indirectly affect the decision-making of requirements engineers. The factors include related problems.

This contribution has resulted in the following publication:


- A list of desirable, user-centred, high-level characteristics of an RE decision support.

All of these contributions constitute the basis for our future research.

1.5 Future work

Future research is planned to focus on how to provide better support for analysis of change proposals through requirements management tools. To do this, evaluations of current tools will be conducted from a human-centred perspective focusing on this particular decision-making task, usability and cognitive load. Based on the results of this evaluation, we plan to create a low fidelity prototype that in a more effective and satisfying way supports requirements engineers when carrying out analysis of change proposals. Thus, a concrete way of providing better requirement engineering decision support should be the outcome of our research.

1.6 Thesis outline

The remainder of this thesis is structured as follows:

Chapter 2  describes the problem domain, requirements engineering (RE), which is the domain that we primarily contribute to. First, the goals of RE are presented together with the RE process and a definition of requirements. Second, the skills and knowledge of requirements engineers are described as well as their tasks and social context. Third, RE as decision-making is discussed. Fourth, different kinds of RE decision support are exemplified.
Chapter 3 contains theories of human decision-making, which were used when the decision situation framework was created and were also used as a basis for the case study. First, the concept of decision is discussed. Second, different classes of decision-makers are presented along with psychological types and decision styles of decision-makers. Third, decision-making is described, which includes theories of problem solving: models of decision processes; theories of individual, behavioural decision-making; theories of group decision-making; and theories of organisational decision-making.

Chapter 4 discusses the concept of decision support systems (DSS) and their characteristics, which have inspired the formulation of desirable characteristics of requirements engineering decision support. First, DSS is defined. Second, the characteristics of DSSs are described. Third, different types of DSSs are discussed. Forth, the use of DSSs are presented, which includes both how decision-making can be supported and the benefits of DSSs.

Chapter 5 reports the method that has been used to answer the research questions. First, methodological considerations are discussed. Second, the research process is presented, which includes the literature analysis, the case study, and the synthesis. Third, reflections on the research process are discussed.

Chapter 6 presents the results of the research process as answers to the research questions. First, the decision situation framework is presented. Second, the decision situation of requirements engineers is described, which includes RE decision processes; RE decision-making activities; RE decision matters and their characteristics; and the input used by the decision-making requirements engineer. Third, factors that affect the decision-making requirements engineer are described. The factors are attitudes toward requirements work, communication and coordination, resource, pressure, cognitive load, knowledge, and other. Forth, desirable characteristics of RE decision support are outlined. The characteristics are structured in three levels: the requirements engineer as a single user; the nature of RE decision-making tasks; and the requirements engineer in the social context.

Chapter 7 provides a discussion about the research results and their limitations.

Chapter 8 outlines the research questions and research plan for future work.
2 Requirements Engineering and Requirements Engineering Decision Support

In this chapter requirements engineering (RE) is presented. First, the goals of RE and the RE process is described together with an explanation of the concept of requirement. Second, the perspective of requirements engineers is discussed. Third, RE as decision-making is introduced, and finally, different types of RE decision support are outlined.

2.1 Goals, process, and requirements

The development of interactive systems as well as embedded software is an expensive and complex process. Therefore, it is important that the process is successful in terms of each software component fulfilling its purpose and requirements. However, to define such purposes and requirements is by no means a trivial task in the development process. This task is called requirements engineering (RE). RE is a “systematic process of developing requirements through an iterative cooperative process of analyzing the problem, documenting the resulting observations in a variety of representation formats, and checking the accuracy of the understanding gained” (Pohl, 1996, p 3). There are three main goals of the RE process (Pohl, 1994):

- Develop a complete system specification starting from vague ideas about the system to be.
- Change informal knowledge about the system into formal representations.
- Negotiate agreement on the specification from a number of personal views.

Specific RE processes vary depending on several factors. For example, the RE process depends on development context. There are three different types of development contexts: a) contract development, b) product development, and c) in-house development. For instance, each type has different opportunities and obstacles concerning user involvement and must therefore be dealt with in different ways (Grudin, 1991). However, in general the RE process consists of related activities that are concerned with deriving, validating and maintaining a systems requirements document (Sommerville & Sawyer, 1997).

As can be seen in Figure 3, an RE process has several kinds of input that has to be taken into account, such as existing systems information, stakeholders needs, organisational standards, regulations, and domain information. The RE process can result in agreed requirements, a system specification, and system models. Within the RE process, the requirements are elicited. In this activity the requirements engineers use the input and try to comprehend the nature of the problem domain in order to generate requirements. Then the proposed requirements are analysed and negotiated. The requirements have to be evaluated in order to decide which alternatives are the most feasible and most cost-efficient. Then the requirements, the system specification, and system models are documented. The requirements should
be validated to reduce inconsistencies and incompleteness (Kotonya & Sommerville, 1998).

An essential concept in RE is requirement. Sommerville (1995, p. 64) defines a requirement as “a statement, in natural language plus diagrams, of what services the system is expected to provide and the constraints under which it must operate. It is generated using customer-supplied information”. The requirements are documented. Macaulay (1996) lists three different types of requirements documents. First, there are market requirements documents, which is important when developing a product for a potentially large number of customers. Second, there are user requirements documents, which can consist of descriptions of the nature of the problem and the general constraints, e.g. cost and time. It normally also contains a description of the desired functionality of the system to be, acceptance criteria, performance monitoring, quality attributes, and technical constraints. Third, there are software requirements documents. A software requirements document contains, according to Pressman (2000), a detailed functional description, a representation of system behaviour, an indication of performance requirements and design constraint, appropriate validation criteria, and other relevant information. A requirements specification defines the system services in detail. It may function as a contract between the customer and the software developer. A software specification forms the basis for design and implementation. It consists of an abstract description of the software and it can complement the requirements specification (Sommerville, 1995). Hence, the work of requirements engineers pervasively comprises requirements in different ways.
2.2 Requirements engineers

The persons working with RE are called requirements engineers. Requirements engineers need different kinds of skills and knowledge to efficiently and effectively perform the RE tasks. To facilitate the tasks there are tools and techniques that requirements engineers can use. Something that additionally affects their work situation is the social context in which they work.

2.2.1 Skills and knowledge

The requirements engineer needs several skills and knowledge in order to be able to effectively carry out the RE tasks. Macaulay (1996) lists a number of such skills and knowledge. Desirable skills are for instance interviewing, group work, facilitation, and negotiation skills. Other skills are analytical, problem solving, presentation, and modelling skills. The requirements engineer should have knowledge of and experience in CASE tools, modelling techniques and languages, traceability and management tools, human-computer interaction, as well as product planning and marketing. It is, of course, difficult for a single individual to possess all of these skills and to have knowledge about and extensive experience in so many different topics. However, this account of desirable skills shows that RE is complex and that “just anybody” cannot successfully carry out RE tasks.

2.2.2 Tasks

Requirements engineers carry out several different types of tasks, which for example are presented by Kotonya and Sommerville (1998). They formulate requirements, which can be formulated in natural, semi-formal, or formal language. They manage requirements changes, and relationships between requirements. They also manage dependencies between requirements documents and other documents that are produced in the development process. They elicit requirements and conduct requirements analysis in which they look for missing, ambiguous, conflicting, overlapping, and unrealistic requirements. Requirements engineers negotiate which requirements should be accepted and how the requirements should be prioritised. They check the requirements’ necessity, consistency and completeness, as well as feasibility. They validate the requirements, i.e. identify in the final requirement document potential lack of conformance to quality standards; poorly worded requirements which are ambiguous; errors in models of the system or the problem to be solved; and requirement conflicts (Kotonya & Sommerville, 1998).

The tasks of the requirements engineer are facilitated by using tools and techniques. A requirements management tool provides support by storing requirements and providing for example a requirements browser, a requirements query system, a traceability system, and a general report generator. It can also include a change control system, which can maintain information of requirements change requests together with links to requirements affected by the changes (Kotonya & Sommerville, 1998; Finkelstein & Emmerich, 2000). There are a large amount of various techniques that can make the RE tasks easier to perform. There are for example analysis checklists; prototyping techniques that visualise the meaning of the requirements;
and interaction matrices to discover the interactions between requirements and to highlight requirements conflicts and overlaps (Kotonya & Sommerville, 1998). These tools and techniques are sometimes used in cooperation or in relation to other actors that is part of the social context of the development process.

2.2.3 Social context

The requirements engineers work in a social context in which they interact with other actors in the development process. Domain experts and end users are important actors during requirements elicitation (Bray, 2002). Other actors in the development process are for example managers, system customers, system engineers, system maintenance engineers, and system test engineers. Managers can use the requirements to plan a bid for the system and plan the system development process. System customers can specify changes to the requirements, and read and check the requirements. System engineers and system maintenance engineers use the requirement to understand the system. The system test engineers use the requirements to develop tests for the system (Kotonya & Sommerville, 1998).

The tasks performed by requirements engineers can be viewed as decision-making activities within a decision-making process.

2.3 Requirements engineering as decision-making

RE is largely a decision-making process (Aurum & Wholin, 2003) or to put it in the words of Evans et al (1997, p 435) “For the engineering of computer-based systems, the term [and the associated process] of “requirements” might well be replaced with the term “decisions” and a decision process”.

Decisions can be categorised as belonging to three levels in an organisation: strategic planning, management control, and operational control (Anthony, 1965). In the RE process the decision matter on the strategic level mainly concerns organisational considerations, such as the requirements consistency with the product strategy or business goals. Tactical decisions, i.e. management control, focuses on the project level, for example human resource planning. The lowest level, operational control, involves making decisions on realisation issues and decisions on quality, classification, and property of requirement (Aurum & Wholin, 2003; Regnell et al., 2001). To assist RE decision-makers and to increase the effectiveness and efficiency of RE decision-making activities, several aspects need to be focused on (Aurum & Wohlin, 2003);

- Keeping track of RE decisions and their effect on the software product.
- Identifying the type of stakeholders who participate in each RE activity and accordingly consider specific decision aids for each type of stakeholder.
- Identifying the decision types involved at each RE phase as well as the meaningful actions or options that each decision-maker carries out for each decision type.
- Identifying the information type (or knowledge) needed at each phase.
- Providing decision support tools.

Such decision-making is not always straightforward and may need to be supported in order to enhance the effectiveness of the decision outcome and make the decision processes more efficient.

### 2.4 Requirements engineering decision support

Based on a literature analysis of requirements engineering decision support (REDS), we have identified three different types of REDS. These types are:

- Requirements-based decision support
- Requirements decision support
- RE process decision support

In *requirements-based decision support* the primary purpose of a REDS is to use the existing requirements as input in for instance software engineering decision-making. An example of this is the work of Maiden et al. (2002). This work integrates a multi-criteria decision-making technique called analytic hierarchy process (AHP) and a requirements modelling technique called $i*$. In this way trade-offs can be dealt with and decisions concerning which system architecture and design is most appropriate compared to the systems requirements can be supported. Another example is supporting commercial-of-the-shelf (COTS) decision-making. Alves and Finkelstein (2003) support choice of COTS features. The support involves comparing and reaching the best balance between the customer requirements and the COTS constraints. A third example focuses on supporting software release planning. An approach for such support is provided by Greer and Ruhe (2004). This approach, called EVOLVE, is evolutionary and iterative. Based on a set of requirements, including their effort estimations and their categorisation into priorities by stakeholders, candidate solutions are generated from which the decision-maker can choose. A forth example is the decision support method proposed by Svanberg et al. (2003), which is a multi-criteria decision method that supports the choice of architecture based on quality requirements.

In *requirements decision support* decisions concerning the requirements as such is supported. Examples of this are techniques that support decision-making with regard to the priorities of requirements. Karlsson et al. (1998) have conducted an evaluation of methods for prioritising software requirements, and they found that the analytic hierarchy process (AHP) was the most promising method. Another example is the work of Pomerol (1998), aiming to support the decision-maker in the requirements analysis phase. The support is provided through scenarios. A scenario is viewed as a branch in a decision tree and Pomerol (1998) presents a way to reduce the complexity and propose ideas for scenario management. A third example is the decision-making methodology developed by Rosca et al. (1997). This methodology supports analysing and extracting the requirements that fall into the category of business rules. A fourth example is the support for selecting requirements called Quantitative WinWin developed by Ruhe et al. (2002). Quantitative WinWin is
intended to be used in requirements negotiation and is based on the preferences of stakeholders, the business values of requirements, and a given maximum development effort.

*RE process decision support* assists requirements engineers in determining proper ways to carry out the RE process. An example of this is the ACRE (ACquisition of REquirements) framework, which is developed by Maiden and Rugg (1996). ACRE includes guidelines that are to be used when choosing acquisition method. Another example is the work of Jiang and Eberlein (2003) and Jiang et al. (2004) resulting in a methodology as well as a framework that support requirements engineers to tailor the RE process and decide on suitable RE techniques for a certain project. A third example is the MODDE methodology (Model of Decision support system Design and Evaluation), which is developed by Meikle (2002). MODDE uses concepts from the legal domain and gives support in the requirements specification process. The concepts guide the requirements engineers’ considerations in the decision-making environment.

The boundaries between these types of REDS are not firm, e.g. decisions concerning requirements may also be based on requirement. However, the purposes of REDS found in the literature can be categorised as primary addressing one of these types of REDS.

Closely related to REDS is software engineering decision support (SEDS). SEDS is decision support for the whole life cycle of software development and evolution. Decisions concern processes, products, tools, methods, and techniques (Ruhe, 2003). We view REDS as a subset of SEDS as can be seen in Figure 4. A SEDS can for example support software reliability engineering strategy selection (Rus & Collofello, 1999), software project management (Raffo & Setamanit, 2003), software product and process assessment (Morisio et al., 2003), and management decisions in the software inspection process (Miller et al., 2002).
In summary, the purpose of requirements engineering (RE) is to understand the problem domain of which a system is to become part. This understanding results in agreed requirements that are documented and managed during the lifetime of the system. The RE tasks, which are performed in the social context of the development process, are conducted by requirements engineers, who are supported by tools and techniques. RE can be viewed as decision-making and as such we can argue that requirements engineering decision support (REDS) is needed. We have identified, from the literature, three types of REDS with different primary purposes.
3 Decision-making – an analysis of theories in use

In order to support decision-makers, e.g. decision-making requirements engineers, efficiently, there is a need to understand the decision-makers’ situation. In this chapter decision-making are presented. First, the concept decision is elaborated. The central part of decision-making is the decisions, and a decision matter can have different characteristics. Second, the decision-maker is in focus. The person or persons that make the decision are decision-makers. Decision-makers carry out decision-making activities within a decision process. Decision-making activities and decision processes are described in the last section of this chapter. There are many decision-making theories that for example concerns individual decision-making, group decision-making, and organisational decision-making.

3.1 Decisions

Decision is a commonly used word. Large amounts of literature have been written on how people make decisions, how we should make decisions, consequences of decisions et cetera. However, the definition of the concept decision is still not unambiguous. The reason for this could be that it is taken for granted; everybody “knows” what a decision is. If this is the case, there may be a risk that we interpret the term decision differently. Two sources that define decision are Mintzberg et al. (1976) and Mallach (1994). They define the concept of a decision as a “specific commitment to action” (Mintzberg et al., 1976, p 246) and as “a reasoned choice among alternatives” (Mallach, 1994, p 28). These definitions focus on different aspects. Mallach (1994) focuses on the choice, which in this case must be preceded by an evaluation of alternatives. This means that decisions are viewed as two steps within a decision process. The decision process is often considered to include more steps, which makes it a bit strange to define decisions as the last part of a decision process. The definition of Mintzberg et al. (1976) views decisions as a consequence, and it also implies that some type of action is always the consequence. It is reasonable to consider decisions as a result of a decision process, but it does not necessarily cause action. The result can be the decision not to act. In this thesis the central concepts are defined as follows:

- A decision has two meanings. It is the outcome of decision-making, which often is a part of a decision process. A decision can also be viewed as the decision matter that is dealt with in a decision process. The decision matter is going to be an outcome.
- Decision-making is considered to be activities, mentally or physically, made by a decision-maker.
- A decision-maker is a person who carries out the decision-making activities, alone or together with others, but is not necessarily the one who authorises the decision.
- Decision process is viewed as a number of phases or steps related to each other that result in a decision.

These concepts are related to each other which is shown in Figure 5.
Decisions can be characterised in several ways. According to Mintzberg et al. (1976) there are three ways of classifying decisions, a) by the stimuli that starts the decision process, i.e. opportunity, crisis, and problem, b) by solution, i.e. given, ready-made, custom-made, and modified, and c) by its process. Another way of characterising decisions is presented by Holsapple and Whinston (1996): structuredness, negotiation, management level, functional area, and managerial function (see Figure 6). Three of the categories are specifically focused on management and business organisations, which is not the focus of this work. Therefore they have been generalised to fit decision-making in general. The management level is labelled scope and time frame. The new term for functional area is domain-specific functional area, and managerial function is called general functions. The characteristics are described in the following.

Figure 5, The relation between the central concepts

Figure 6, Ways of characterising decisions (adapted from Holsapple & Whinston, 1996)
Degree of structuredness

Simon (1960) suggests that decisions can be termed as programmed and nonprogrammed. Programmed decisions are repetitive and have a defined procedure and nonprogrammed decisions are to a higher extent novel and unstructured. These are not distinct types of decisions; instead they are at the ends of a continuum (Simon, 1960). Gorry and Scott Morton (1971) introduced new terms for these types, *structured* for programmed and *unstructured* for nonprogrammed. They also introduced a new term, *semi structured*, for decisions that are partly structured and partly unstructured. This way of viewing decisions is widely used in decision support system literature (see for example Mallach, 1994; Holsapple & Whinston, 1996; Marakas, 1999; Power, 2002).

Scope and time frame

This way of characterising decisions is based on what Holsapple and Whinston (1996) call management level, which was introduced by Anthony (1965).

Anthony (1965) categorises decisions as belonging to three levels in an organisation. However, this way of viewing decisions can be used to describe other decision situations, e.g. on the political arena, in private life, or in military settings. As can be seen in Figure 7, it is primarily a matter of scope (from wide range to short range) and time frame (from long-term to short-term). The levels are a) strategic decisions, b) tactical decisions, and c) operational decisions.

![Figure 7, Scope and time frame for strategic, tactical, and operational decisions.](image)

At the top level there are *strategic decisions*. This level is called strategic planning and is defined as “the process of deciding on objectives of the organization, on changes in these objectives, on the resources used to attain these objectives, and on the policies that are to govern the acquisition, use, and disposition of these resources” (Anthony,
1965, p 16). Decisions at this level affect a major part of the organisation for a long period of time (Mallach, 1994).

The next level below is tactical decisions, which is termed by Anthony (1965) as management control. Management control is defined as “the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization’s objectives” (Anthony, 1965, p 17). Mallach (1994) claims that decisions at this level are made in the context of previously made strategic decisions and affect a part of the organisation for a limited period of time.

At the lowest level can operational decisions, denoted operational control by Anthony (1965), be found. They are defined as “the process of assuring that specific tasks are carried out effectively and efficiently” (Anthony, 1965, p 18). Decisions on this level affect on a more daily basis.

The characteristics of the needed information differ between the levels. The source of information is to a higher extent external at the higher levels and largely internal at the lower levels. The scope of information is wider and the level of aggregation is higher on the top management level (Gorry & Scott Morton, 1971). It would be interesting to compare the statements of Gorry and Scott Morton (1971) to more recent work, and to see to what extent they are agreed upon today. However, such a comparison is beyond the scope of this thesis.

Focus with regard to domain-specific functional areas

According to Holsapple and Whinston (1996) decisions are often classified in terms of functional area of management. Laudon and Laudon (2002) present several functional areas. The sales and marketing function is concerned with identifying customers and their needs, selling the organisation’s products, advertising, communicating with customers and so on. The function of manufacturing and production deals with the planning, development, and production of products. Handling of the financial assets is made by the functional area finance and accounting. The human resources function is concerned with the employees and is responsible for attracting, developing, and maintaining the workforce (Laudon & Laudon, 2002).

The disadvantage of using this classification is that it is too narrow. It is too focused on a specific domain, i.e. business organisations. There are other domains, e.g. health care, which do not in include all of the mentioned functional area above and might include others. But if this way of classifying decisions is generalised, it can be valuable. So, depending on domain, decisions can be classified in functional areas (see Figure 8).
Degree of negotiations

According to Holsapple and Whinston (1996) decisions can also be categorised as *negotiated* or *unilateral*. Negotiated decisions are made by multiple participants who must agree. Unilateral decisions may also involve several participants, but there is one individual that actually make the decision. The other participants must not agree on the matter (Holsapple & Whinston, 1996).

General function

A decision-maker, such as a manager, carries out general activities, which include decisions. Fayol (1984, first published in 1916) identified five managerial functions called the POCCC view of management. The functions are general, and are not only managerial activities. The functions are:

- Planning
- Organising
- Coordinating
- Commanding
- Controlling

Planning is concerned with outlining what to do. Structuring of human resources is regarded in organising, which focuses on responsibility, authority, and expected flow of communication. The coordinating function deals with harmonising activities in an organisation, i.e. determine sequence and timing of activities; allocating resources, time, and priority to things and actions; and adapting means to ends. Commanding is done when an organisation starts the process of achieving a goal and the function controlling is concerned with ensuring that the plan is followed, verifying the given instructions, and controlling that the appropriate principles are established (Fayol, 1984).

These five aspects through which decisions can be characterised make it possible to create a decision profile. Such a decision profile can deepen the understanding of the nature of the decision matter of interest.
3.2 Decision-makers

Decisions are made by decision-makers, sometimes alone and sometimes together with others. However, regardless of the number of people involved, each person has his or her own characteristics.

3.2.1 Classes of decision-makers

Decisions can be made by different types of decision-makers. As can be seen in Figure 9, decisions can be made by either a single decision-maker or by multiple decision-makers together. The single decision-maker can be a person or a machine. In this thesis, though, only human decision-makers are of interest. When there are multiple decision-makers involved, they are a team, a group, or an organisation. Each of these types has its own characteristics.

![Decision-maker classification diagram](image)

**Figure 9, Classification of decision-makers (adapted from Holsapple & Whinston, 1996; Marakas, 1999)**

An individual, human decision-maker has the responsibility for the whole or the major part of a decision process. The outcome of such a process is affected by the person’s unique characteristics, such as knowledge, experience, personality, and cognitive style. Depending on the characteristics, decision-makers benefit from different kinds of decision support (Holsapple & Whinston, 1996; Marakas, 1999). For example an inexperienced decision-maker may benefit from a decision training system and an experienced decision-maker may be better supported by decision performance aid.

In cases where there are multiple decision-makers, they are all stakeholders in the decision process. However, they do not necessarily have equal authority to make a decision, or perhaps none of them has the authority to make a decision on his or her own (Marakas, 1999). In a team of decision-makers there is a manager (or a similar role) and assistants (or similar roles). The manager is the deciding member of the team and the assistants support the manager. The assistants can for example be
specialists that provide the manager with information, and in this way they influence the outcome of a decision process (Holsapple & Whinston, 1996; Marakas, 1999). In a group of decision-makers there is not a single person that has the authority to make the final decision. Instead all members together authorise a decision, which can be made through voting or reaching consensus. The group may or may not have a leader, but a leader has no formal rights to decide (Holsapple & Whinston, 1996; Marakas, 1999). Decision-makers on an organisational level have similarities to individuals, teams, and group decision-makers, but as Marakas (1999, p 42) stresses “decision makers at the organizational level are those who are empowered with the authority and charged with the responsibility of making decisions on behalf of the entire organization”.

This classification of decision-makers can be used to clarify the decision situation of the decision-makers. Probably the need of support is different for these classes. Additionally, all of these include individuals and an individual has a decision style that likely affects the decision process.

### 3.2.2 Psychological types and decision styles

The impact of personality type on decision-making style is important since the decision support must reflect the decision-making methods of the persons that will use it (Mallach, 1994). Two ways of summarising decision-making styles are presented here. The first is constructed by Huitt (1992), and is based on the psychological types defined by Briggs-Myers and McCaulley (1985), with its roots in the work of the psychiatrist Carl Jung. The second decision style model is made by Rowe and Boulgarides (1992).

According to Briggs-Myers and McCaulley (1985) the psychological type of a person can be determined by four categories of preferences.

- **Introversion vs. extraversion** is the extent to which an individual prefers to obtain an understanding of the world. Extraverts prefer acting in the world and an introvert prefers to ponder about it.
- **Sensing vs. intuition** is concerned with someone’s preferred perception process. Sensing people prefer to take in information through the senses and detailed observations. They find verification important. An intuitive person favours meanings, relationships, and “reading between” the lines.
- **Thinking vs. feeling** is the preferred judgement process. A thinker wants to make conclusions and be rational and logical, while a feeling person finds it more important to take emotional aspect into account.
- **Judgement vs. perception** is a life style preference. Mallach (1994) describes this as people that prefer a judgement process in life like planning and want things to be settled and organised. A perception process-prefering individual wants life to be spontaneous and flexible.

These characteristics have an effect on how decision-makers act in a decision process. Huitt (1992) has put together psychological types with their characterising decision-making techniques. Extraverts prefer brainstorming in groups, outcome
psychodrama, and thinking aloud, while introverts prefer private brainstorming and incubation. A sensing person considers facts (often deliberately overloading) and uses inductive reasoning, i.e. developing rules from specific instances. Intuitive people classify, categorise, reason deductively, i.e. apply rules on specific instances, and visualise. A thinking person also classifies and categorise like the intuitive person. However, a thinking person is more analytical and prefers to use analytical methods. A feeling person shares personal value, pays attention to others’ feelings, and finds clarification important. A judging person prefer evaluation, plus-minus techniques, and backward planning, while a perceiving person prefer brainstorming, provocation techniques, and taking other’s perspectives (Huitt, 1992).

Rowe and Boulgarides (1992) introduce a decision style model, which can be seen in Figure 10. This model consists of two dimensions, value orientation and cognitive complexity, that shape four categories of decision style. These categories are directive, analytical, conceptual, and behavioural decision styles.

![Figure 10, Decision style model (adapted from Rowe & Boulgarides, 1992)](image)

A decision-maker with a directive decision style has low tolerance for context ambiguity and focuses on decisions of a technical nature. He or she does not want to have large amounts of information of many options. His or her problem solving strategy is using policies and procedures, and has a focused nature of thought. Verbal communication is preferred rather than written channels (Rowe & Boulgarides, 1992).

The analytical decision-maker can handle large amounts of information compared to the directive decision-maker. He or she can handle ambiguity well. He or she has an analytical and insightful problem solving strategy and has a logical nature of thought. Written communication is preferred (Rowe & Boulgarides, 1992).

A person with a conceptual decision style has a high tolerance to high complexity, but is more oriented towards other individuals compared to an analytical decision-maker. This person is a creative thinker, but not a doer, and solves problems through intuition and judgement (Rowe & Boulgarides, 1992).
When someone has a *behavioural* decision style he or she centres attention on other persons and the organisation. Like with the directive decision-maker the need for structure and low complexity is high. Problems are solved through feelings and instincts. He or she is an emotional thinker (Rowe & Boulgarides, 1992).

If there are several decision-makers that are to use the decision support, we can argue that it is important that it can be used in a flexible way. Otherwise there is a risk that it does not suit the decision-makers personalities, and perhaps they do not use the decision support effectively if they find it uncomfortable.

### 3.3 Decision-making

Decision-making are the activities, mental or physical, that are carried out by the decision-maker. These activities take place in a decision process. There are many theories of decision-making and models of decision processes. We have developed a conceptual model containing the main research traditions of and related to decision-making (see Figure 11). In sections 3.3.1-3.3.5 the sources that are used as a foundation for the model is presented.

![Decision-making diagram](image)

**Figure 11, Categorisation of decision theories from different research domains**

*Problem solving* literature does not include decision theories, but is closely related to decision-making. Often, when a decision is to be made, work has to be done concerning identifying a problem and finding or developing alternative solutions for it. It is difficult to discuss decision-making without including aspects of problem solving.

Models of *decision processes* include activities, viewed as steps or phases, that can or must be performed, and how these are related to each other. Such models can enhance our understanding of the work flow of decision-makers, and might be used for example as a base for connecting the right type of information, analysis tools,
communication tools et cetera to a certain decision-making task when developing
decision support. They can also be related to decision-making theories, because it
should be possible to connect each theory to one or more activities in a decision
process.

Decision-making is done by a single individual or by a group of individuals. This
person or these persons might belong to an organisation and make decisions for the
organisation. The individual, behavioural decision theories are divided into three
groups: normative, descriptive, and prescriptive theories.

3.3.1 Problem solving

Problem solving is a mental activity closely related to decision-making, especially
situations where the decision is unstructured and complex. In such cases the solution
to a problem is not obvious and needs problem solving. According to Klein and
Methlie (1990, p 22) problem solving is “an intelligent activity performed by a person
who is confronted with a situation where there is a gap between what is desired (the
goal) and what is given as the initial state”.

The phenomenon of human problem solving can be studied in several ways, such as
phases that an individual or group go through, frameworks to use when to analyse or
describe a problem solving situation, or differences between novices and experts.

One way of describing the phases of problem solving is proposed by Wallas (1945),
who claims that complex problem solving consists of four stages:

- Preparation includes collecting information and attempting to make initial
  solutions.
- Incubation is when the individual does not think consciously of the problem.
- Illumination is the stage in which a solution suddenly appears.
- Verification is when the solution is ensured.

A framework that can be used for studying a problem solving situation is the concepts
introduced by Newell and Simon (1972): problem space and task environment. The
problem space is the mental representation of a problem, and the task environment is
the social and physical environment in which problem solving takes place. This
distinction makes it possible to study both the requirements of the task environment
and the problem solving behaviour within a task environment (Newell & Simon,
1972).

There are differences between experts and novices in their ways of solving problems,
since experts have gained experiences and skills that can make them more successful
and efficient. According to Klein and Methlie (1990) and Zachary and Ryder (1997)
experts have several characteristics:

- Performance: Experts are more efficient and can use their knowledge to draw
  correct conclusions, even if the available information is not complete.
- **Discrimination**: An expert does not start solving a problem through specifying all possible causes. Instead, experts quickly distinguish relevant information from irrelevant and possible causes from impossible causes.

- **Pattern recognition**: An expert can recognise the pattern of a certain type of problem, and connect a possible solution to it.

- **Domain knowledge**: Expertise consists mainly of domain knowledge, rather than general problem solving strategies and methods. An expert knows the interrelationships between concepts, causal relationships, while the domain knowledge of a novice primarily consists of facts and basic concepts.

- **Unconscious knowledge**: Much of the knowledge related to the expertise is not the expert consciously aware of. Experts often have difficulties to verbalise his or her knowledge. They must be contextually stimulated in order to make their knowledge conscious.

- **Theoretical and experiential knowledge**: The theoretical knowledge of an expert is both conceptual and analytical, and the experiential knowledge is gained through training and practice.

- **Goals**: An expert has the ability to chunk subgoals and has a global focus, while novices have a more local focus and treat subgoals in a more sequential way.

- **Methods**: Experts have the possibility of performing case-based and more intuitive problem solving. They use strong domain-dependent methods. Novices tend to be more analytical in their problem solving and they use weak general methods.

The evolution from novice to expert can be especially important to consider when decision training is a purpose of the decision support. It can also be valuable to keep in mind when using a decision-maker-centred development process, particularly when defining the decision-makers’ characteristics.

### 3.3.2 Models of decision processes

A decision can be preceded by a decision process. A decision process can continue for years or be much shorter. Sometimes a decision must be made here and now, for example when an accident has occurred. In such cases there may be no time to consciously consider the alternatives, the decision is more of a reaction to the current situation. In other cases a decision process can continue for some time, which allows the decision-maker to actively and consciously work towards solving a problem and making a decision.

A decision process is, according to Mintzberg et al. (1976, p 246), a “set of actions and dynamic factors that begins with the identification of a stimulus for action and ends with the specific commitment to action”. There are many models of decision processes, e.g. Fischhoff and Johnson’s (1997) four-step scheme of decision-making and Klein’s (1993) recognition-primed decision model. Three decision processes are presented here, first Simon’s (1960), then Power’s (2002), and last Mintzberg’s et al. (1976). Simon’s (1960) is a fairly simple model and is often adopted in the decision support system literature (see for example Gorry & Scott Morton, 1971; Sprague &
Carlson, 1982; Silver, 1991; Mallach, 1994; Marakas, 1999; Power, 2002). The model of Mintzberg et al. is the most complex of the three and is a thorough model that includes many activities, is highly iterative, and has a flexible view on decision processes. It is flexible in the sense that there are several paths through the process. Both Simon’s (1960) and Mintzberg’s et al. (1976) models are developed some years ago and they are therefore contrasted to a recent model presented by Power (2002). Fischhoff and Johnson’s model (1997) is similar to Simon’s (1960) and therefore not described here. Klein’s (1993) RPD model focuses on how experienced decision-makers make rapid “here and now” decisions, when a decision-maker react to a situation. That kind of reaction-oriented decision processes are beyond the scope of this thesis.

Simon (1960) suggests a decision process consisting of three phases, which can be seen as an iterative process where each phase in itself is a complex decision-making process. These phases are the intelligence, design, and choice phases (see Figure 12).

![Diagram of decision process]

**Figure 12, Decision process according to Simon (1960) and Sprague and Carlson (1982)**

According to Sprague and Carlson (1982) a fourth phase, implementation, can be added.

1. **Intelligence** is searching for and formulation of the problem that calls for a decision.
2. **Design** is the phase where alternatives, i.e. courses of actions, are developed and analysed.
3. **Choice** is evaluation of alternatives from the design phase, and one of them is chosen.
4. **Implementation** is when the choice is implemented.

Angehrn and Jelassi (1994) argue that Simon’s phase model has provided a sound conceptual basis for building early decision support systems (DSS), and that it was assumed to be valid and useful. This model has, however, become an obstacle for evolution of DSS theory and practice, since alternative perspectives has not been
included (Angehrn & Jelassi, 1984). They argue further that adopting other perspectives or models of human decision-making can enhance the possibilities of supporting decision-makers. Alternative perspectives are for example decision-making as a learning process and focus on decision-making biases.

The main advantage of Simon’s (1960) decision process is the impression of simplicity, which makes it manageable. This impression of simplicity may also be a disadvantage. Since decision-making is a complex process, it can be treacherous to view it as a plain set of related activities. It can be misleading and make us overlook aspects that may be important to consider.

A general decision process model that includes a larger number of steps is presented by Power (2002). It partly overlaps with Simon’s (1960) model and consists of seven steps (see Figure 13).

![Diagram](image)

**Figure 13, A general decision process model (adapted from Power, 2002)**

The first step is to *define a problem*. It is important to define problems well, because if the wrong problem is defined it is not possible to make a correct decision. Organisations are often complex, which makes it harder to recognise a real problem and define it well. It can be difficult to separate real problems from problem symptoms (Power, 2002).

Depending on the decision situation, Power (2002) claims, the decision can be made by a single decision-maker or by a group. Therefore, there is a need to *decide who should actually make the decision*. Then *information is collected*, so that the decision is not made by hunch and intuition. This step is iteratively related to the fourth step, where the *alternatives are then identified and evaluated*. Brainstorming and generating ideas are important tasks in this step (Power, 2002). It can be questioned why the phase collecting information is not iteratively related to other phases, especially defining
problems and follow up and assessment. These phases probably also need information gathering in order to be carried out properly.

In the fifth step a decision is made, i.e. a commitment to a certain course of action or commitment to passiveness is made (Power, 2002). Decisions trigger actions. The decision is implemented by communicating decisions, plan actions, and track performance. Finally, the last step is follow-up and assessment, where the consequences of decisions are checked. This may lead to the identification of new problems (Power, 2002).

The model of Power (2002) has the advantage over the model of Simon (1960) that it includes more steps and the risk of overlooking important aspects is hopefully reduced. However, the description of the decision process gives a sequential impression. Probably, decision processes seldom are sequential. It seems reasonable to assume that a decision-maker needs to go back in the process at some point to for instance reconsider the defined problem.

A model that offers a more iterative perspective on the decision process is produced by Mintzberg et al. (1976). Their model shows the related activities of the strategic decision-making process and aims to describe the structure of unstructured processes. This framework consists of three phases: identification, development, and selection. Each phase consists of routines, which are shown in Figure 14. The process is iterative. Supporting routines and dynamic factors are also part of the framework, although not shown in the figure.

![Image showing a model of the strategic decision process](image)

**Figure 14, A model of the strategic decision process (adapted from Mintzberg et al., 1976)**

The identification phase consists of two routines. The first, decision recognition, is concerned with recognising an opportunity, problem or crisis that call for a decision
activity. Opportunities, e.g. an idea in somebody’s head, and a crisis are often single stimulus and problems are often multiple stimuli, which cumulate over time and finally call for a decision. Thus, there are several ways to start a decision process, not just by identifying problems. The other routine in the identification phase is the diagnosis routine. This is when the decision-maker is trying to understand the stimuli and the decision situation.

The second phase, development, is described through the routines search and design. The search routine is targeted at finding ready-made solutions, and the design routine at developing custom-made solutions or modifying ready-made solutions.

The last phase, selection, can be iterated several times, because a decision is often divided into sub-decisions, where each of them terminates by a selection. This phase consists of three routines: screen, evaluation-choice, and authorisation. The screen routine is a superficial routine in which decision-makers eliminate non-feasible alternatives, but not determine what is appropriate. The evaluation-choice routine includes three modes. The judgement mode in which the decision-maker makes a choice, the bargaining mode in which a group of decision-makers make a choice, and the analysis mode in which the actual evaluation is carried out. The authorisation routine is used when the actual decision-maker does not have the authority to formally make the decision.

Mintzberg et al. (1976) include different types of supporting routines in their framework: decision control, decision communication, and political routines. The decision control routine includes planning the approach and allocation of resources needed to handle the decision process. The decision communication routine is the communication carried out in the whole decision process, and the political routine, which is important in a strategic decision process, is concerned with both internal and external political activities. Included in the framework are also six groups of dynamic factors that disturb the decision process: interrupts, scheduling delays, timing delays and speedups, feedback delays, comprehension cycles, and failure recycles (Mintzberg et al., 1976).

An advantage of Mintzberg’s et al. (1976) model is that it includes many steps and factors, which can support a deeper understanding of the complexity of the decision process. It might, however, be too complex for some purposes. If the purpose is to quickly and easily provide a basic understanding of decision-making, for example when promoting a common understanding within a team with different backgrounds, it is not sufficient. Then Simon’s (1960) or Power’s (2002) models could be more appropriate.

There are both similarities and differences between the three models. All three begin with identifying that a decision may be needed. Power (2002) and Simon (1960) have problem-oriented starting points. Power’s (2002) model starts with defining a problem and Simon’s (1960) with searching for and formulation of problems. Mintzberg et al., (1976), on the other hand, also include opportunities as a type of stimuli that call for a decision. The decision process may be different depending on
what calls for a decision. The model of Mintzberg et al. (1976) has a large number of possible paths in a decision process, which makes their model more flexible. The models of Power (2002) and Simon (1960) gives an impression of being “one way” processes, i.e. mostly sequential and not much iterative. It seems probable that a semi-structured or unstructured decision process is highly iterative and that all instances of decision processes do not go through exactly the same activities. Power’s model and Sprague and Carlson’s (1982) addition to Simon’s (1960) model makes the decision process longer and more complete than the model of Mintzberg et al. (1976). The first mentioned models include what happens after the actual choice, which makes it possible to discuss how the implementation and follow up of a decision can be supported. Power (2002) has an early phase, decide who should decide, that is not represented in the other two models. The nearest representation is the routine authorisation in the model of Mintzberg et al. (1976). The last two activities in Power’s (2002) model complement Mintzberg’s et al. (1976) model. In this thesis these models are put together in order to describe decision processes (see Figure 15).

![A decision process model](image)

**Figure 15, A decision process model**

However, supporting decisions is not only about effective decisions or problem solving, but also about effective organisations (Fletcher and Johnston, 2002). According to Klein and Methlie (1990) do models of the decision-making process, such as the models of Mintzberg et al. (1976) and Simon (1960), lack in describing decision-making in an organisational context. There is a need of a conceptual framework to enhance the understanding of decision-making in an organisation, a basic understanding of organisation theory and the organisational constraints under which decisions are made (Klein & Methlie, 1990). This means that it is necessary to take an even more holistic perspective on decision-making. The whole organisational context should be taken into account. However, this is beyond the scope of this thesis.
3.3.3 Individual, behavioural decision-making

Bell et al. (1988) suggest that theories about decision-making can be seen as normative, descriptive, or prescriptive. Descriptive decision theories aim to describe how decisions are actually made. Normative decision theories show how decisions ought to be made, and prescriptive decision theories are concerned with how people can be helped and trained to make better decisions (Bell et al., 1988). In this thesis the difference between normative, descriptive, and prescriptive decision theories is viewed as follows:

- **Normative** theories state how to choose the optimal alternative, where optimal is defined in a quantitative way.
- **Descriptive** theories describe how decisions are actually made.
- **Prescriptive** theories give guidance on how to act within a decision process.

Klein and Methlie (1990) stress that both descriptive and normative decision theories can be used to gain understanding of decision-making in order to recommend better methods and offer advice so that the decision process can be improved. A descriptive approach can for example be a good starting point for improvement and development of prescriptive theories (Klein and Methlie, 1990).

An important aim of decision support is to increase effectiveness in decision-making. To be able to reach better decisions; there is a need to understand why a certain support increases the quality of a decision (Klein & Methlie, 1990). The normative approach can explain why a supported decision is better than an unsupported one. Decision-makers do not master normative principles by themselves. Therefore the designer of decision support should use design methodologies that include such principles (Klein & Methlie, 1990).

From this account follows that all types of individual, behavioural decision-making theories can be used when supporting decision-makers. In the following, all three types of theories are described.

**Normative theories**

Normative theories are the result of research within the discipline of Classical Decision-Making (CDM). According to Lipshitz et al. (2001) and Plous (1993) CDM has its roots in the work of Daniel Bernoulli, who 1738 published an important work called “Exposition of a new theory of the measurement of risk” (originally published in Latin).

Normative theories are based on a rationality paradigm and that those normative models define conditions for perfect utilisation. The decision-maker is seen as “the economic man”, who acts rationally, calculates the consequences of each alternative, ranking the consequences and finally makes the optimal decision, i.e. maximises utility (Klein & Methlie, 1990). An optimal decision is the best option, measured in a quantitative way (Edwards & Fasolo, 2001). Klein and Methlie (1990) claim further that within the normative approach theories concerning how to choose and handle uncertainties are developed, which, according to Edwards and Fasolo (2001), are
based on mathematics. People are not always good at making rational decisions, but it is possible to formulate theories on how to make a rational decision (Gärdenfors & Sahlin, 1988). Three decision theories that are the “heart of most traditional decision technology” are a) subjective expected utility maximisation, b) Bayes theorem, and c) multi-attribute utility (MAU) (Edwards & Fasolo, 2001, p 581).

Expected utility theory is a well-known theory of normative decision-making (Plous, 1993; Lipshitz et al., 2001). Expected utility theory was invented by von Neumann and Morgenstern and was first presented in 1944. The purpose of this theory is stated by von Neumann and Morgenstern (1953, p 31) as describing the “mathematically complete principles which define ‘rational behavior’ for the participants in a social economy, and to derive from the general characteristics of that behavior”.

Bayes theorem is a formula that calculates probability (Plous, 1993), and that includes the decision principle of maximising utility: “In a given decision situation the decision maker should choose the alternative with maximal expected utility (or one of the alternatives with maximal expected utility if there are more than one)” (Gärdenfors & Sahlin, 1988, p 5).

MAU can be seen as both normative and prescriptive. The borderline between these types of decision theories is not clear. An example of this is the work of Edward and Newman (1982). They present an approach to support evaluation of alternatives called multiattribute utility technology (MAUT). A MAUT evaluation is based on some key ideas that include both judgement parts and quantitative parts, i.e. it views both subjectivity and objectivity as natural components of the evaluation process (Edward & Newman, 1982). They prescribe seven steps on how to do a MAUT evaluation, where for example step two is ‘identify stakeholders’. These steps together with the idea of subjectivity make MAUT to prescriptive theory according to the definition in this thesis. But MAUT does also have a normative side since it includes ways to add quantitative values on qualitative attributes. These values give an aggregate utility, which makes it possible to choose, in a quantitative sense, the optimal option or options. MAUT is viewed as a normative decision theory by for example Edwards and Fasolo (2001).

If the purpose of supporting decision-making is to reach more, from a measurable and objective point of view, rational decisions, normative decision theories can be appropriate to use. When the purpose is to gain an understanding of which difficulties decision-makers face, normative theories are unsuitable. Instead descriptive theories should be used.

**Descriptive theories**

There are two kinds of descriptive theories of individual decision-making, the “traditional” theories that are based on laboratory studies, i.e. Judgement and Decision-Making (JDM), and theories based on studies made in natural environments, i.e. Naturalistic Decision-Making (NDM).
Judgement and decision-making

JDM theories are focused on how people make choices from a set of alternatives. They do not to large extent take contextual factors, such as stress, into consideration. According to Lipshitz et al. (2001) JDM can be traced back to 1954 and the work of Edwards called “The theory of decision making” and Meehl’s work “Clinical vs. statistical predictions: theoretical analysis and review of the evidence”.

Two examples of JDM theories are the satisfying theory by Simon (1956) and prospect theory by Kahneman and Tversky (1979). The first theory claims that decision-makers do not necessarily choose the optimal alternative, rather an alternative that is good enough in order to satisfy the needs of a decision-maker (Simon, 1956). The option that first reaches an acceptable level is chosen (Simon, 1978). The other theory, the prospect theory, includes two phases. In the first phase the prospects are preliminary analysed and in the second phase the prospects are evaluated and a choice is made. Decision-makers perceive possible outcomes as gains and losses, which can be manipulated through the formulation of a prospect. The theory also includes a value function and a decision weight function (Kahneman & Tversky, 1979).

Other work within this research tradition that is also often cited in the literature is the work by Amos Tversky and Daniel Kahneman cornering judgement under uncertainty (cited in e.g. Plous, 1993; Eysenck, 1993; and Cohen, 1995). They have carried out studies on how decision-makers use heuristics in complex situations and which biases, i.e. patterns of errors, they can lead to. According to Tversky and Kahneman (1974) heuristics are sometimes good because they can reduce time and effort and result in an acceptable decision, but they can also give negative effects. Two heuristics introduced by Tversky and Kahneman (1974) are the representativeness heuristic and the availability heuristic. The representativeness heuristic describes that decision-makers judge probabilities “by the degree to which A is representative of B, that is, by the degree to which A resembles B” (Tversky and Kahneman, 1974, p 1124). Biases resulting from this heuristic are for example that decision-makers often believe that a more detailed scenario is more probable to be representative of some phenomenon, than a more general scenario (Tversky & Kahneman, 1982). The availability heuristic is used by a decision-maker when he or she assesses “the frequency of a class or the probability of an event by the ease with which instances or occurrences can be brought to mind” (Tversky and Kahneman, 1974, p 1127). This heuristic also leads to biases. Just because an instance of an event comes easily to mind does not necessarily imply that this event is more probable to occur than other events (Plous, 1993).

Naturalistic decision-making

Naturalistic decision-making (NDM) is a relatively new research tradition, which begun in the second half of the 1980’s (Klein et al., 1993). The work of Gary Klein, which is called “A recognition-primed decision (RPD) model of rapid decision making” is the root of NDM (Lipshitz et al., 2001). It begun as a reaction to the studies made CDM and JDM. Studies within NDM are made in a natural context, in
contradiction to laboratory studies made in traditional decision-making. As Orasanu and Connolly (1993, p 6) stress, decisions are part of larger tasks and “decision event research in the laboratory tends to require decisions apart from any meaningful context. In natural settings, making a decision is not an end in itself.”

Orasanu and Connolly (1993) claim that earlier decision research have not taken into account the features of the task and the subject’s knowledge and experience relevant to the task, which they argue NDM does. An example of how the experience level of decision-makers influences decision-makers is provided by Fischer and Kingma (2001). They claim that the experience level affects the way decision-makers use information. It might seem apparent that more experienced persons have more possibilities to effectively use available information. However, as argued by Fisher and Kingma (2001), there can be both positive and negative consequences. An experienced decision-maker may for instance have an increased potential to detect errors in a familiar set of data, but there is also a risk that he or she relies too much on a feel for the data.

Orasanu and Connolly (1993) list eight factors characterising decision-making in natural settings.

- **Ill-structured problems:** problems that need to be taken care of in a decision-making process seldom reveal themselves in a clear and unambiguous way.
- **Uncertain, dynamic environments** include poor data quality and environments that changes during the decision-making process.
- **Shifting, ill-defined, or competing goals** or values, which may cause conflicts and a need to make tradeoffs.
- **Action and feedback loops** are part of the decision process, since NDM views decision-making as often containing a series of events.
- **Time stress** is often found to be a part of NDM setting, which causes pressure on the decision-maker. Such pressure causes, according to Payne and Bettman (1988), that less complicated reasoning strategies might be used.
- **High stakes:** the outcome is of actual significance for the decision-maker.
- **Multiple players:** more that one person is actively involved in the decision process.
- **Organisational goals and norms:** the values and goals used in decision-making are often part of a broader context, i.e. the tasks carried out in an organisation. It is not only personal preferences that are used when a decision is made.

All these factors affect a decision-maker and the way decision-making is carried out. These factors are related to each other, which can be seen in Figure 16.
Goals and norms of an organisation can directly guide the decision-maker for example in weighing and comparing potential outcomes of alternatives, but depending on for instance how the goals are formulated and on its content they can affect the factor vague goals. Vague goals can be shifting, ill defined or competing. If the goals of the individual or the group, e.g. ethical goals, and the organisation, e.g. economical goals, are in opposition to each other, the decision-maker has to do trade-offs. Vague goals, together with ill-structured problems and multiple players, can influence the factor uncertain, dynamic environment. The more participants of a decision process the more can happen during the time a task is carried out. Uncertainty concerning a specific matter, in this case of ill-structured problems, brings uncertainty to the wider context in which the matter is a part. Uncertain and dynamic environments directly influence a decision-maker, who must decide how to deal with this uncertainty, for instance how to be flexible enough. Since a decision process can include several events and can be going on for some time, together with a need to obtain information from the uncertain and dynamic environment, feedback loops is necessary. Two other factors that directly affect the decision-maker are high stakes and time stress. Both may increase the pressure on a decision-maker. The dynamic factors presented by Mintzberg et al. (1976) that disturb the decision process probably have an effect of the time stress. The more interrupts, failure delays et cetera the more time pressure on decision-maker, especially if there is a deadline.

A large number of studies have been conducted within the research domain of NDM; two examples are the work of Brehmer (1992) and Beach (1993). Brehmer (1992) has made studies on what he calls dynamic decision-making concerning human control of complex systems. Beach (1993) invented the image theory, in which he argues that the decision-maker uses three images when he or she makes a decision. The images are: how things should be; which goals to reach; and images of plans for reaching the goals.
Both JDM and NDM theories are important from a decision support perspective. JDM provides a narrow-focused view on decision-making, which can be used to reach an understanding of for example the importance of how alternatives are presented. NDM gives a broader setting for aspects affecting decision-making, which can constitute a foundation of studies of what aspects can be supported and what aspects cannot. JDM and NDM theories can also form a basis for development of prescriptive decision theories.

**Prescriptive theories**

Prescriptive decision theories can be used in different ways. They can be used by a decision-maker as a checklist for what to do and how to think. They can be a source for learning how to carry out effective and efficient decision-making. In decision support system development such theories can be applied as a basis for enhancing the outcome of a decision process. Another way to use prescriptive theories, suggested by Vetschera and Walterscheid (1995), is as an evaluation tool for managerial support systems. Their evaluation model has its roots in the decision models of Simon (1960) and Mintzberg et al. (1976).

Matheson and Matheson (1998) suggest a prescriptive theory for strategic decision-making. Their theory can primarily be seen as an organisational decision-making theory. According to Matheson and Matheson (1998) decision quality can be viewed as a chain consisting of six links. A decision-maker can use these links and the questions that are related to each link in order to make better strategic decisions. The links in the chain are:

- **Appropriate frame** includes checking if the right background and context is used for the decision.
- **Creative, doable alternatives** are concerned with finding undiscovered alternatives.
- **Meaningful, reliable information** embraces not only to have the right information, but also to increase awareness of the limits of the knowledge, i.e. what is not known.
- **Clear values and trade-offs** handles establishment of measurement criteria and how to make rational trade-offs among them.
- **Logically correct reasoning** brings together the four already mentioned links to logically evaluate the alternatives.
- **Commitment to action** connects decision to action. The right people in the organisation must be willing to implement the decision; in other case the decision is useless.

Since decision-making is not only conducted by single decision-makers, another layer of decision-making theories can be added, i.e. group decision-making. Group decision-making can be viewed as including all problems and difficulties facing individuals, but groups not only have those problems. Other types of difficulties can be brought in.
3.3.4 Group decision-making

The discipline of group decision-making (GDM) addresses questions concerning what characterises decision-making with multiple participants, what kind of problems they face and how group decision-making can be improved (Miner, 1992). A decision-making group can be defined as “two or more people who are jointly responsible for detecting a problem, elaborating on the nature of the problem, generating possible solutions, evaluating potential solutions, or formulating strategies for implementing solutions” (DeSanctis & Gallupe, 1987, p 590).

GDM includes for example processes and potential problems. Two basic phases in GDM processes are idea generation and idea evaluation. The aim of idea generation is to enhance creativity through reducing negative effects of social interaction. Group norms and pressures can hinder group members to generate or present ideas (Miner, 1992). In idea evaluation a choice among the ideas has to be made. Hill (1982) claims that evaluation of alternatives is performed better if it is made by a group compared to what an individual can perform. The same cannot be said of idea generation. It is possible that performance potential of an individual in the idea generation phase has been underestimated (Miner, 1992).

There are several potential traps in GDM, such as conformity, groupthink, group polarisation and risky shift, and escalating commitment (Miner, 1992). The conformity phenomenon was, according to Miner (1992), identified by Solomon Asch. This phenomenon raises when there is a social pressure on one or more individuals in a group to change attitude and behaviour, and when it is more important to reach a consensus rather than making a good decision (Miner, 1992).

Another potential trap is groupthink, which can be seen as related to conformity. This phenomenon was found by Janis (1982) and occurs when the desire for consensus among the group members is very strong. In such cases their motivation to think realistically about decision alternatives are reduced. When groupthink occurs it has several symptoms, for example illusion of vulnerability, stereotypes of out-groups, and illusion of unanimity (Janis, 1982).

Two related phenomena are group polarisation and risky shift. The characteristic of group polarisation, as described by Bazerman (1998) and Miner (1992) is that the predominant view in a group discussion is intensified during the session. The risky shift is concerned with the fact that a group tends to make riskier decision, compared to how risky decision each individual, independently of each other, would make (Bazerman, 1998; Miner, 1992).

The escalating commitment phenomenon is not a pure GDM problem. It can also occur among single decision-makers (Miner, 1992) and must also be dealt with from an organisational point of view (Staw, 1997). Staw (1997) describes an escalation dilemma as when things have gone wrong, but in which corrective actions can make things worse. A decision must then be made. Should the person carry on in the current situation or start anew? There is a tendency that people and organisations get stuck in a losing course of action, the escalation of commitment (Staw, 1997). This
causes a group to invest more and more in the initial decision in order to justify a bad decision (Miner, 1992). This phenomenon can for example be one of the causes behind the problem discussed by Lyytinen and Robey (1999). They claim “many ISD [information systems development] organizations appear unable or unwilling to adjust their practices even when they fail to produce beneficial results” (Lyytinen & Robey, 1999, p 87). These organisations may have invested too much, such as knowledge, prestige, and money, in current practices, which makes it hard to change even if it is obvious to an observer that the practice ought to be changed.

All together, these aspects that a group perspective adds to decision-making add more complexity. However, both individuals and groups are affected by the context where they work. Thus, theories coming from the discipline of organisational decision-making can be a complement, which can deepen the understanding of decision-making.

3.3.5 Organisational decision-making

Organisational decision-making (ODM) has its roots in the work of Herbert Simon “Administrative behavior” back in 1945, and his work together with James March called “Organizations” published 1958. March has also published an important book together with Richard Cyert called “A behavioural theory of firm” first published 1963 (Lipshitz et al., 2001).

ODM has a focus on aspects characterising and affecting decision-making in an organisational context. Shapira (1997) describes five characteristics of ODM, which presumably can be used to describe a certain decision context:

- **Ambiguity** often has to be dealt with by decision-makers in an organisation, such as ambiguity of information, preferences, and interpretation of the history of decisions.
- **Longitudinal context** is a context that decision-makers act in, because decisions in organisations are part of an ongoing process.
- **Incentives**, and penalties, affect the decision-maker.
- **Repeated decisions** are often made by decision-makers. Especially persons in middle management makes repeated decisions on similar issues, e.g. a loan officer makes repeated decisions on new loans.
- **Conflicts** can be seen as a part of ODM, since organisations can be seen as political systems, which decision-makers act in. Therefore power considerations and agenda setting influence the decision-making.

These characteristics have similarities to the list of factors characterising NDM. Ambiguity and longitudinal context can be viewed as part of the uncertain environment. Incentives and penalties can increase the stakes for the individual decision-maker, and in order to be conflicts there has to be multiple participants having different opinions, i.e. competing goals. The relations between behaviours and the factors of NDM and ODM are further discussed later in this section.
The list of ODM characteristics shows that organisational decision-making is a complex process, and that it needs to be studied with different approaches. Keen and Scott Morton’s (1978) present a classification of decision-making literature from an organisational point of view:

- The rational manager view
- The “satisfying” and process-oriented view
- The organisational procedures view
- The political view
- The individual differences perspective

The rational manager view overlaps with CDM and its normative decision theories described in section 3.3.3 on page 31. The satisfying, process-oriented view partly coincides with JDM. This view has, according to Keen and Scott Morton (1978), a descriptive focus. It also includes for example the work of Simon (1997) concerning bounded rationality, which is presented below. The organisational procedures view is concerned with the formal and informal structures of the organisation, organisational roles, procedures, and communication channels (Keen & Scott Morton, 1978). The work of for example Cyert and March (1992) is included by Keen and Scott Morton (1978) in this view. In the political view the bargaining process is important, and it also focuses on power and its influence on the decision. The last view, the individual difference perspective, includes aspects such as personal decision-making styles (Keen & Scott Morton, 1978), which is presented in section 3.2.2.

The “satisfying” and process-oriented view

Normative theories are based on the idea of rationality, especially objectively measurable rationality, but as argued by Lindblom (1959) and Simon (1997) decision-making is not rational. Instead of having a rational behaviour, Lindblom (1959) argues that the decision-maker searches incrementally for alternatives. These alternatives do not differ so much from the existing situation. The focus is on marginal values. Evaluation and empirical analysis are intertwined, i.e. values and policies are chosen at the same time. The organisation is “muddling through” (Lindblom, 1959).

Simon (1997) has another way of arguing against the assumptions of rationality. He stresses that rationality can have different meanings and limitations, which can be used to describe decision-making. Simon (1997, p 85) presents different meanings of rationality. A decision is:

- “‘Objectively’ rational if in fact it is the correct behavior for maximizing given values in a given situation.”
- “‘Subjectively’ rational if it maximizes attainment relative to the actual knowledge of the subject.”
- “‘Consciously’ rational to the degree that the adjustment of means to ends is a conscious process.”

39
- ‘Deliberately’ rational to the degree that the adjustment of means to ends has been deliberately brought about.’
- ‘Organizationally’ rational if it is oriented to the organization’s goals.”
- ‘Personally’ rational if it is oriented to the individual’s goals.”

The first meaning of rationality, objectively rational, is the same as in normative decision-making theories. In those theories the aim is to optimise the outcome of decision-making. Two other meanings of rationality, consciously rational and deliberately rational, resemble each other. Both types define rationality as a relation between the used resources and the outcome. The last two meanings of rationality, organisationally and personally rational, can be oriented towards the same specific goals. In such cases, decision-making can be relatively easy to conduct. In other cases, when the goals are competing, decision-making can be more difficult.

The different meanings of rationality raise questions that probably are essential to answer when developing decision support. For example, when evaluating alternatives, is it organisational rationality that is most important or to what extent personal goals is taken into account? Is it more important to be objectively rational than to include the relation between potential outcome and the resources that has to be spent?

The second meaning of rationality, subjectively rational, is in some senses related to another concept invented by Simon (1997) called bounded rationality. Bounded rationality describes decision-making within constraining conditions:

- Incompleteness of knowledge and lack of information
- Difficulties of anticipation
- Scope of behaviour possibilities

It is the first of these conditions, incompleteness of knowledge and lack of information, which is especially similar to subjective rationality, but the other two can also be regarded as part of a decision-makers actual knowledge. Difficulties of anticipation stand for that it is hard to anticipate the actual consequences and the experiences of a consequence (Simon, 1997). There can be several reasons that it can be hard to predict consequences. One reason is that they might be impossible to forecast. Another reason can be that the decision-maker does not possess enough knowledge to conduct prediction to an acceptable level of probability. A third possible explanation can be that the relationships between cause and outcome are too complex for human beings to manage. A similar discussion could be carried out for the condition scope of behaviour possibilities. Simon (1997) explains this condition, as the difficulty for a decision-maker to imagine all possible ways of acting.

The satisfying, process-oriented view of ODM describes how decision-making in organisations is actually carried out and what goals are used. Descriptive theories and models that result from work within this view may form a basis for developing solutions to the problem of reducing existing problems in decision-making. It can also be advantageous to include other views of ODM as a foundation for solutions, for instance the organisational procedures view.
The organisational procedures view

Two theories are presented in this section, first Cyert and March (1992) theory of decision-making within business organisations, concerning how firms make economic decisions, and second the garbage can model by Cohen et al. (1972).

The theory that Cyert and March (1992, p 162) have developed is primarily focused on “large, multiproduct firms operating under uncertainty in an imperfect market”. Their theory on organisational decision-making consists of two parts:

- A framework consisting of a set of variables affecting organisational decision-making:
  - Goals
  - Expectations
  - Choice
- Key relations among system variables:
  - Quasi resolution of conflict
  - Uncertainty avoidance
  - Problemistic search
  - Organisational learning

An example of a variable affecting organisational goals is past performance of other comparable organisations. The variables that have an effect on organisational expectations are either affecting the inference drawing process or the process in which information is made available to the organisation. One aspect in organisational choice that can be affected is standard decision rules, which for example can be affected by the variable called past experience of the organisation. The second part of the theory is, according to Cyert and March (1992), the heart of the theory. The first relation, quasi resolution of conflict, assumes that an organisation is a coalition of people having different goals, which forces the organisation to handle conflicts and consider latent conflict of goals. These conflicts are “resolved” in different ways. The second relation, uncertainty avoidance, states that organisations try to avoid uncertainties. Such an avoiding strategy is “avoiding planning where plans depend on predictions of uncertain future events and by emphasizing planning where the plans can be made self-confirming through some control advice” (Cyert & March, 1992, p 167). Problemistic search is a search directed towards finding a solution (but not necessarily an optimal solution), i.e. it is goal-driven. The last relation, organisational learning, includes three phases of organisational adaptation: adaptation of goals, adaptation of attention rules, and adaptation in search rules. Cyert and March (1992) stress that all these concepts are fundamental to understand the decision-making process of a business organisation.

The relations in the theory of Cyert and March (1992) can be considered as activities carried out in organisations. These activities can be regarded as a result of factors that characterises NDM and ODM. The NDM factors (see section 3.3.3 on page 33) are characteristics of decision-making in any natural context, a context that is not specified. The ODM factors are characteristics of decision-making in context the specific of an organisation. Then NDM factors can be assumed to be related to and
affect the ODM factors, which in turn can be assumed to cause certain behaviours in an organisation. These relations can be seen in Figure 17. The figure does not include all factors defined by Shapira (1997). The excluded factor ‘incentives’ is supposed to not be affected by the NDM factors in the same way as the other ODM factors. The figure is not intended to be a complete chart of the relationships between factors and behaviour, rather an example of a possible way of explore causes and effects. All behaviours are presumed to have several more causes and each factor is assumed to affect in several more ways.

![Figure 17, A way of viewing factors affecting behaviours](image)

One cause of the behaviour ‘trying to avoid uncertainty’ can be the ambiguity that decision-makers in an organisation have to deal with. The ambiguities can be effects of ill-structured problems, uncertain and dynamic environments, and shifting, ill-defined, or competing goals. The need of ‘trying to solve conflicts’ has, of course, its roots in the conflicts that is claimed to be a characteristic of ODM. Conflicts need multiple players to arise, and can be caused by competing goals and values. The longitudinal context of ODM and repeated decisions may raise a need to ‘learn within the organisation’, so that the decision-making competence increases. Since the ‘problemistic search’ is stated to be goal-driven the NDM factor organisational goals and norms may direct the search. High stakes and time stress may also influence on how the search for a solution is carried out.

This way or reasoning can for example be used when supporting certain behaviour in a decision situation. If organisational learning is meant to be improved in order to enhance the possibility to make more effective decisions in the future, then perhaps the information gained from action and feedback loops should taken into account.
Another theory within the organisational procedures view is the “garbage can”, which was introduced by Cohen et al. (1972). The garbage can is a model that describes decision processes in organisations. The garbage can model shows a process where problems are not solved well, but enable choices to be made and problems to be solved, in spite of the conditions being ambiguous and poorly understood. According to the garbage can model, a decision is an “outcome or interpretation of relatively independent streams within an organization” (Cohen et al, 1972, p 2-3). Four streams are identified: problems, solutions, participants, and choice opportunities. A choice opportunity is when an organisation is expected to make a decision, and can be viewed as a garbage can where problems and solutions are dumped by participants. According to Cohen et al., (1972) decision situations in organisations can be described in terms of organised anarchy, characterised by:

- **Problematic preferences**, i.e. the organisation works under inconsistent and ill-defined preferences.
- **Unclear technology**, i.e. the processes of the organisation are not fully understood.
- **Fluid participation**, i.e. the participants come and go and each participant can provide a certain amount of effort which differ over time.

A third view of ODM is the political view, where one important aspect is power.

**The political view**

Organisational decision-making can be viewed as a political process (Klein & Methlie, 1990), where political models of decision-making can be developed (Browne, 1993). A central concern is power, which can be seen as potentiality to influence people in their way of acting and thinking. According to Pfeffer (1992) power is important both in the activities preceding a decision and in the implementation of a decision. The amount of power that is involved in a decision process depends on the characteristics of a decision. Power is used to a higher extent in situations such as interdepartmental coordination, on a top management level, in functional areas such as marketing, as well as in decisions concerning e.g. reorganisations. Power is used to a lower extent in situations such as work appraisals, on lower management levels, in functional areas such as production, as well as in decisions concerning rules and procedures (Pfeffer, 1992). Thus, it is advantageous to state the characteristics of a certain decision. Depending on the decision characteristic it is possible to decide on whether to use political decision models or not when developing decision support.

Harrison (1999) and Browne (1993) describe the characteristics of political decision-making models and the political perspective of decision-making. The focuses, views, and concerns are:

- Behaviour of individuals in organisations.
- Compromise and bargaining strategies of decision-making.
- Finding alternatives acceptable to all stakeholders.
- Alternatives that differ from existing policies, which often imply a small number of options and a limited number of consequences.
- Continual redefinition of the problem.
- There is no right choice, only different ways of tackling the problem.
- Short-term rather than long-term results.
- Information is a resource that can give power depending on how it is used.
- An organisation is a coalition of individuals with goals and ambitions, which forces the decision-making process to take this into consideration.
- To what extent and in what ways the decision-making group is influenced by external stakeholders.
- The power of individuals and roles within the organisation.

Hence, ODM is concerned with decision-making from an organisational point of view, where individuals and groups are natural components. Its purpose is primarily to describe what “actually happens”:

- Actual types of goals
- The actual activities and behaviours
- Factors affecting decisions

In order to effectively support decision-making, there is a need to understand of the reality in which the decision-makers act. Otherwise there is a risk to support something that does not need support, or to try to support in an appropriate way.

**In summary**, the term decision is viewed as both decision matter and decision outcome. Decision-making is the activities that a decision-maker carries out during the decision process. Decision-makers have their own psychological types and decision styles. Decision-makers can be classified as either an individual decision-maker or multiple decision-makers. An individual decision-maker can either be a person or a computer. Multiple decision-makers can be classified as team, group, or organisation. There are a large amount of decision-making theories. Each theory belongs to a certain research traditions. Problem solving theories is not viewed as decision-making theories, however closely related to decision-making. Related is also the decision process, in which the decision-making activities take place. Decision-making theories can be divided into three categories; individual, behavioural decision-making, group decision-making, and organisational decision-making. Individual, behavioural decision-making has the subcategories normative, descriptive, and prescriptive decision theories. Normative decision theories state how a person should choose an alternative in order to make an optimal decision in a quantitative sense. Descriptive decision theories describe how a decision-maker actually makes decisions. Prescriptive decision theories propose how a person should act to make better decisions. We argue that it is important to understand the decision situation from the decision-makers’ perspective in order to provide effective and efficient decision support.
4 Decision Support Systems

To be able to support decision-makers, we need not only to understand decision-making, but also the potential support that can be provided by a decision support system (DSS). The potential support is in this chapter described through definitions and characteristics of DSS, the different types of DSS and its components, the ways of supporting decision-making and the benefits that can be gained by using a DSS.

4.1 Definitions

There is no consensus concerning what a DSS is and how it should be defined. Some definitions focus on what a DSS does, and others focus on how to accomplish the DSS’s objectives. Definitions that are categorised as having a “what focus” consists mostly of concepts such as: the purpose of DSS, the people using them, and the type of problem that can be supported. An example of a definition that has a “what focus” is Keen and Scott Morton’s (1978, p 1): “Decision support implies the use of computers to: (1) Assist managers in their decision processes in semi structured tasks. (2) Support, rather than replace, managerial judgment. (3) Improve the effectiveness of decision making rather than its efficiency.”

The definitions that are categorised as having a “how focus” consist of concepts such as system components and development process. Bonczek et al. (1981, p 69), for example, have a distinct “how focused” definition. They define DSS as having “... three principal components: a language system (LS), a knowledge system (KS), and a problem-processing system (PPS)”.

There are definitions that include both “what concepts” and how concepts”. One example is Turban’s (1990, p. 109) definition: “A DSS is an interactive, flexible, and adaptable CBIS [Computer-Based Information system] that utilizes decision rules, models, and model bases coupled with a comprehensive database and the decision maker’s own insights, leading to specific, implementable decisions in solving problems that would not be amenable to management science optimisation models per se. Thus, a DSS supports complex decision making and increases its effectiveness.”

It is surprising that so many of the definitions contain system components, because components may differ between systems. In our view the most important parts of a DSS definition are system objectives, problem type, and population. These parts show what we are aiming at, i.e. to support decision-makers so that they can make more effective decisions when dealing with semi-structured and unstructured problems. The others can differ over time and between systems, so definitions containing such parts may be out of date. Therefore, the working definition of this thesis is read: A DSS is a computer-based information system that supports either a single decision-maker or a group of decision-makers when dealing with unstructured or semi-structured problems in order to make more effective decisions. The DSS supports one or more decision activities carried out in a decision process.
4.2 Characteristics

Since there is no consensus concerning what DSS is, there is no consensus on standard characteristics (Turban, 1990; Turban & Aronson, 1998). Instead there are a number of characteristics, where some are more commonly agreed on, and other are more rarely mentioned in the literature. All characteristics are not included in every DSS (Mallach, 1994).

A DSS is a computer-based, interactive information system, i.e. it inherits the qualities of information systems in general. The term interactive implies that there is an exchange between the system and the user. A DSS primarily supports managerial activities on various levels. The purpose of a DSS is focused on improving the effectiveness of the decision-making process, rather than its efficiency. The effectiveness of decision-making concerns timeliness, accuracy, and quality, while efficiency is the cost of making the decision, e.g. cost of the decision-maker’s working hours (Alter, 1980; Bidgoli, 1989; Keen & Scott Morton, 1978; Mallach 1994; Marakas, 1999; Sprague, 1989; Turban, 1990; Turban & Aronson, 1998).

DSS provides support for decision-makers when they deal with semi-structured and unstructured problems. Support is provided in all four phases of the decision-making process, i.e. intelligence, design, choice, and implementation. Thus, focus can be both on decision-making and decision implementation. A DSS may provide support for both interdependent and multiple independent decisions (Bidgoli, 1989; Mallach, 1994; Marakas, 1999; Turban, 1990; Turban & Aronson, 1998).

Decision-makers use a DSS actively, which means that the user initiates every instance of use. The user should be in complete control of the decision process and the DSS should support, not replace the decision-maker. A DSS can support learning, both from the perspective of decision-makers and from the perspective of DSS developers. Learning concerns the decision-making process and it involves finding new demands on refinements of the system (Alter, 1980; Bidgoli, 1989; Keen & Scott Morton, 1978; Mallach, 1994; Marakas, 1999; Turban, 1990; Turban & Aronson, 1998).

Decision-makers should be able to confront changing conditions. Therefore a DSS has to be adaptive and flexible in order to meet the decision-makers. There is an emphasis on ad hoc utilisation. A DSS should be easy to use. Support is provided to individuals and groups, and a DSS can be tailored to support different personalities and decision styles, in order to fit the individual decision-maker (Alter, 1980; Bidgoli, 1989; Marakas, 1999; Sprague, 1989; Turban, 1990; Turban & Aronson, 1998).

End-users should be able to construct and modify a simple DSS themselves. A DSS development process is usually evolutionary and iterative, where prototyping and adoptive design is used. In order to support the judgment of decision-makers, analytical techniques should be provided by the DSS. A DSS also incorporate models, which enable experimenting with shifting conditions and data from a variety of sources, formats and types (Bidgoli, 1989; Keen & Scott Morton, 1978; Mallach 1994; Marakas, 1999; Sprague, 1989; Turban, 1990; Turban & Aronson, 1998).
As mentioned above, not all of these characteristics are present in every DSS. A reason for this is that there are several different types of DSS, where each is focusing on supporting decision-making in a certain way. Depending on the type of DSS some characteristics are more present than others, and different types of benefits can be gained.

### 4.3 Types of DSS

There are different types of DSS and one way to categorise DSSs is provided by Power (2002). He introduces a framework, in which the term ‘driven’ is used, that points at the dominant functionality of the DSS. Power’s (2002) categories are:

- Data-driven DSS
- Model-driven DSS
- Knowledge-driven DSS
- Document-driven DSS
- Communication-driven and group DSS.

**Data-driven DSS** provide access to large amounts of data and support analysis. The enable display and manipulation of data sets. Data-driven DSS can be divided in the following subcategories: data warehouses, on-line analytical processing (OLAP) systems, executive information systems (EIS), and spatial DSS (Power, 2002). A data warehouse is defined by as a “subject-oriented, integrated, time-variant, non-volatile collection of data in support of management’s decisions” (Inmon & Hackathorn, 1994, p 2). It is concerned with the major subjects of an organisation, and provides a base for integration of separate system. The data can have a historical perspective, and the non-volatility characteristic stands for that “data is loaded into the warehouse and is accessed there, but once the snapshot of data is made, the data in the warehouse does not change” (Inmon & Hackathorn, 1994, p 10). Through data mining a decision-maker can obtain “answers” from a data warehouse. Data mining is defined as “the set of activities used to find new, hidden, or unexpected patterns in data” (Marakas, 1999, p 356). On-line analytical processing (OLAP) is software technology that carries out multidimensional analysis of data (Marakas, 1999). An EIS is a “computer-based system intended to facilitate and support the information and decision-making needs of senior executives by providing easy access to both internal and external information relevant to meeting the stated goals of the organization” (Marakas, 1999, p 185). Spatial DSS are described by Seffino et al. (1999, p 105) as “decision support systems where the spatial properties of the data to be analysed play a major role in decision making”.

**Model-driven DSS** mainly provide support through models, e.g. financial or optimisation models (Power, 2002). According to Shim et al. (2002), a model-based decision support includes three stages: a) formulation, i.e. generation of an acceptable model, b) solution, i.e. the algorithmic solution of the model, and c) analysis, i.e. the what-if analysis and interpretation of the model solutions. Model-driven DSS can be compared with spreadsheet-oriented DSS, which belongs to a classification of Holsapple and Whinston (1996). Spreadsheets can be used to create
models and do what-if analysis, and are often used in end-user developed DSS (Turban & Aronson, 1998).

Knowledge-driven DSS consist of knowledge, understanding of problems, and problem solving “skills” within a specific domain (Power, 2002). Power (2002) states that knowledge-driven DSS are related to Alter’s (1980) term suggestion models, and other terms such as rule-based DSS and intelligent DSS. Techniques from artificial intelligence (AI) and expert systems are used in knowledge-based DSS (Bonczek et al., 1981). With help of these techniques an intelligent DSS behave in a better (more “intelligent”) manner (Turban & Aronson, 1998). A rule-based system is “a system in which knowledge is represented completely in terms of rules (for example, a system based on production rules)” (Turban & Aronson, 1998, p 867).

Document-driven DSS are focused on gathering, retrieving, classifying, and managing unstructured documents, and where a search engine can be a useful tool. Such a system can deal with for example policies, procedures, and product specifications (Power, 2002). There are materials that decisions can be based on, that are not ordinary data and therefore cannot be put in a database, e.g. letters from customers, written reports, and news items. This information needs also to be handled in a DSS, and therefore information retrieval is important (Federowicz, 1989). Document-driven DSS can be compared text-oriented DSS, which belong to the classification of Holsapple and Whinston (1996). Text-oriented DSS keep track of textually represented information. Hypertext is a technique that can be used in text-based DSS (Holsapple & Whinston, 1996; Marakas, 1999).

Communication-driven and group DSS, where communication-driven DSS focus on supporting collaboration, communication, and coordination, while group DSS (GDSS) focus on supporting groups of decision-makers to analyse problem situations and performing group decision-making tasks. An example of a GDSS is Electronic Brainstorming that generates stimulating questions to the meeting participants (Power, 2002). DeSanctis and Gallupe (1987) introduce a foundation for the study of GDSS. There are different task purposes and task types that can be supported by different levels of GDSS. The first level of GDSS aims at supporting communication through removing common barriers. Level two aims at supporting the group’s decision process through reducing uncertainty and providing decision-modelling techniques. On the third level expert advice are included in order to select and arrange rules that can be used during a meeting. The task purpose ‘generating’ consists of the task types ‘planning’ and ‘creativity’, which can be supported on level one and two. The purpose ‘choosing’, consisting of ‘intellective’ and ‘preference’, can be supported on all three levels, and so does the purpose ‘negotiating’, that consist of ‘cognitive conflict’ and ‘mixed-motive’ (DeSanctis & Gallupe, 1987).

4.4 The use of DSS

A DSS can be used in different ways, i.e. there are various approaches to support decision-making. Depending on the current type of support diverse benefits can be gained.
4.4.1 Supporting decision-making

Zachary and Ryder (1997) claim that there are two main different kinds of support for decision-makers. The first is to aid the decision performance in a specific decision situation, and the other is to train decision-makers so that they can perform better in the future. An example of the first kind of support is presented by Benbasat and Lim (2000), which aims to reduce availability bias (see section 3.3.3) in group judgement. They found that an electronic brainstorming tool increases the number of generated ideas and decreases the availability bias. An example of the last kind of support is provided by McGrath and More (2001), who describe the Greta system. The Greta system is primarily a pedagogical aid, which is based on a power-political model of organisational decision-making. In the Greta system the users are faced with the task of successfully implementing a customer support system, where each simulation cycle begins with a number of tactics from which the user chooses.

Another way of presenting approaches to decision support is provided by Silver (1991), who claims that substantive decision support addresses one or more of the following parts:

- Decision-making process
- Decision-making needs
- Decision-making environment

Each of these three can be viewed as supporting either decision performance or decision training. However, it can be presumed that Silver (1991) considers them to be focused on decision performance.

When the decision-making process is in focus, the support of a DSS is directed to reduce effects of human decision-making weaknesses or cognitive limitations in general (Silver, 1991). Holsapple and Whinston (1996) give two ways of supporting this: a) facilitating or extending the user’s ability to process information, i.e. acquiring, transforming, and exploring information, and b) stimulating the perception, imagination, and creative insights of the decision-maker.

If the prime concern is to support the decision-making needs, then the DSS is aimed to support the identified needs of a decision-maker in a certain decision situation. These needs are identified by the decision-maker or an analyst. Examples of needs can be lack of necessary information or problems in generating alternatives. These needs can be derived from limited cognitive capabilities (Silver, 1991). Four ways of support in this approach are: a) a decision-making opportunity and challenge is alerted to the decision-maker, b) recognising problems that needs to be solved in a decision-making process, c) problem solving, and d) the decision-maker is offered advices, expectations, evaluations, facts, analyses, and designs (Holsapple & Whinston, 1996).

A DSS that considers the decision-making environment goes beyond the individual decision-maker and also includes implications of the context. This can embrace for instance organisational or group settings. A way of doing this is to coordinate and facilitate relations between multiple decision-makers (Holsapple & Whinston, 1996).
4.4.2 Benefits

There are many benefits of using a DSS, and many of them can lead to cost savings (Keen, 1989) and create advantages over competing organisations (Marakas, 1999). Every DSS, though, does not give all possible benefits. There are also limitations of DSS, such as that the “knowledge” and “skills” of a DSS are constrained and that it cannot “perform” creativity and imagination (Marakas, 1999). The benefit categories used are Alter’s (1980):

- Improving personal efficiency
- Expediting problem solving
- Facilitating interpersonal communication
- Impact on learning or training
- Impact on overall control

By improving personal efficiency it is possible to save time associated with tasks connected to decision-making (Alter, 1980; Keen, 1989; Marakas, 1999). The tasks should be carried out in less time, be carried out more thoroughly in the same amount of time, or more appropriate tasks should be carried out with less effort. This can be done by increasing the number of alternatives examined. Solutions, for example, imagined by the user, can be tested or simulated (Keen, 1989). With a proper DSS tool it should also be possible to make better use of data resources (Keen, 1989). The ability of decision-makers to process information and knowledge can be extended (Marakas, 1999).

In order to support the overall problem solving, of which a task is a part, the ability of decision-makers to tackle large-scale, time-consuming, complex problems can be extended (Marakas, 1999). The DSS makes it possible to give fast responses to unexpected situations and to do ad hoc analysis (Keen, 1989). Not only could the time needed be reduced. The quality of problem solving can also be enhanced. Through a better understanding of the business, e.g. better abilities to see relationships between variables, and through increased depth and sophistication of analysis, better decisions can be made (Keen, 1989). This can also be done by revealing new approaches of dealing with the problem (Marakas, 1999).

A DSS can facilitate interpersonal communication (Alter, 1980; Keen, 1989). A DSS provides communication support in at least two ways. It provides decision-makers with tools for persuasion and facilitates communication across organisational boundaries (Alter, 1980). The individual decision-maker can obtain substantiated arguments, which can be particularly useful when implementing the decision. As claimed by Marakas (1999) a DSS gives enhanced possibilities to generate new evidence in confirming existing assumptions and reliability of outcome. It is not clear what Marakas (1999) means by reliability of outcome, but it can be interpreted as enhanced possibilities to evaluate possible consequences for example through simulation. Alter (1980) claims that communication between organisational units can be made through standardising the mechanics and vocabulary of negotiation and by providing a common conceptual basis. Groupware provides additional
communication paths, which may improve the communication (Mallach, 1994) and more effective teamwork can be obtained (Keen, 1989).

A DSS can have an impact on learning or training. To improve learning was seldom a goal of early DSS, but nowadays it is more often incorporated (Mallach, 1994). A DSS can promote both organisational and individual learning, for instance by making it possible for decision-makers to obtain a better understanding of the business. An example is a decision-making team in a company that used a strategic planning system. The decision-makers claimed that through using this system they obtained a better understanding of the strengths of the business, the constraints under which it operates, and what manoeuvring room that was available (Alter, 1980). Keen (1989) and Marakas (1999) confirm this view and suggest that a DSS can lead to new insights and learning, which can encourage decision-makers to explore.

A DSS can have an impact on overall control, i.e. increase organisational control (Alter, 1980; Keen, 1989). Organisational norms and requirements can be made clear to the decision-makers. They can constrain the individual decision-maker and ensure consistency across organisational units (Mallach, 1994).

There are, as described, a number of benefits, but it is not always clear how to measure them. This difficulty to establish DSS success measures causes problems to determine DSS success factors. The two most important success measures are that the DSS is actually frequently used and that the users are satisfied (Finlay & Forghani, 1998). User satisfaction can be viewed in three perspectives, user satisfaction in terms of attitudes, information quality, and effectiveness (Kim, 1989). Other measures are; fast response to unexpected situations, ability to carry out ad hoc analysis, cost and time savings, and better use of data resources (Keen, 1989). Probably, all these success measures are not unique for DSSs and EISs. They are most likely the same for information systems in general.

There are also potential problems with DSSs, although not elaborated here. There can for example be problem with trust or responsibility problems. The decision-maker must trust the DSS in order to really use it in decision-making. There can be disagreements of who is responsible for the decision. Is it always the decision-maker or can the persons behind the DSS be blamed for a bad decision?

In summary, a decision support system (DSS) is a computer-based information system that supports either a single decision-maker or a group of decision-makers when dealing with unstructured or semi-structured problems in making more effective decisions. The DSS supports one or more activities in a decision process. A DSS can be data-driven, model-driven, knowledge-driven, document-driven, communication-driven or a group DSS depending on the dominant functionality. A DSS can either support the decision-maker in the on-going decision situation or it can prepare the decision-maker to perform better in the future through decision training.
The benefits of using a DSS are that it can improve personal efficiency, expedite problem solving, and facilitate interpersonal communication. It can also have an impact on learning and overall control.
5 Method

In this chapter methodological considerations, the research process, and reflections on the research process are presented. The nature of the research questions motivates a qualitative research approach. The research process consists of three stages. First, a literature study was conducted, followed by a case study. Finally, the results were synthesised.

5.1 Methodological considerations

The starting point of research is a problem or a hypothesis, sometimes vague and sometimes clear and explicit. The research is heading somewhere, which can be expressed in aims, objectives, and research questions. The route between the starting point and the goal is the research method. The researcher has to choose a suitable route, i.e. approach and methods, which lead to the goal. Otherwise the researcher risks getting lost along the way and ending up somewhere not achieving the goal. Hence, the guiding star for methodological considerations should be what we want to accomplish. The methodological decisions depend on which type of answer suits the question. Some questions need numerical answers and other questions need characterising descriptions (Patton, 2002; Repstad, 1993).

The essence of this research project is to understand how requirements engineers, viewed as decision-makers, experience their decision situation. We aim to provide improved decision-maker-centred decision support. When the nature of a research problem is to grasp the meaning or characteristics of the experiences of individuals a qualitative research approach is appropriate (Strauss & Corbin, 1998). Hence, qualitative data collection methods and qualitative data analysis techniques is the most suitable alternative for our research problem.

Patton (2002) proposes twelve themes that function as a strategic framework for qualitative research. These themes contain fundamental postulations and epistemological ideals. The first three themes of the framework are design strategies: 1) Naturalistic inquiry denotes that the research should be carried out in a real-world setting and that the phenomenon of interest should not be manipulated. It also denotes that open-ended, conversation-like questions are the appropriate interview technique. 2) Emergent design flexibility means openness to ambiguity and uncertainty in the research process and to avoid getting locked in rigid designs. Discoveries can show new paths in the process. 3) Purposeful sampling suggests that since small samples cannot be generalised – still a lot can be learned from them – it is important to select the cases for study carefully. The cases should be information rich and enlightening (Patton, 2002).

The next four themes are strategies that concern data collection and fieldwork: 4) Qualitative data should describe. It should consist of someone’s experience expressed in citations, observations, and extracts from documents. 5) The theme personal experience and engagement stands for the character of the fieldwork. The researcher should get in direct and personal contact with the persons of interest and
their natural environment. 6) Empathetic neutrality and mindfulness concerns the emotional and cognitive behaviour of the researcher. He or she should find the balance between getting too involved and staying too distant. If the researcher gets too involved judgement can be dimmed and if the researcher stays too distant from the persons of interest a lack of understanding can occur. 7) Dynamic systems denote that the qualitative researcher should pay regard to the changes and view the dynamics of persons and their situations as natural and expected. Thus, the researcher should not try to control the phenomenon of interest (Patton, 2002).

The last five themes are analysis strategies. 8) Unique case orientation stands for being true to the unique individual cases and describe the unit of analysis, whether it is a person, an event, or a community, holistically in depth and detail. 9) Inductive analysis and creative synthesis mean that general patterns evolve from the findings in the cases. A theory emerge from the categories and relationships found in the data. 10) The theme holistic perspective embraces the viewpoint that the phenomenon under study is too complex to be reduced to a few variables and a cause-effect relationship. Instead, the natural context must be present during the analysis in order to understand the complex interdependencies and dynamics. 11) Context sensitivity stresses the importance of the natural setting, which for example includes temporal, physical, cultural, and historical aspects. This can be compared to laboratory experiments, which strive to generate context free findings that can be generalised. In qualitative research transferability can be more desirable than generalisation. 12) The last of Patton’s (2002) themes is voice, perspective and reflexivity. He argues that the personal voice and the perspective of the researcher should be used and be explicit in writing about the findings. The researcher is the instrument in qualitative research. Thus, the researcher has to be self-aware and to be reflexive “is to undertake an ongoing examination of what I know and how I know it” (Patton, 2002, p 64).

These themes of the strategic framework for qualitative research have permeated the design of our research process. The case study took place in a natural setting and the context was not manipulated. The interview technique was open-ended questions and a conversational style was used. The research design emerged during the process and was not firmly planned from the beginning. The case and the chosen interviewees were not many – but information rich. The data was in the interviewees’ own words, since all but one interview was recorded and transcribed. We got in personal and direct contact with the interviewees. The analysis was inductive and general patterns emerged from the empirical data. A holistic perspective was taken on the requirements engineers’ decision situation and contextual information was included.

### 5.2 Research process

With the qualitative approach in mind the research process was designed and carried out. The research process consists of three stages as described in Figure 18.
To summarise the research process, the following activities were carried out:

1. The research process began with a literature analysis. The purpose was to answer the first research question:

   - How can the decision situation of a decision-maker be described?

   The literature analysis embraced a variety of decision-making theories and decision support systems. This stage of the research process resulted in a decision situation framework, presented in section 6.1.

2. Then a case study was carried out at a software development company. The purpose of this study was to answer the research questions:

   - Which are the decision situations of requirements engineers?
   - Which problems and difficulties face the requirements engineers in their decision situations?

   The data collection techniques were open-ended interviews and a focus group session. The interviewees were requirements engineers and stakeholders related to them. The decision situation framework resulting from the first stage of the research process was used as a mean to structure the data analysis. The results from the case study was a) identification of decision matters, decision-making activities, and decision processes in RE (see section 6.2.1), b) input used by requirements engineers (see section 6.2.3), and c) factors that affect the decision-making requirements engineer (see section 6.3).
3. The last stage synthesised the previous results from stages 1 and 2 of the research process. It aimed at answering the research question:

- What kind of decision support do requirements engineers need and how should such a decision support be constituted?

This synthesis resulted in high-level characteristics that are desirable for requirements engineering decision support.

In the following, a more thorough presentation of the different stages of the research process is provided.

5.2.1 Literature analysis

The analysis began with decision support system (DSS) literature in order to define what kind of knowledge is needed when developing a DSS. Then literature from different research domains related to decision-making was included in the survey. This literature addresses how decisions can be defined and characterised; psychological types and decision styles; problem solving; and decision processes. Different kinds of individual behavioural decision-making theories were included: normative, descriptive (both “traditional” and natural decision-making), and prescriptive. The literature analysis also covers the research on group decision-making and organisational decision-making.

The search for literature was first broad, in order to find and embrace all relevant aspects of decision-making from the decision-makers perspective. The analysis of literature was conducted in a systematic way. During the reading of papers and books the content was summarised in a document. These summaries were then grouped and the content groups were given denotations. Then the content groups were structured in a hierarchical way. When no new content groups emerged, the search for more literature was more focused in order to deepen the understanding of each content group. The result from this step was synthesised into the framework, where the decision-maker was placed in the centre.

The strength of the literature analysis is the scope. Since several different and related areas were covered it was possible to create a holistic view of decision-making from the decision-makers’ perspective. The weakness of the literature analysis is that it is somewhat shallow. There was a need to make a trade off between breadth and depth, due to time limitations, and breadth was prioritised.

5.2.2 Case study

The aim of this part of the research project was to gain knowledge of how to provide better decision support for requirement engineers in a software development company. To gain this knowledge case study was chosen as research strategy. Case study is defined by Yin (1994, p 13) as an “empirical inquiry that investigates a contemporary phenomenon within a real-life context, especially when the boundaries between phenomenon and context are not clearly evident”.
The approach is human-centred and focuses on the experiences of the requirements engineers and the actors in the development process, who are closely related to requirements engineers. Requirements engineers are viewed as decision-makers. The purpose of the case study is to investigate the actual decision situations of requirements engineers. We carried out the case study at Ericsson Microwave Systems AB, who develops military radar systems. The research was carried out in three stages: a) open-ended interviews with requirements engineers, b) a focus group, and c) open-ended interviews with actors in the development process related to the requirement engineers.

**The case**

The case study organisation was Ericsson Microwave Systems AB (EMW) in Sweden. EMW has several products, e.g. military radar systems. Customers may have specific requirements on the product and each product therefore needs to be tailor-made. A typical development project at EMW is long and expensive and only a few units of each product are delivered. A project in which a product is tailored to a customer’s needs involves between 3000 and 6000 requirements depending on the type of product. Such a project typically runs for 2-4 years and consists of about 25 000 man hours. When a new product is developed a typical project runs for 5-10 years and consists of about 250 000 man hours.

As seen in Figure 19, a project begins when a contract is signed with a customer. The product is sometimes to be integrated with the customer’s existing products, which results in several “folders” of customer requirements. On the system level the customer requirements are transformed into system requirements. The system requirements are then allocated to different subsystems. The requirements engineers then create subsystem requirements based on the allocated system requirements. A subsystem consists of between 700 and 1300 requirements. Some functions, and thereby also requirements, are used by two or more projects at the same time.

Figure 19 shows the focus of concern in this research project, i.e. the requirements engineers, and the stakeholders that were interviewed.

---

1 /www.ericsson.com/microwave/
Interviews I

In the first interview round five requirements engineers were interviewed. The interviewees were suggested by our contact person. They had worked between 4 and 25 years at EMW and had been requirements engineers for between 1 and 10 years. Open-ended interviews were used, since, to cite Patton (2002, p 21) “open-ended responses permit one to understand the world as seen by the respondents. The purpose of gathering responses to open-ended questions is to enable the researcher to understand and capture the points of view of other people without predetermining those points of view through prior selection of questionnaire categories”. The interview technique was inspired by analysis of information utilization (Gulliksen et al., 1997) and contextual inquiry (Holtzblatt & Jones, 1993).

Analysis of information utilisation is a technique that provides guidance on how to describe and analyse the way information entities are used in work situations. Work tasks are identified in terms of judgement and decision-making situations (Gulliksen et al., 1997). In our interviews their advice on how to identify decisions were used.

The purpose of contextual inquiry is to provide an understanding of current work practice and fundamental work concepts, which is to be used in system design to reach usability. Three principles underpin the contextual inquiry process: context, partnership, and focus. The first principle denotes that the most appropriate way to understand the others’ work is to talk to them in their natural work environment. The second principle stands for creating an equal dialogue between the interviewer and the interviewee concerning a few areas. The third principle means that the interviewer should try to avoid getting caught in false or too narrow presumptions of
the interviewee’s work by actively trying to expand the focus area (Holtzblatt & Jones, 1993). All three principles were kept in mind during planning and execution of interviews. All interviews were conducted at the workplace of the interviewees. As prescribed by Holtzblatt and Jones (1993) the questions were not standardised. Instead, an interview guide was used. An interview guide helps to make certain that the basic parts of the interviews remains the same and remind the interviewer of the subject areas. The interviewer can this way establish a conversational style (Patton, 2002). The interview questions mainly concerned a) the tasks they carries out, b) the decisions, judgements, and trade offs they make, and c) the problems and difficulties that face them. We also tried to remember to expand the focus area by asking more about aspects that did not just verified what was already known.

Each interview lasted between 1.5 and 4 hours. Two of the interviewees were interviewed together, because they wanted it to be that way. All interviews but one were recorded and transcribed, since this interview was somewhat different from the others. It also included much more background questions for example concerning the company. An interview guide was used in all interviews, but the four-hour interview had a more informal and conversational nature than the others. During the four-hour interview notes were taken. When the first interview part had been carried out, the material was analysed.

The data collection techniques worked well and the samples were information rich. Thanks to the recordings of the interviews and the focus group session the reflection on our own behaviour was facilitated. We have not detected any leading questions and we tried to expand the focus area as prescribed by Holtzblatt and Jones (1993). However, we did not always manage to expand the focus, which became clear during the data analysis. As consequence, it has not been possible to provide elaborate descriptions of the decision outcomes.

Data analysis I

After the interviews with the requirements engineers, the recordings were transcribed into written documents and then a content analysis was conducted. Content analysis is the sense-making effort in which patterns or themes are identified (Patton, 2002). Some of the analytical tools and coding procedure provided by grounded theory (Strauss & Corbin, 1998) were used, particularly during the analysis of factors that affect the decision-making requirements engineer. The decision situation framework provided high-level categories, which offered a structure to the data analysis process. However, during the analysis categories emerged within the framework categories and it was these lower-level categories that formed the basis for the outcome of the research project. The analysis was performed in four steps.

1. The categories from the decision situation framework were used while reading the documents thoroughly. Sentences and sections were marked as belonging to a certain framework category. The purpose was to identify all pieces of relevant information concerning the decision situation in the documents.
2. Short sentences were made for each mark. Each of these short sentences where listed in its framework category.

3. The short sentences were grouped and conceptualised. This means that categories emerged from the data, which constituted the foundations of the results. These were documented in a table organised in the categories.

4. The combined decision process model (see Figure 15 on page 30) was used to recreate the decision processes. The decision-making activities were connected to the routines in the decision processes. The supporting communication routine in Mintzberg’s et al. (1976) model was also used. The processes were documented in tables.

The results from this analysis, the preliminary results, were then reported in the focus group session.

Focus group

To strengthen a study, triangulation can be used (Yin, 1994). A way to triangulate is to use methodological triangulation, which means that multiple methods are used to study a single problem. There are two forms of methodological triangulation; within-method triangulation and between-method triangulation. Within-method triangulation is when multiple strategies are used within one method, e.g. different measuring scales in a survey questionnaire. Between-method triangulation is when different methods are combined (Denzin, 1978). Denzin (1978) advocates the latter, since this way the weaknesses of a method can be balanced by the strengths of another method. Therefore, focus group was used as a data collection method to complement the interviews.

The focus group session was held at the company with nine participants. Two of the interviewed requirements engineers were present. The other participants were system engineers, a product manager, a system manager, requirements engineers, and subsystem test engineers. In the first part of the session the preliminary results were presented and in the second part the participants discussed the results. The session lasted for two hours. The discussion was recorded and transcribed.

Interviews II

In the second interview round, five persons related to requirements engineers were interviewed. This way it was possible to, to some extent, make data triangulation. According to Denzin (1978) data triangulation is when a variety of data sources is used, such as dissimilar groups or settings. In this research project the former way is used. The variety of data sources is the different roles of the interviewees between the first and the second round of interviews.

The interviewees were a system manager, a subsystem test manager, a subsystem manager, who also worked as a software engineer, and two system engineers, one of which also worked as a software engineer. Two of them had participated in the focus group. As in the first interview round, open-ended interviews, inspired by contextual
inquiry, were used. The interview questions mainly concerned a) the tasks of the interviewees, b) the tasks of requirements engineers, c) the decisions, judgements, and trade offs made by requirements engineers, and d) the problems and difficulties related to the requirements engineers. These interviews were also conducted at the workplace of the interviewees and each interview lasted between 1 and 1.5 hours. Two interviewees were interviewed together, because they wanted it to be that way. All interviewees were first asked to describe their own work and then to discuss the work carried out by the requirements engineers, as well as problems and difficulties related to that. The interviews were recorded and transcribed.

Data analysis II

In the second data analysis the results from the first data analysis were compared to the new data. In the comparison the preliminary results were verified and nothing was removed. The second data analysis provided more nuance and deepened the understanding of the context in which the requirements engineers act as well as the decision situations. One factor and one input were added at this stage, and more relationships between factors were identified. Finally, we explicitly used external theories as prescribed by multi-grounded theory (Goldkuhl & Cronholm, 2003). The empirical results were related to relevant decision-making theories.

5.2.3 Synthesis

In the synthesis the results from the literature analysis on decision-making and decision support systems were merged with the empirical results. This work resulted in a number of high-level characteristics that are desirable for requirements engineering (RE) decision support. An example of such a characteristic is that there should be high flexibility, with respect to cognitive style, decision style, as well as knowledge and experience (see section 6.4.1 on page 85). This characteristic is based both on empirical results and decision-making theory. The empirical results state that there are knowledge problems and a high turnover of requirements engineers. As a consequence, there is a need to support both novices and experts. The theoretical base gives that decision-makers have different decision styles (see section 3.2.2 on page 21). Accordingly, the RE decision support should be flexible in that sense too.

The characteristics are categorised at different levels of support: 1) the single user, 2) the nature of tasks, and 3) the social context. These levels coincide with the conceptual model for human-computer interaction (HCI) by Eason (1991). A support system can only be useful in relation to the characteristics of the target users, the tasks that are supposed to be carried out, and the context in which the system is going to be used (e.g. Maguire, 2001). It is very important to adopt a user-centred design approach to obtain a successful decision support (Parker & Sinclair, 2001). Thus, these levels suit the purpose of proposing characteristics of RE decision support and make clear that all levels are, at least to some extent, covered.
5.3 Reflections of the research process

From a quantitative point of view the qualitative research approach has limitations. Shaughnessy and Zechmeister (1997) stress that scientific control is the essential ingredient and what needs to be controlled are independent variables. In that view, qualitative research is unscientific. Obviously, we do not agree with Shaughnessy and Zechmeister (1997). Their characterisation of scientific and non-scientific approaches applies to, what Starrin et al. (1991) call, the context of justification, which includes hypothesis, operational definitions and hypothesis testing. However, the context of justification is not the only way. The other way is, what Starrin et al. (1991) call, the context of discovery. The context of discovery results in formulation of theories or hypotheses, and in the context of discovery creativity, intuition, and sensitivity are important (Starrin et al., 1991). This research project follows the way of discovery. It has for instance resulted in descriptions of the decision situation of requirements engineers and desirable characteristics of requirements engineering decision support. These have been generated but not proved. The context of discovery was necessary in this project since there do not yet exist a cohesive body of knowledge on RE decision-making and RE decision support. When such a body of knowledge has evolved, the context of justification will be the most appropriate way.

The quality criteria for quantitative research are not appropriate for qualitative research (Gummesson, 2001). Lincoln and Guba (1985) argue that the appropriate criteria for trustworthiness in qualitative research are credibility, transferability, dependability, and conformability.

Credibility

Credibility is the substitute for internal validity and denotes that the reconstructions, i.e. the outcome of the research process, are “credible to the constructors of the original multiple realities” (Lincoln & Guba, 1985, p 296). They claim that credibility is strengthened through techniques such as prolonged engagement, persistent observation, triangulation, peer debriefing, negative case analyses, referential adequacy, and member checking.

Efforts to triangulate were made. There were methodological triangulation in form of different data collection techniques and data triangulation in form different roles of the interviewees. It is advantageous to triangulate. However, it would perhaps be even more advantageous if more different data collection techniques and data sources had been used. It would probably be informative to carry out a longitudinal observation of requirements engineers’ daily work or ask them to write diaries. For practical reasons this was not possible.

Lincoln and Guba (1985) note that there can be distortions stemming from the interviewees that affect the data quality and thereby the credibility. During the data collection in this research two specific possible distortions were identified. The first was that two persons were interviewed at the same time at their own discretion. There may be a risk that they influenced each other. There may e.g. have been things they wanted to say but for some reason chose not to. However, they did not appear
to avoid discussing somewhat delicate aspects, and they did not always agree. It was rather the opposite, they triggered each other and the discussion was rich. Neither of the two was particularly dominant. The second potential distortion was that two of the interviewees at the third stage of the research process had participated in the focus group. This may have influenced their answers, but we did not explicitly discuss the preliminary results that had been presented in the focus group session. However, the interviewees did relate to the results a couple of times.

To reach credibility the researcher has to identify the important aspects and sort out the irrelevant aspects (Lincoln & Guba, 1985). During the data analysis, the decision situation framework provided support in several ways compared to using no framework at all. In a broad sense, it enabled a more complete view of the decision situation. The framework provided predefined high-level categories, where each category is represented by a “box” in the framework. These predefined categories made it possible to, in a structured way, walk through the data category by category, and the risk of missing important aspects of the decision situation was reduced. When we found that there was not enough information concerning a certain aspect, e.g. decision outcome, it was possible to collect complementary data pertaining to this aspect. The framework enabled the gathering of extensive information within each aspect of the decision situation. The framework directed our attention to aspects found in the data that we believe could have been more easily overlooked without the framework. It forced us to identify actual decision activities as well as finding the real problems and difficulties that face the decision-makers, instead of identifying e.g. organisational procedures and information flows. Organisational procedures and information flows are – of course – important, but they are not enough. The decision-maker perspective of the framework made us focus on the needs and requirements of the requirements engineers.

The framework was supportive, as argued above. On the other hand, there is a risk that it and the preceding literature analysis made us less open-minded to the empirical data. The open-mindedness to the empirical data is one of the underpinnings of grounded theory. To put it in Strauss’ and Corbin’s (1998, p 49) words, “the researcher does not want to be so steeped in the literature that he or she is constrained or even stifled by it”. Conversely, this position is criticised by Goldkuhl and Cronholm (2003). They argue that if the researcher is un-prejudiced in data collection and data analysis, then there is “a risk of being naïve and even ignorant when entering the empirical field (Goldkuhl & Cronholm, 2003, p 3).

Transferability
Transferability is related to the concept of external validity, but Lincoln and Guba (1985) argue that in a strict sense it is impossible to reach external validity. Instead, the researcher has to provide a detailed description of the context in which a working hypothesis is found to hold. The transferability is then connected to the degree of correspondence between the sending and receiving contexts. The sending context is the case from which the conclusions are made. The receiving context is the case that may use the results. The judgement of transferability lies with the person who wishes
to use the results (Lincoln & Guba, 1985). It has been our intention to provide a
detailed portrayal of the research context of this case study (see section 5.2.2).

**Dependability**

There can be no credibility without dependability. Dependability replaces in
qualitative research the notion of reliability in quantitative research. In research
design like ours it is not possible to replicate the inquiry, since it is not possible to
“cross the same stream twice” (Lincoln & Guba, 1985, p 299). As an alternative, they
propose to use techniques such as overlap methods and inquiry audit. The overlap
methods technique is a type of triangulation and has been used in this research
project as described and discussed above. The technique inquiry audit is concerned
with examining the research process and the research product. This has been done
through exposing the process and product by submitting our research to and
attending peer reviewed conferences and workshops.

**Conformability**

The last of Lincoln and Guba’s (1985) quality criteria is conformability, which is the
qualitative term for objectivity. Conformability is not concerned with the objectivity
of the researcher; instead the focus is on the quality of report. It should be possible to
audit the process and trace between the raw data and the final outcome. It has been
our intention to be transparent and reach traceability when reporting the process and
the findings.

**In summary**, the nature of the research problem made it necessary to use a
qualitative research approach. The research process was conducted in three steps.
First, a literature analysis was made which resulted in a decision situation
framework, which answered the first research question. Second, a case study was
carried out at a system development company. In the case study, requirements
engineers and actors related to them in the development process was interviewed. A
focus group session was also carried out. The case study answered the second and
third research question. Third, theories from decision-making and decision support
system was merged with the result from the case study, which are related to the forth
research question. The result from this synthesis was high-level characteristics that
are desirable for requirements engineering decision support. The main positive
aspects of the research process are that method and data triangulation were used;
that the high level framework provided support to the data analysis; an intention to
provide a detailed portrayal of the research context; that the process and results have
been exposed to peers; and an intention to be transparent. The main negative aspects
are that the methods and data sources may not have been different enough, and that
the framework may have influenced too much during the data analysis.
6 Results

In this chapter, the results from the literature analysis, case study, and synthesis are presented. First, the decision situation framework is presented, which takes a human-centred, holistic perspective on decision situations in general. Second, the decision situation of requirements engineers is described. Third, factors that affect requirements engineers as decision-makers are discussed. Finally, desirable high-level characteristics of requirements engineering decision support are presented.

6.1 A decision situation framework

In this section we answer the first research question: How can the decision situation of a decision-maker be described? The proposed framework provides a holistic view of the decision situation and aims to support the early phases of decision support development, i.e. when analysing a decision situation at hand. In the following, the framework is presented in its entirety.

The framework in Figure 20 is the result of a thorough analysis of decision-making literature. It describes important aspects related to a decision-maker and demonstrates the complexity of decision-making.

Figure 20, Framework describing a decision-maker’s situation
Decisions can be made by different types of decision-makers: a) an individual decision-maker b) a team or c) a group. Even if the decision-maker is an individual, he or she often also is a part of a group or an organisation. This in turn, is part of the context in which the decision-maker acts and the decisions of interest is often related to an organisation.

The decision-maker deals with a decision matter. A decision matter can for example be a reorganisation of a company, a new marketing campaign or a new investment. Such decision matters are not just a choice between alternatives, but several more steps within a decision process are needed.

The decision process can be divided into two parts, a “pre choice” part and a “post choice” part. The pre choice phase includes for example understanding the problem, generating alternatives, evaluating alternatives, and this process ends when the decision-maker makes a choice, i.e. results in a decision. This decision is viewed as the outcome of the decision process. The decision is then implemented and perhaps later on also followed up.

A decision process consists of several decision-making activities, which can be described by decision theories. There are two kinds of descriptive theories of individual decision-making, the “traditional” theories that are based on laboratory studies, i.e. Judgement and Decision-Making (JDM) and theories based on studies made in natural environments, i.e. Naturalistic Decision-Making (NDM). JDM theories are focused on how people make choices from a set of alternatives, for example how decision-makers use heuristics in complex situations and which biases, i.e. patterns of errors, they can lead to (see e.g. Tversky & Kahneman, 1974). Studies within NDM are made in a natural context. NDM aims to describe how decisions are made in the natural environment (see e.g. Orasanu & Connolly, 1993). The discipline of group decision-making (GDM) addresses questions concerning what characterises decision-making with multiple participants, what kind of problems they face and how group decision-making can be improved (Miner, 1992). Organisational decision-making (ODM) is studied with different approaches, e.g. process-oriented view, organisational procedures view, and political view (Keen & Scott Morton, 1978). The process-oriented view of ODM describes how decision-making in organisations is actually carried out and what goals are used. The organisational procedures view is concerned with the formal and informal structures of the organisation, organisational roles, procedures, and communication channels (Keen & Scott Morton, 1978). In the political view the bargaining process is important, and it also focuses on power and its influence on the decision (Keen & Scott Morton, 1978).

There are three aspects that affect the decision-makers behaviour when carrying out decision-making activities. These are the characteristics of a decision-maker, factors, and input. The decision-maker has characteristics, such as knowledge, experience, personality, and cognitive abilities. These characteristics affect the way and possibilities for a decision-maker to carry out the decision-making activities. Some characteristics, such as psychological types and decision styles, are individual. Other
characteristics, such as degree of expertise, can be identified for a certain group of decision-makers.

The decision-maker’s behaviour in decision-making activities is also affected by factors that originate from the context. There is ambiguity which may be caused by ill-structured problems, uncertain, dynamic environments, shifting, ill-defined, or competing goals or values, ambiguity of information, and interpretation of the history of decisions. There are multiple players involved who can be involved in conflicts. There are repeated decisions and a longitudinal context call for action and feedback loops. There can be organisational goals and norms, time stress, and high stakes.

Another aspect that can affect a decision-maker’s behaviour and the choice that is made is input. The decision-maker receives input, e.g. information from a database or ideas from a colleague that he or she can use. This input has characteristics, e.g. data quality.

Using the decision situation framework we can portray a particular decision situation of a certain decision-maker in a human-centred and holistic manner. In this thesis the decision situation of requirements engineers is in focus.

### 6.2 The decision situation of requirements engineers

In this section we answer the second research question: Which are the decision situations of requirements engineers? The focus area is requirements engineers in a contract development context, where both projects and systems to be developed are large and complex. The decision situation is that there are two separate decision processes in the studied RE process. The first decision process concerns the establishment of requirements in a new project, and the second decision process concerns management of requirement changes. These two processes have similarities, but also important differences from a decision-making perspective. Both processes include a number of decision-making activities in different decision phases. Both are highly iterative and embrace several sub-decisions. These sub-decisions are work-related and product-related, and affect the efficiency of the software engineering process as well as the quality of the product. The requirements engineers use different information sources as input. They use for instance requirements, formal as well as informal reports, and written as well as verbal sources.

#### 6.2.1 Decision matters, decision-making activities and decision processes in RE

The decision-making activities in the two identified decision processes in RE have been structured using the phases and routines in the decision process model of Mintzberg et al. (1976), complemented with the last two phases of the decision process model of Power (2002) (see Figure 15 on page 30). With this addition both the pre-choice and post-choice activities are represented in the decision process.
Mintzberg’s model also provides three sets of supporting routines: a) decision control routines, e.g. allocating organisational resources, b) decision communication routines, and c) political routines, e.g. clarifying power relationships in the organisation. In the empirical findings there are no activities that can be categorised as decision control and political, at least not in the way Mintzberg et al. (1976) describes them. However, activities that can be categorised as decision communication frequently occur in the empirical findings, and are therefore included in the presentation below. There are three decision communication routines: a) the exploration routine, i.e. “general scanning for information and passive review of what comes unsolicited”, b) the investigation routine, i.e. “focused search and research for special-purpose information”, and c) the dissemination routine, i.e. disseminating information of the progress of the decision process and the decision outcome (Mintzberg et al., 1976, p 261).

**Establishment of requirements in a new project**

This decision process concerns establishment of requirements in a new project. Hence, it occurs early in the project.

*The identification phase*

The decision process begins with the decision recognition routine. The decision process called ‘establishment of requirements in a new project’ is activated when the subsystem requirements engineer receives new customer and system requirements.

In the diagnosis routine “the decision maker is faced with an array of partially ordered data and a novel situation” (Mintzberg et al., 1976, p 254). In this routine, the requirements engineer conducts several decision-making activities. They find out what the customer requirements and system requirements mean. They investigate ambiguities in system requirements. They initiate themselves into interfaces provided by the customer. They analyse what matters for the subsystem and they perform a basic analysis of the desired functionality. All of these activities are system-related. However, there is also a process-related activity, in which they create a general view of the needs and problems in the development process to come.

Two decision communication activities are identified in the diagnosis routine. The requirements engineers conduct investigations in which they get an understanding of the problem by searching documents and talking to relevant stakeholders e.g. the customer. The dissemination that takes place is to notify those who are responsible for the entire system when there are problems in the customer requirements.

*The development phase*

In the search routine the decision-maker seeks ready-made solutions and in the closely related screen routine these alternatives are reduced to a few feasible ones (Mintzberg et al., 1976). In these routines the requirements engineer compare the new requirements with existing components and find out if something can be reused.
In the design routine custom-made solutions are developed and ready-made solutions are modified (Mintzberg et al., 1976). The requirements engineers create use cases and write requirements, such as internal requirements and requirements that specify the interface between the subsystems. Dependences between use cases are also drawn in this routine.

Three decision communication activities are identified. All three are categorised as belonging to the investigation routine. The requirements engineers discuss ideas and solutions with those who are responsible for the entire system. They also discuss with other people who are responsible for subsystem requirements. Each person documents the result of these discussions in their “own” use cases. They also have to stay alert on the customer requirements and system requirements, so that they are covered in the subsystem requirements.

**The selection phase**

The evaluation-choice routine consists of three different modes: analysis, bargaining, and judgement. In the analysis mode the alternatives are evaluated (Mintzberg et al., 1976). In this mode, the requirements engineers trace the requirements to higher level requirements. They check the requirements together with other stakeholders, and also analyse risks together with others. The decision communication that is carried out is to call everybody concerned together for a requirements check.

In the bargaining mode, there are several decision-makers with different goals that make the choice (Mintzberg et al., 1976). Two system-related decision matters are dealt with by the requirements engineers:

- Which system requirements belong to which subsystem?
- Which actors are there?

In the judgement mode, an individual makes the choice (Mintzberg et al., 1976). Three system-related decision matters are handled by the requirements engineers:

- Can the requirements become baseline?
- How is the subsystem going to behave and what is it going to look like?
- Which use cases are needed?

There are also work-related decisions that the requirements engineer make. These are:

- Which level of detail should the requirements have?
- What type of information should the requirements contain?
- In which order shall the requirements be implemented, i.e. which is the priority of the requirement?
- Which level of effort should an investigation, e.g. of functions in order to write requirements, have?

There is also an authorisation routine in the decision process model of Mintzberg et al. (1976), in which the decision is approved by someone in order to commit the
organisation to this course of action. In our case we have not found any specific authorising decision-making activities.

The implementation phase

Decisions trigger actions, and in the implementation phase several decision activities are performed, such as communicating decisions, plan actions, and track performance (Power, 2002). In this phase the requirements engineers set up the requirements document that is to be used. They document trade offs, decisions and rationale for decisions together with the functionality. They check design specifications, and support the persons who verify, design, and implement to interpret the requirements and to be a service function for all requirements stakeholders. The decision communication that is carried out is dissemination, i.e. the requirements engineers inform others of the decisions.

The follow-up and assessment phase

In the last phase the consequences of decisions are checked. This may lead to the identification of new problems (Power, 2002). In this phase the requirements engineers check the verification and test specifications. They also have user group meetings in order to validate the outcome with the users.

Management of requirement changes

This process concerns the management of requirements changes during the lifetime of the project. Hence, it occurs frequently during the project.

The identification phase

There are three different ways requirements engineers recognise problems that initiate the decision process called management of requirements changes. There can be error reports from verification or construction, or there can be direct requirement change proposals that start the process. Requirements errors can also be discovered by the requirements engineer and in such cases he or she carries out dissemination activities in writing an error report.

In the diagnosis routine, the requirements engineer check change proposals, investigate error reports, and initiate himself or herself into input from the customer, depending on what initiated the decision process.

The development phase

In the design routine the requirements engineer solve error reports, as well as change and add requirements. We have not identified specific activities that can be categorised neither in the search routine nor in the screen routine.

The selection phase

In the analysis mode in the evaluation-choice routine, the requirements engineers check so that a change proposal is not going to become a problem for other subsystems.
In the bargaining mode, there is one system-related decision matter. This decision matter is negotiated when the requirement in question is shared with other projects:

- Is a requirement change proposal going to be approved or not?

There are also two work-related decision matters that are managed in this mode:

- When is the requirement change going to be activated?
- When is the requirement change going to be implemented?

In the judgement mode, there is one system-related decision matter, which is dealt with by the individual requirements engineer when the requirement in question is project unique:

- Is a requirement change proposal going to be approved or not?

There is also one work-related decision matter to handle:

- How should requirements changes be managed?

As in the previously described decision process, we have not identified authorisation activities in the requirements change decision process.

The implementation phase

In this phase the requirements engineers generate requirements documents and documents aimed for the verifiers and implementers that show the differences between former and current requirements documents.

The follow-up and assessment phase

We have not identified any specific activities in the decision process that can be categorised as belonging to the follow-up and assessment phase.

There are similarities between the two decision processes. More important, though, is the differences between them.

Differences between the decision processes

There are diversities between the decision process of establishment of requirements in a new project and the decision process of management of requirements changes. These differences imply that the decision support should be dealt with in separate ways in order to be optimised.

The decision recognition routine of establishment of requirements begins, in our case, with the arrival of a set of higher-level requirements. As a consequence, the main activity of requirements engineers is in the following routine, i.e. diagnosis, comprehension activities. These activities embrace gaining knowledge of the problem domain, which includes the system as a whole and the customer needs. Thus, these decision-making activities have a larger scope compared to the other decision process. The other process, management of requirements changes, starts
with error reports and change proposals. Accordingly, the decision-making activities in the diagnosis routine are focused investigation. Hence, these activities have a more narrow scope than in the other decision process. Another difference is the amount of information. The amount delivered in the decision recognition routine is usually lesser in the management process compared to the establishment process.

In the search and screen routines of establishment of requirements, the requirements engineer search for existing components to reuse. In the other decision process, management of requirements changes, we have not found any decision-making activities in our case data that can be categorised in these routines. Nevertheless, there may exist such activities, for example searching for solutions of similar error reports, although not present in the data.

The design routine involves different challenges for the requirements engineers depending on decision process. In the establishment process the activities concern creating use cases and requirements. Thus, there are creative challenges and the effort is more about idea generation compared to the other process. In the management process, requirements engineers’ tasks are solving errors as well as changing and adding requirements. Therefore, the main activities, and thus the main challenges, are problem solving and idea evaluation.

In the analysis routine of the establishment process the requirements engineer conducts requirements checking, requirements tracing, and risk analysis. In the management process the analysis concerns the change proposal in order to state its potential consequences. In the first mentioned process, the requirements engineers work in teams with several other actors. In the other process, he or she, to a higher extent, carries out the analytical activities on their own. However, they communicate with other stakeholders, but stakeholders do not participate that actively in these decision-making activities.

In the implementation phase of the establishment process the requirements engineers take an active part. They document, check design specification, and last but not least act as a service point for all requirements stakeholders. In the management process, the role of the requirements engineers is comparatively of less importance. They are not, in this phase of the process, engaged in that many decision-making activities.

In summary, there are two different RE decision processes: a) establishment of requirements in a new project, and b) management of requirements changes. Both processes are highly iterative and include several sub decisions. The first decision process occurs once in the lifetime of a project, while the second decision process occurs frequently. The first process embraces more decision-making activities than the second one. Some of the decision-making activities are similar in the two processes, and some activities differ. Both processes have several decision matters and decision outcomes, which have certain characteristics.
6.2.2 Characteristics of decision matter and decision outcome

The decision matters that are dealt with by requirements engineers have certain characteristics. The characteristics are summarised in Figure 21. In Figure 6 on page 16, which is the origin of this figure, there was a fifth characterising dimension called ‘focus with regard to domain-specific functional areas’. We did not find that dimension applicable in this case.

![Figure 21, Characteristics of decision matters](image)

The *degree of structuredness* is semi-structured. This means that the decision matter is partially structured and partially unstructured. For example when deciding the behaviour of the system, some system behaviours are more or less necessary due to certain well known circumstances. Hence, such parts of the decision are structured. Other system behaviour is more difficult to decide. Perhaps they have to be generated, analysed and weighed against conflicting goals before a decision can be made.

The *scope and time frame* is that the decision matters are categorised as either tactical or operational. Tactical decisions affect a part of the organisation for a limited period of time. An example of a tactical decision matter is to decide in which order the requirements shall be implemented. Such a decision directly affects the work process of several actors within the current project. Operational decisions affect the project on a more daily basis. An example of such a decision is when a requirements engineer decides which level of effort an investigation, of e.g. a function in order to write requirements, shall have. The scope and time frame of a decision is then narrow. The decision matters handled by the requirements engineers in the case study have not been found to be strategic.

There are *general functions* that can be related to decisions matters. The functions in the POCCC view are planning, organising, coordinating, commanding, and controlling (see section 3.1 on page 19). The decision matters in this case are related
to planning, coordination, and commanding. These general functions are intertwined in the decision matters. Planning is outlining what to do, for example deciding when a requirements change is going to be current. Coordinating is carried out when activities are harmonised. An example of this is when decisions are made concerning how requirements changes are to be managed. Commanding is when a process is started, a process that is targeted towards reaching a certain goal. This is for instance made when deciding if a requirements change proposal is going to be approved or not.

The degree of negotiations is that both unilateral and negotiated decisions are made. Unilateral decisions denote that several persons are involved, but there is one person that actually makes the decision. An example of a unilateral decision is to decide if the requirements can become baseline. In negotiated decisions multiple persons has to agree, such as deciding which system requirements belong to which subsystem.

The decision outcomes have not extensively been discussed neither during the interviews nor in the focus group session. However, some inferences can be made. The product-related decisions have, in our case, more visible outcomes than the work-related decisions. When requirements are become baseline they are disseminated via a physical document and the requirements are placed in a certain tool. Requirements change proposals are marked current when that decision is made. Use cases, system actors, behaviour and appearance of the product are documented. The work-related decisions are not made clear to the same extent. Instead such decisions usually only result in for example a new or different way of working. The characteristics of the decision outcome probably have consequences for both product as well as the process. However, we have not elaborated this enough to make any claims with respect to this.

Another aspect related to the decision-maker is the input that he or she can use during the decision process.

6.2.3 Input used by requirements engineers

There are different types of input sources that requirements engineers use in their decision-making activities. The types of sources that were identified in the case study were:

- Requirements and requirement-related information
- Customer
- Points of view
- Records and reports
- Theory
- The Internet

The source requirements and requirement-related information consists, in this case, of customer requirements, system requirements, and sub-system requirements that all are about the current system under development. There are existing requirements with existing code from related systems as well as history from resembled
constructions. There are requirement change proposals, and a matrix concerning system requirements allocation between different subsystems.

The source customer for example delivers technical data of their existing systems which are going to interact with the system to be. The customer is also a communication partner. The requirements engineer obtains points of view from internal stakeholders, such as system manager, resource personnel e.g. cognitive scientists, project manager, software engineers, and other requirements engineers.

The source records and reports consist for instance of error reports, reports from investigations concerning functions, design reports, records from requirements check meetings, and informal records such as mail exchange with stakeholders. It also happens that the requirements engineers use relevant theories, which in this case is radar theory. They also use the Internet to find more information about for example concepts in the documentation that are difficult to understand.

The information varies along characterising dimensions. These dimensions can be seen in Figure 22.

![Figure 22, Characterising dimensions of input](attachment:figure22.png)

The input can be more or less governing or advising. Sometimes the requirements engineers have to base their decisions on the input, e.g. higher level requirements, and sometimes they can use the input as a guide, e.g. point of views given by internal stakeholders. The input is given verbally or written, or a combination of these two. The input can be more or less formal. There can for example be formal records or informal mail conversation. The input can come from internal sources, e.g. error reports, as well as external sources, e.g. technical data from the customer. Some input is created by the requirements engineer himself or herself, such as reports from investigations. Other input is created by other stakeholders, such as higher level requirements. Input along all dimensions may be of equal importance to the decision-making requirements engineer.
Thus, the decision situation of requirements engineers is complex. There are different decision-making activities carried out during the two decision processes. Each decision process involves several sub decision matters and the decision matters have characteristics. The decision-making requirements engineer uses various sources to motivate his or her decisions. However, there are also factors in the decision situation that cause difficulties for the requirements engineer.

6.3 Factors that affect the decision-making requirements engineer

In this section we answer the third research question: Which problems and difficulties face the requirements engineers in their decision situations? We have found seven general factors that directly or indirectly affect the requirements engineers during decision-making. The factors are: attitudes towards requirements work, communication and coordination, resources, pressure, cognitive load, knowledge, and other. The study indicates that problems related to these factors pose threats to the quality of RE decision-making. As seen in Figure 23, the factors are related to each other. It is reasonable to assume, however, that these factors are not a complete set of factors and that more relationships than the ones found may exist.

6.3.1 Attitudes towards requirements work

A source of several problems in the RE decision processes was the status of the RE discipline and the attitudes of individuals in the development process towards requirements work. We have identified three types of problems:

- Low status of requirements work
- Prestige between subsystems
- Departmentalisation of work
RE as a discipline and as a competence has generally a low status. There is to some extent a lack of understanding of the difficulties that face a requirements engineer and the actual benefits of requirements work. One of the interviewees expresses that “There are persons […] where we work that seriously say that this is only blah-blah, we shouldn’t do this”\(^2\). The low status of requirements work has consequences. To become a requirements engineer is not viewed as a step upwards in someone’s career. Thus, experienced software engineers do not want to have that role. Instead, engineers fresh out of university are often recruited. Since there is a low understanding in the organisation of the difficulties of being a requirements engineer, education in RE is not, as far as we have seen in our case study, a requirement to become a requirements engineer. This results in requirements engineers having limited experience and limited knowledge about the product as such, the domain in which the product is to be used, and the RE tasks. The low status and lack of understanding also have other consequences. There are fewer possibilities to improve qualifications and fewer and less developed support tools. A couple of interviewees compare the support given to requirements engineers and the much more developed support a compiler gives to a programmer.

There is prestige between at least some sub-systems. Each subsystem group wants their subsystem to be important on its own. They do not want their sub-system to be just a resource for other sub-systems. This affects how requirements related to the interface between sub-systems are written. The requirements tend to include more detailed solutions, rather than only describing the behaviour and characteristics of the system. There is also a risk that the solution for the system as a whole is not optimised due to this prestige. Thus, decision-making in RE is directly affected.

There is also departmentalisation of work between different groups within the development process. This is shown by the fact that information sometimes is not forwarded to requirements engineers. As an example, an interviewee describes how he or she has been answered when asking for more system information “This is all you need to know”. This directly affects the possibilities to make relevant and reasonable decisions about requirement.

Both prestige and departmentalisation of work can be further analysed and related to the research domain of organisational decision-making. Organisational decision-making can be viewed as a political process (Klein & Methlie, 1990). A central concern is power, which can be seen as the potential to influence people in their way of acting and thinking. Power is important both in the activities preceding a decision and in the implementation of a decision (Pfeffer, 1992). The amount of power that is involved in a decision process depends on the characteristics of a decision. Power is used to a higher extent in situations such as interdepartmental coordination, and used to a lower extent in situations such as work appraisals (Pfeffer, 1992). In the political view of organisational decision-making information is viewed as a resource

---

\(^2\) All citations from interviewees are translated from Swedish.
that can give power depending on how it is used. The power of individuals and roles within the organisation is also viewed as an important aspect (Browne, 1993).

6.3.2 Communication and coordination

Decision communication is carried out in the whole decision process (Mintzberg et al., 1976), i.e. both the decision matter and the decision outcome can be communicated. The factor communication and coordination was ranked as the factor with highest priority by the participants in the focus group. It consists of four problems:

- Lack of coordination of way of working
- Little involvement in discussions
- Time-consuming coordination (with respect to calendar time)
- Little communications of decisions

The way of working with requirements is not coordinated enough. This entails requirements not being written in a consistent way. Each requirements engineer has his or her own way of writing requirements, so there are different styles, levels of detail, and there is a lack of cohesion among the requirements. The consequence of this is that the requirements specification becomes muddled and more difficult to use. This affects the cognitive load both for the requirements engineers themselves, but also other actors that use the requirements in their work.

The requirements engineers have too little involvement in discussions, especially in discussions in early development phases. Since they do not take enough part in discussions with customers and in discussions concerning system requirements, it becomes more difficult to understand the problem to be solved by the system and the system as a whole, i.e. this increases the cognitive load. Since requirements engineers are often inexperienced, the actors on the system level and the software engineers avoid forwarding information to requirements engineers. The system level actors and the software engineers are afraid that the requirements engineers unintentionally distort the information. This can directly and negatively affect the RE decision-making, since the requirements engineers may not have enough or correct information to base their decisions on.

Requirements changes may concern other subsystems or the system as a whole. Some requirements are used by two or more projects at the same time. This causes a need to coordinate requirements changes within the project and between different projects. The coordination can be time-consuming, especially with respect to calendar time. This increases the pressure on the requirements engineer.

Once a decision is made, there is a commitment to a certain course of action or a commitment to passiveness. The next step in the decision process is implementation of decision (Power, 2002). In decision implementation decisions are communicated, actions are planned, and performance should be monitored (Mintzberg et al., 1976), (Power, 2002). In our case study there is a problem that decisions are not always made clear to the persons that are supposed to act upon them. For example the outcome
from discussions concerning decisions is not always documented and another example is that software engineers overlook certain requirements, e.g. performance requirements, because their attention is not drawn to them when needed. Thus, the RE decision process is negatively affected.

### 6.3.3 Resource

There are three problems related to the factor resource that affect the decision-making of a requirements engineer. These are:

- Usability problems in requirements management tools
- Lack of resource personnel
- Lack of introduction to and education in RE

The requirements management tool used in our case study suffers from usability problems. There are problems with effectiveness, efficiency, as well as learnability. The tool is described by the requirements engineers as cumbersome to use, and there is a high learning threshold. The actors related to the requirements engineers claim that the usage of the tool has caused illegible requirements. To cite an interviewee, “one gets a lot of aid to do many errors quickly if one uses a tool in the wrong way”. Thus, the effectiveness of the tool is low. These problems have caused that the use of requirements management tools has had low penetration in the organisation. It is only the requirements engineers that use the tool, while for example the actors at the system level or the software engineers do not. The requirements engineers use the tool despite its usability problems because it has utility qualities, i.e. certain useful functionality. Thus, inadequate use of requirements management tools increases the cognitive load of the requirements engineer, and hence negatively and indirectly affects the RE decision process.

Resource personnel are sometimes needed, for example requirements engineers that work with the user interface may need to ask cognitive scientists for help. In our case study there are too few cognitive scientists available, which forces the requirements engineers, as one of them puts it, “to go very much on feeling”. This directly affects the RE decision process in a negative way.

There is not enough introduction to and education in RE for novice requirements engineers, which makes it difficult to carry out the RE tasks. This affects the factor knowledge-related problems, and thus indirectly affects the quality of RE decision-making in a negative way.

### 6.3.4 Pressure

Two problems in the factor pressure are identified:

- Time pressure
- Several actors with different needs
There is often time pressure involved in the RE process. The requirements engineers are given the needed information too late, in their opinion, so that there is not enough time to work thoroughly with the functionality and to investigate how different functions affect each other. The software engineers are also in time stress so they begin to construct before the requirements are written. Instead, the software engineers base their work on hearsay. This results in incorrect code, which becomes clear when the requirements are written. An additional problem is that the software engineers then experience the requirements to be an obstacle in their work and not an aid.

Time stress is often found to be a part of naturalistic decision-making setting, which causes pressure on the decision-maker. In severe time pressure decision-makers tend to focus on a subset of the available information and less complicated decision strategies may be used. When subjected to severe time pressure decision-makers to a higher extent rely on heuristics (Payne & Bettman, 1988).

There are several actors that use the requirements, and they have different needs. Different actors want different levels of detail, and want requirements to be written in a certain way. This problem is also discussed in naturalistic decision-making theories. When there are multiple players involved there is a risk that the players do not share the same understanding of goals and situational status. This can entail that the information needed in the decision process is not brought forward (Orasanu & Connolly, 1993). Since there are multiple players involved there can be what is called shifting, ill-defined, or competing goals. In such cases there are several purposes that direct the decision-maker and some of the purposes may not even be clear (Orasanu & Connolly, 1993).

### 6.3.5 Cognitive load

Cognitive load means a mental exertion, the purpose of which is to interpret and process information to decide an action within a given space of time (Gulliksen & Göransson, 2002). Our mental capacity to consciously process information, which is called controlled processing, is limited. Thus, it is important that the individual uses this limited capacity for the most important and mentally demanding tasks (Schneider, 1993). The cognitive load is in our case study expressed in three problems:

- Lack of general overview
- Lack of understanding
- High memory load

The large number of requirements and the limitation of the requirements management tools make it difficult to obtain a general view. A general overview facilitates the understanding of a subsystem, its internal characteristics, as well as relationships and dependencies within and outside the subsystem. This problem has a direct affect on the RE decision process.
It is sometimes difficult to understand the meaning of a requirement. This is for example caused by ambiguity and bad translation. In our case requirements are written and read in English by Swedes, and it is often more difficult to write well and obtain a correct understanding when a foreign language is used. Since existing requirements are used in decisions concerning requirements, and also other types of decisions, this directly affects the potential quality of RE decision process.

There is also a problem with high memory load. The requirements engineers have to keep several aspects concerning requirements in their minds. As one of them says: “one has to keep much in the head and it is not possible to write everything down”. Aspects that are kept in the human memory are for example dependencies between requirements and aspects in relation to requirements to look for. Thus, the RE decision process is directly affected by this problem.

These problems can be visualised through a model of human information processing, as seen in Figure 24.

![Image of human information processing model](image)

**Figure 24, The information processing model (Barber, 1988)**

This model shows that we first encode environmental information to an internal representation; second this representation is compared to other representations stored in the human memory. In the third stage we decide how to respond to the input and in the forth stage the response is organised and carried out. All four stages affect and are affected by our attention, and at all stages our memory is used (Barber, 1988). If there are difficulties in one or more of these stages of our information processing, there is a risk that the decision-making is affected. An example of this is cognitive tunnel vision. This means that when we make a decision we have difficulties to fully take into consideration information that is not directly in front of us, even if we know that it exists and is important (Sandblad et al., 1991).

### 6.3.6 Knowledge

The low status of requirements work often results in high turnover of requirements engineers. Therefore, there are sometimes knowledge-related problems among them. The problems concern knowledge about:
The knowledge-related problems influence both problem solving and decision-making. Problem solving is a mental activity closely related to decision-making, especially situations where the decision is unstructured and complex. In such cases the solution to a problem is not obvious and work has to be done concerning identifying a problem and finding or developing alternate solutions for it.

There are differences between experts and novices in their ways of solving problems, since experts have gained experiences and skills that can make them more successful and efficient (Klein & Methlie, 1990; Zachary & Ryder, 1997). Experts are more efficient and can use their knowledge to draw correct conclusions, even if the available information is not complete. An expert does not start solving a problem through specifying all possible causes. Instead experts quickly distinguish relevant information from irrelevant and possible causes from impossible causes. An expert can recognise the pattern of a certain type of problem, and connect a possible solution to it. Expertise consists mainly of domain knowledge, rather than general problem-solving strategies and methods. An expert knows the interrelationships between concepts, causal relationships, while the domain knowledge of a novice primarily consists of facts and basic concepts. The theoretical knowledge of an expert is both conceptual and analytical, and the experiential knowledge is gained through training and practice. An expert has the ability to chunk sub-goals and has a global focus, while the novice has a more local focus and treats sub-goals in a more sequential way. Experts have the possibility of performing case-based and more intuitive problem solving, and use strong domain dependent methods. Novices tend to be more analytical in their problem solving and they use weak general methods (Klein & Methlie, 1990; Zachary & Ryder, 1997).

The experience level also affects the way decision-makers use information. It might seem apparent that the more experienced decision-makers have more possibilities to effectively use available information. However, there can be both positive and negative consequences. An experienced decision-maker may for instance have an increased potential to detect errors in a familiar set of data, but there is also a risk that he or she relies too much on a feel for the data (Fischer & Kingma, 2001).

Thus, the quality of the RE decision process is directly affected by the level of expertise that the requirements engineer has.

### 6.3.7 Other

We have not been able to group these difficulties into a named factor. However, these are difficulties that face the decision-making requirements engineer and that are of importance. These are:

- Missing requirements
- Domino effects
- Avoiding solution requirements
- Obtaining an accurate flow in broad use cases

When there are missing requirements there is lack of information. The interviewees also find it difficult to predict domino effects when new functions are implemented. They also sometimes find it difficult to avoid writing requirements that include solutions, and also to create accurate flows in broad use cases. All of these difficulties generate direct effects in the RE decision process.

These difficulties can be related to bounded rationality. Bounded rationality describes decision-making within constraining conditions (Simon, 1997):

- Incompleteness of knowledge and lack of information
- Difficulties of anticipation
- Scope of behaviour possibilities

Difficulties of anticipation means that it is hard to anticipate the actual consequences and the experiences of a consequence, and scope of behaviour possibilities is the difficulty for a decision-maker to imagine all possible ways of acting (Simon, 1997). There can be several reasons for the difficulty to predict consequences. One reason is that they might be impossible to forecast. Another reason can be that the decision-maker does not possess enough knowledge to conduct prediction to an acceptable level of probability. A third possible explanation can be that the relationships between cause and outcome are too complex for human beings to manage.

In summary, there are a number of factors that directly or indirectly influence RE decision-making and as a consequence may have negative effects on the decision outcome. Still, we have not looked into the actual effects within the organisation. Instead, we motivate the arguments using decision-making theories. Altogether, there are several difficulties to manage in order to be able to improve RE decision-making. A way to do this is to provide better requirements engineering decision support that is adapted to the needs of the requirements engineers.

### 6.4 Desirable characteristics of RE decision support

In this section we answer the fourth research question: *What kind of decision support do requirements engineers need and how should such a decision support be constituted?* We present high-level characteristics of a RE decision support (REDS). These characteristics can be viewed as a wishing list and the more characteristics that are fulfilled the more effective and efficient the REDS will be. The desirable characteristics are based on the needs of the requirements engineers and the nature of their tasks. The wishing list consists of the following characteristics:

- Reduce the cognitive workload
- High usability
- High flexibility
- Support availability of different types of information
- Support idea generation
- Support creating an understanding of the problem domain
- Support idea evaluation and problem solving
- Support communication
- Support coordination

The characteristics are structured using Figure 25. First, the characteristics of the support related to the requirements engineer as a single user is described. Then, the characteristics originating from the nature of the decision-making tasks within the RE decision processes are presented. Finally, the characteristics that support the requirements engineer in the social context are introduced.

Figure 25, Levels of support

6.4.1 The requirements engineer as a single user

We have identified three characteristics of a REDS from the requirements engineer as single user view. These are a) reduce the cognitive workload, b) high usability, and c) high flexibility.

Reduce the cognitive workload

One of the factors that affect the decision-making requirements engineer is the high cognitive workload. To reduce the cognitive workload the REDS should:

- Present both overview and details
- Provide memory aid

One way to manage the cognitive workload is to present both overview and detail (Schneider, 1993). The requirements engineer should always be able to obtain a global view of the system and the dependencies that exist within it. It should be possible for the requirements engineer to understand the relationship between on one hand a requirement and its detail and on the other hand the system and the development process.

The human memory can for instance be supported by a decision support system function called Case Memory (Chen & Lee, 2003). Case Memory lets the decision-maker manage “soft” information of a business case such as personal experiences and opinions of others (Chen & Lee, 2003). If such a function or similar functions are
implemented in a REDS the memory load and hence the cognitive workload can be reduced.

**High usability**

One of the problems that the requirements engineers in the case study have is that their requirements management tool suffers from usability problems. This gives negative consequences, for instance low penetration of the tool in the organisation (see section 6.3.3 on page 79). To avoid that kind of consequences, the REDS have to have high usability. Usability consists of several goals (Preece et al., 2002), which should be fulfilled by the REDS:

- Effectiveness
- Efficiency
- Safety
- Utility
- Memorability
- Positive experience

It is important that the effectiveness is high, so that the result of using the REDS is valuable. The REDS should be efficient, since it otherwise would be too cumbersome to use it and the productivity of work is lowered. To ensure that the REDS is used in the right way and to prevent errors the safety should be high. It should also provide the functionality that is needed from the requirements engineers’ perspective, i.e. it should have high utility. To lower the learning threshold, the learnability of the REDS should be high. Memorability, i.e. to remember at infrequent use, is probably of minor importance from the requirements engineers’ perspective, because they hopefully will use the REDS frequently. The use of the REDS should also be a positive experience. The subjective feelings towards the tool can for example be trustworthiness, satisfaction, motivation, and helpfulness.

**High flexibility**

Individuals in a population of requirements engineers are different from each other, as are people in general. For that reason, it should be possible to use the REDS in a variety of ways and it should be possible to get the information presented in an individualised way. The REDS should meet the needs stemming from:

- Cognitive style
- Decision style
- Level of knowledge and experience

All persons have their own cognitive style, affecting their way of processing information. There are several dimensions and one of them is field dependency versus field independency. A person with a field dependent style tends to tackle a task in a holistic manner, avoid details and is more interested in the global picture. On the contrary, the field independent individual is more serialistic when approaching a task, concentrates on details, and has a tendency to separate figures from their context (Witkin et al., 1977; Chen et al., 2005). Chen et al. (2005) argue that
a flexible user interface is important to meet the different preferences stemming from cognitive styles. Their work on flexible interface design for web directories show for instance that it is supportive for a field independent user to get the main categories and subcategories sorted and listed on the same page. The field dependent user on the other hand finds it more helpful to have the main categories and subcategories presented on different pages. It can therefore be argued that a REDS also should provide support in a flexible manner according to different cognitive styles so that each requirements engineer is supported in the most effective way. In the same way individuals have their own decision styles, which are related for example to preferred communication channels and problem solving strategies (Rowe & Boulgarides, 1992). This also implies a need for high flexibility in the REDS.

The case study showed that requirements engineers can be novices regarding both RE, the domain, and the product. Consequently, the REDS must meet the needs of both inexperienced as well as experienced requirements engineers. For example, the way of interacting with the REDS can differ. A novice may need support on what can be performed and how it could be carried out. More explanation and more instruction may be needed. An expert may instead want to interact through short cuts.

The requirements engineer carries out several tasks and the nature of these tasks call for certain characteristics of the REDS.

6.4.2 The nature of RE decision-making tasks

We have identified five characteristics of the REDS that originate from the nature of the decision-making tasks in the RE. These are: a) support availability of different types of information, b) support different types of decision matters, c) support idea generation, d) support creating an understanding of the problem domain, and e) support idea evaluation and problem solving.

Support availability of different types of information

Requirements engineers use several sources of input in their decision-making activities (see section 6.2.3). Therefore, it would probably be beneficial for them to have a document-driven decision support system. The purpose of such a decision support system is to gather, retrieve, classify and manage unstructured documents (Power, 2002). This way the requirements engineer can use the certain information needed in a specific decision-making activity in a more efficient way.

Support different types of decision matters

The REDS should support the different types of decision matters dealt with by the requirements engineers (see section 6.2.2). It should not just support the main decision matters but also the sub decisions, since the sub decisions has consequences on the main decisions as well as the development process. It should support both system-related and work-related decisions.
In our study we have found two different RE decision processes: a) establishment of requirements in a new project and b) management of requirements changes. Although they have similarities, there are also important differences. Both processes are highly iterative and include several sub-decisions. The first decision process occurs once in the lifetime of a project, while the second decision process occurs frequently. The first process embraces more decision-making activities than the second one. Some of the decision-making activities are shared by the two processes, and some activities are unique to each process (see section 6.2.1 on page 71).

The nature of the tasks conducted by the requirements engineers within these two different decision processes is different. These differences imply that the requirements engineers need different types of decision support depending on which decision process he or she works in. These are a) support idea generation, b) support creating an understanding of the problem domain, and c) support idea evaluation and problem solving.

**Support idea generation**

The process of establishing requirements includes many creative challenges for the requirements engineer. He or she has to a higher extent than in the process of managing requirements changes to generate ideas. This may need support. Such decision support can be directed towards reducing the effects of human decision-making weaknesses or cognitive limitations in general and stimulate the perception, imagination, and creative insights of the decision-maker (Holsapple and Whinston, 1996; Silver, 1991).

**Support creating an understanding of the problem domain**

A difficulty, which is of vital importance, in the decision process of establishing requirements is to understand the problem domain. In some development contexts the problem domain remains the same during at least some years. In such contexts knowledge management perhaps could be integrated in the REDS and function as a complement to requirements elicitation. The purpose of knowledge management is to make the sharing of knowledge possible beyond sharing of information (Alter, 1999). In knowledge management the knowledge about a company is created, gathered, stored, maintained, and disseminated (Laudon & Laudon, 2002).

**Support idea evaluation and problem solving**

The process of managing requirements changes is more of a routine process compared to establishing requirements. The stimuli that initiate the process of requirements changes are requirements errors and change proposals. Consequently, the nature of the task is idea evaluation and problem solving. In order to support the problem solving, the ability of a decision-maker to tackle large-scale, time-consuming, complex problems can be extended (Marakas, 1999). The quality of problem solving can be enhanced through e.g. better abilities to observe relationships between variables and through increased depth and sophistication of analysis (Keen, 1989).
The requirements engineer acts in relation to other actors. This social context also generates characteristics of a REDS.

### 6.4.3 The requirements engineer in the social context

We have identified two desirable high-level characteristics stemming from the social context in which the requirements engineers carry out their decision-making tasks. These characteristics are: a) support communication, and b) support coordination.

**Support communication**

Decision communication activities are carried out during the RE decision processes. The activities that should be supported are:

- Investigation
- Dissemination
- Negotiation

The decision communication routine named investigation (Mintzberg et al., 1976), in which discussions with stakeholders concerning the decision matters, is frequently conducted. The decision outcome is disseminated to the stakeholders that are going to act upon it. Thus, decision communication should be supported during the whole decision processes. This can be done with, what Power (2002) calls, a communication-driven decision support system (DSS). Such a DSS facilitates interpersonal communication through for example assisting communication across organisational boundaries (Alter, 1980) by using groupware that provides additional communication paths.

Some sub-decisions are negotiated which also can be supported by using a group decision support system (GDSS). A GDSS facilitate performing group decision-making tasks (Power, 2002). For example, an approach for supporting requirements negotiation is provided by Ruhe et al. (2002), which is called Quantitative WinWin.

**Support coordination**

When there is lack of coordination of the way of working and when there is time-consuming coordination the requirements engineer is affected and there can be potential quality problems in the RE decision process. Therefore, coordination should be supported for example using a communication-driven DSS. This way the outcome of coordination is improved and the amount of time needed for coordinating activities is reduced.

Based on RE decision-making in the social context two desirable characteristics have been described. These form, together with the characteristics stemming from the nature of RE decision-making tasks and the needs of the requirements engineer as a single user, a wishing list for requirements engineering decision support (REDS).
In summary, this chapter has provided the answers to the four research questions. First, a decision situation framework was presented. It has a human-centred and holistic perspective, and it is the result of a thorough literature analysis of decision-making theories. It has the potential to provide a structure when to analyse the decision situation of decision-makers in a domain. Second, the decision situation of requirements engineers was described based on the outcome of the case study. We found two decision processes which contain several decision-making tasks and sub decision matters. The decision matters have several attributes. The decision-making requirements engineers use a number of input sources to underpin their decisions. These input sources have several dimensions of characteristics. Third, there are factors generated in the organisational context that affect RE decision-making. These factors were found during the case study. Fourth, the material from the case study and the literature analysis were synthesised and formed desirable high-level qualities of requirements engineering decision support (REDS). These characteristics were structured in separate levels. These levels are the requirements engineer as a single user; the nature of the RE decision-making tasks; and the social context of the requirements engineer.
7 Discussion

This chapter first discuss the contributions and its main limitations. Then, the usefulness of the decision situation framework is elaborated. Finally, future work is outlined.

7.1 Contributions and limitations

There are four main contributions of this thesis. First, a decision situation framework that provides a holistic perspective on decision-making in general and which places the human decision-maker at the centre has been created. Second, a comprehensive description of the decision situation of requirements engineers is presented. Third, a model of factors that affect the decision-making of requirements engineers has been produced. Forth, a list of desirable, user-centred, high-level characteristics of an RE decision support is outlined. These contributions compose a foundation for development of RE decision support. This thesis consists of the first part of a larger research project that has the aim to enhance the ability of RE tools to effectively support RE decision-making. This means that we are not going to develop a complete RE decision support, but rather take the first steps towards it.

The decision situation of requirements engineers in a contract development context has been described, using the decision situation framework. In our case study both the projects and systems to be developed are large and complex. The description includes RE decision processes; RE decision-making activities; RE decision matters and their characteristics; and input used by requirements engineers in decision-making.

There were both ‘final’ decisions and sub decisions among the RE decision matters. By final decision we mean the last decision that is made in each decision process. The final decisions can also be seen as defining what the decision-makers’ work “is all about”. The sub decisions, though, were not viewed as decisions by the interviewees. Instead, they were hidden as activities, judgements, and trade offs. Nevertheless, the sub decisions do have an impact on both the current work and also the outcome of the decision processes. The sub decisions may escalate. Escalating commitment means that a person, group, or organisation invests more and more in an initial decision. This can lead to getting stuck in a certain course of action (Miner, 1992; Staw, 1997). The requirements engineers do for example decide what level of effort a requirements investigation should have. This is also indirectly a prioritisation of requirements. As a consequence, the requirements engineers invest more work load in some requirements and less in others. This can influence the experienced level of importance of the requirements. Therefore, it is important to also be aware of decisions that are not directly expressed as decisions.

There are two different RE decision processes: a) establishment of requirements in a new project, and b) management of requirements changes. There are similarities between the processes, but more importantly there are differences. The nature of the differing tasks implies that different decision support is needed within the two
processes. This has been elaborated in section 6.2.1 and section 6.4.2. We assume that these two decision processes exist in most, if not all, development projects. However, the main limitation is that only one company has been studied. The specific decision-making activities as well as the decision matters may be unique for each project. At this stage of our research we do not claim to have a complete set of decision-making activities or decision matters. More research is needed to determine which activities and decision matters occur in most RE decision processes as well as which activities vary. The limitation also applies for the input used by requirements engineers.

Despite the limitations, the results take us towards our aim to improve decision support to requirements engineers. RE decision-making is complex and can also be project specific. Therefore, future enhancements of RE tools need to focus on improving decision support by concentrating on certain decision matters or a certain activity in a certain decision process. In our future research we will investigate how different RE tools support the processes described in this thesis. The problems and difficulties, presented as factors, which face requirements engineers will also be considered.

We have identified seven factors which directly or indirectly affect the decision-making requirements engineer in our case study, which represent the problems and difficulties that face the decision-making requirements engineer. These factors are interrelated. Each factor consists of several problems, which have been related to decision-making theories. It is reasonable to assume that the factors are not unique for Ericsson Microwave Systems, and that they can be found more or less in every development organisation. We can conclude that when one or more of these problems appear in a development organisation, then there are potential quality problems in the RE decision process. Nevertheless, the main limitation of this research is that only one company has been studied. It is therefore difficult to determine to what extent the factors apply to other development companies.

The factors provide a step towards understanding the complex decision situations of requirements engineers. The factors can form a basis for focusing future research in order to provide better decision support to requirements engineers. We can for example choose to focus on improving the usability of requirements management tools, which in turn partly can lower the cognitive load of the requirements engineer.

In order to provide support that covers the needs of requirements engineers in their decision situations there are several high-level desirable characteristics that an RE decision support should have. There are characteristics stemming from the requirements engineers viewed as single users. Other characteristics are implied by the nature of RE decision-making tasks, and some are based on the attributes of the social context in which the decision-making requirements engineers act. The main limitations are that the characteristics have not been validated and used. Therefore, it is not proved that the characteristics have an actual impact on the outcome of RE decision-making or to what extent they have an effect. In consequence, we cannot conclude which characteristics are the most critical for RE decision support.
However, based on the results of the case study and the literature analysis of decision-making and decision support it is possible to argue that it is likely that the proposed high-level characteristics of RE decision support positively affects the effectiveness and efficiency of RE decision-making. The set of characteristics can also be viewed as an initial hypothesis to be further developed and validated by future research.

7.2 The decision situation framework

The decision situation framework is a theoretically based framework that takes a holistic perspective on the decision situation from the viewpoint of a decision-maker. The framework facilitates qualitative analysis of empirical data when studying decision-making in a particular context. It may also be supportive in a quantitative research setting, for example structuring the research design. However, in this research project, it has only been used in a qualitative research setting. Thus, we can only claim usefulness for qualitative analysis. The framework supports the qualitative analysis in three main ways compared to using no framework at all. It a) enables a more complete description of the decision situation; b) enables the gathering of extensive information within each part of the decision situation; and c) forces us to identify actual decision activities as well as finding the real problems and difficulties that face the decision-makers.

In a broad sense, the framework enables a more complete description of the decision situation. The framework provides predefined categories, where each category is represented by a “box” in the framework. These predefined categories make it possible to, in a structured way, walk through the data category by category, and the risk of missing important aspects of the decision situation are reduced. If the analyst finds that there is not enough information concerning a certain part, e.g. decision outcome, it is possible to collect complementary data on this part. An example of this is when missing information concerning decision outcome was located during data analysis in the case study. After the analysis in the case study, it became obvious that there was not enough information concerning decision outcome. In our case study, ten decision matters and two different decision processes were found. However, it was not possible to state in what way each of these was expressed. For example, the decision matter ‘In what way shall we deal with requirement changes?’ had no related decision outcome in the data. Questions such as: are these decisions documented and is information concerning the decision distributed to others, was raised. The interviewees had described in what way the ‘final’ decisions were expressed. However, the outcomes of all sub-decisions, which preceded the final decision, were not in the data. We had to make complementary interviews to “fill the gaps”. If we had not analysed our data in terms of both decision matter and decision outcome, which is prescribed by the framework, we doubt that we had observed the discrepancy. A more complete picture was gained.

The framework enables the gathering of extensive information within each part of the decision situation. The framework directs our attention to aspects found in the data that we believe are more easily overlooked without the framework. An example of
this is when decision matters that were not explicitly stated as decisions by the interviewees were identified. During the analysis we found that there were more actual decision matters than the interviewees explicitly articulated. The decisions that they claimed they made were of a ‘final’ nature. However, in our case (and probably in most cases) there were decisions preceding the final decision, which we call sub-decisions. Some of these sub-decisions, for example ‘Which system requirements should belong to which subsystem?’, were “hidden” in the data as activities. The interviewee spoke about them as “things they do”. The given example was in fact an important tactical decision negotiated between several decision-makers. Thus, this information was not found directly thanks to the questions that were asked during the interview session. This information was found because the data was analysed in terms of decision matters, as prescribed by the framework. More thorough information concerning the category was gained.

The framework forces us to identify actual decision activities as well as finding the real problems and difficulties that face the decision-makers, instead of identifying e.g. organisational procedures and information flows. Organisational procedures and information flows are – of course – important, but they are not enough. The decision-maker perspective of the framework makes us focus on the needs and requirements of people who are going to use the decision support system (DSS).

The main limitation of our research so far is that the information generated from the analysis has not yet been used in the most subsequent DSS development phases. Thus, it is not possible to state the usefulness of this kind of information in that respect. Further research is needed. Another limitation is that the benefits of using the framework for analysis have not been compared in an experimental way. Also, the framework has only been used by its inventors, and it is possible that we are biased when using the framework. Further research is clearly needed here.

The framework can hopefully be extended so that it can form a bridge between empirical findings regarding the decision situation of interest and relevant theories. That could provide a more thorough understanding and explanation of the complex decision situation. Also, the framework can potentially be used for development of other types of information systems. Other information systems also support decision-making, although they perhaps do not specifically address decision-making activities.

Thus, the framework provides a holistic overview of decision situations from the decision-makers perspective. Such an overview can be used to discuss and direct the coming efforts in a decision support system development process, e.g. to decide which parts of the decision process that should be supported or decide which factors affects the decision-maker that should be addressed by the decision support system.

7.3 Future work

There are several possibilities for future work based on the results presented in this thesis. The decision situation framework needs to be investigated further. The
information generated with help of it needs to be used in subsequent development phases in order to state its real usefulness. It should also be used comparatively and also by others than its inventors.

The decision situation framework has potentiality to be extended to include for example guidelines, techniques, or proposed relevant theories. Thus, it needs to be both developed further, but also to be tested in different settings.

The decision situation of requirements engineers needs to be validated in organisations with similar development contexts. This would indicate what parts of the decision situation that often occur and what parts are specific to a project or an organisation. It would be interesting to see along which dimensions the decision situation differ and what causes the differences.

The decision situation of requirements engineers should be compared to other development contexts, such as market-driven and in-house development, small projects, or immature organisations. Such research would further contribute to a cohesive body of knowledge concerning RE decision-making in general.

The decision situation viewpoint has advantages in that it is holistic. Thereby, it includes all or most of the aspects important for the decision-maker. The wide scope has a serious drawback, it lacks in depth. Therefore, future work should have a narrower scope so that depth can be improved in each part of the situation. This can for instance be a focus on decision outcome, i.e. how the decision is expressed, or drawing a social map of each decision-making activity.

Several factors that may cause quality problems of RE decision-making have been identified. It is beyond the scope of this research project to state the actual cause and effect relationships within an organisation. Nevertheless, such research would be valuable in order to for example prioritise the importance of the factors in relation to each other.

The high-level characteristics are a first step towards RE decision support. A large amount of research remains. The usefulness of the characteristics has to be validated. They also need to be formulated on a more detailed level. The detailed characteristics should be implemented and the result should be evaluated. Then, a substantially useful list of RE decision support characteristics can be created.

In summary, this chapter discusses the results and its main limitations. The decision situation of requirements engineers shows that the nature of RE decision-making tasks in the two RE decision processes differs and therefore we can argue that each process needs its own kind of decision support. The difficulties and problems of the decision-making requirements engineer, represented as factors, can direct attention and efforts of future research in the area of RE decision-making and RE decision
support. The main limitation is that only one company has been studied. Other
development companies may have other decision situations and difficulties. The
desirable high-level characteristics of RE decision support forms a basis for providing
support from the perspective of the requirements engineer. The main limitation is
that the characteristics have not been validated and used, which give the direction for
future work. The decision situation framework has shown its potential to assist in
qualitative analysis of empirical data. The advantages are that it enables a more
complete picture of the decision situation, enables gathering of extensive information
about each part of the decision situation, as well as forces identification of actual
decision activities and the real problems and difficulties that the decision-makers
experience. The main limitation is that the framework has only been used by its
inventors and that the information generated with help of it has not been used in all
subsequent DSS development phases. The proposed future work concerns validation
of RE decision situation, comparison with other development contexts, and more
deep studies of each part of it. Other future work is investigation of consequences of
problems. Finally, more work of the characteristics is needed.
8 Research Plan

In future research we plan to validate results the in a consultancy firm, which has extensive experience of working with requirements engineers in several different companies.

After the validation we plan to focus on how to provide better decision support through requirements management tools, with special attention to analysis of change proposals. Requirements management tools are already available on the market and are in use in many companies. Such tools have possibilities to function as RE decision support. However, it is not possible to embrace all parts of the decision situation and all desirable characteristics of such a RE decision support. Instead, we will concentrate on a subset of the situation and characteristics. Arguments for this approach will be provided in the following.

There are two decision processes in RE; establishment of requirements in a new project and management of requirements changes. Both decision processes are vital for the development process and for the success of the system. However, it is not possible to include both decision processes in the scope of the planned future work. The decision process in focus will be management of requirements changes, because the nature of the RE decision-making tasks in this process have a definite potential to be supported through requirements management tools.

The nature of the decision-making activities in establishment of requirements is more creative and has a wider scope of comprehension activities, such as exploration of the problem domain, compared to the activities in management of requirements changes. The decision-making activities in management of requirements changes consist more of idea evaluation, problem solving, and the involved investigation activities have a more narrow scope. In management of requirements changes it is important to be aware of which consequences a certain change proposal can have, so that the changes do not cause unnecessary problems for other subsystems when implemented. This work is conducted in the analysis mode of the selection phase in the decision process. It precedes the judgement and bargaining modes of the choice routines in which it is decided if a requirements change proposal should be approved or not. The implementation of such a decision can affect both the development process as well as the system. Hence, it is important to support the decision-making activity called analysis of change proposals. During this activity requirements engineers have to use input from existing requirements and other requirements-related information in order to be able to carry out their work. Such information can be stored in requirements management tools. Also, the quality of the tool from a human-centred perspective affects the work of the requirements engineers.

The problems that have been identified and reported in this thesis are for instance usability problems in requirements management tools and that the requirements engineers experience a high cognitive load. The usability problems are concerned with the effectiveness, efficiency and learnability of the tool. The usability problems increase the cognitive load of the decision-making requirements engineer, which in
turn can negatively affect the outcome of decision-making. The problems of cognitive load are stemming from for instance lack of general overview and high memory load. The problem of obtaining a general view concerns for example difficulties to identify relationships and dependencies within and outside the subsystem. An example of the problem of high memory load is that dependencies between requirements are kept in the human memory. This can directly affect the potential quality of RE decisions. This chain of arguments leads to the following research questions to be answered by our future research:

- To what extent and in what ways do commonly used requirements management tools support analysis of change proposals from a human-centred perspective focusing on usability and cognitive load?
- How can the analysis of change proposals be supported in a better way from a human-centred perspective with focusing on usability and cognitive load?

The first research question is planned to be answered by evaluating commonly used requirements management tools, such as Telelogic DOORS\(^3\), Serena RTM\(^4\), Telelogic Focal Point\(^5\), and Rational RequisitePro\(^6\). This way it is possible to describe to what extent the tools used today by requirements engineers potentially could function and actually is functioning as decision support in analysis of change proposals. The evaluation is planned to consist of two stages. First, the tools will be evaluated using usability inspections. The purpose of usability inspections is to evaluate user interface design. Usability inspections consist of a set of methods in which usability inspectors walk through and examine usability-related aspects (Nielsen & Mack, 1994). Second, user testing, e.g. cooperative evaluation (Monk et al., 1993), in the field is going to be used.

This leads to the second research question in which the plan is to propose an approach that supports this particular task in a better way. By better, we mean both the performance and the subjective experience. This can be done for example by measuring and comparing the effectiveness, e.g. time to finish a task, and the satisfaction, e.g. ratings of ease of understanding the information (Dumas & Redish, 1999), between current solutions and our proposed solution. Thus, we plan to create a low fidelity prototype to be able to carry out such a comparison. This comparison is going to be conducted in a laboratory setting in an experimental way.

The expected contributions are:

4 /www.serena.com/Products/rtm/home.asp
5 /www.telelogic.com/focalpoint/
- A description of the current status of requirements management tools with regard to
  o Decision support for analysis of change proposals
  o Usability
  o Cognitive load regarding general view and memory load
- A visualisation and description of an alternative solution to providing decision support for analysis of change proposals that:
  o has high usability,
  o facilitates obtaining a general view, and
  o minimises memory load.

The result of this research is aimed to be used by researchers with an interest in RE decision support and by developers of requirements management tools, with the purpose of providing better decision support to requirements engineers. Decisions about change proposals as well as other system- and work-related decisions are of vital importance for both the development process and the system.

Hence, our research will hopefully contribute to requirements engineers experiencing an improved decision situation and that both the process and the system can benefit from better requirements engineering decision support.
9 References


Anthony, R.N. (1965) Planning and control systems: A framework for analysis. Harvard University, Boston: Division of Research Graduate School of Business Administration


Miller, J., MacDonald, F. & Ferguson, J. (2002) ASSISTing management decisions in the software inspection process. Information Technology and Management, 3, 67-83


