CHALMERS

An Estimation Improvement Method Aiming for Successful Deliveries of Software Projects

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Abstract

High quality estimates are important since they lay the foundation for the planning of projects. Inaccurate estimates increase the risk for project plan overruns and increased project costs. An improved estimation process significantly increases the chance of reaching higher estimation accuracy, resulting in less project plan and budget overruns.

An investigation and analysis of the current estimation practice within ABB organizations has been performed to collect information regarding the need for estimation improvement and how an improved estimation method should be introduced. Findings are that the estimates often are not good enough today, leading to unrealistic project plans in which neither management nor developers trust. Project overruns are not unusual which may be due to the fact that the estimation is performed in an ad hoc manner and that the level of estimation maturity is low. Acknowledging this, improvement needs to be conducted in small steps. Other findings were that factors such as estimation attitudes, political factors and psychological aspects very much exist and affect the estimation negatively. An increased awareness of these factors and how they can be counteracted help decrease their influence.

Derived from available research and observations of current practice in industry, the thesis work has resulted in twelve estimation improvement measures and an improvement method for how to realize the measures. The twelve measures facilitate step-by-step improvement and adjustment for the organizations in an estimation improvement process. The measures consider four areas; *Who to estimate*, *What to estimate*, *How to estimate*, and *How to increase project control*.

Foreword

This thesis is written for our Master of Science Degrees at the Department of Computer Science and Engineering, Chalmers University of Technology.

We would like to give special thanks to our supervisors; Stig Larsson at ABB Corporate Research (CR), for his support, inspiration, and very useful suggestions, and Peter Öhman at the Division of Computer Engineering, Chalmers University of Technology, for awakening our interest for Software Engineering, and giving us inspiration and guidance when selecting thesis. Also thanks to ABB and CR for providing this opportunity, and Fredrik Ekdahl who marketed ABB and CR to us.

Thanks goes also to the persons we have interviewed, within ABB and at Prevas, for showing interest and offering their valuable time.

We would also like to thank all members in the ASPI group at CR for their assistance and encouragement; to UW for entertainment in the cafeteria, JH for interesting conversations, CjP for sharing experience, FE for statistical reasoning, and PB for stimulating discussions. Thanks to all employees at CR for taking such interest in our work; it has truly been an inspiration to us.

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Camilla Lindström and Anna Lindvall

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Section 1

Introduction

The thesis work has been conducted at ABB AB, Corporate Research (CR) in the autumn 2005. In this section, the problem and background are shortly described. These lay the foundation for the problem statement described next. The section ends with definitions of important terms and a description of the thesis outline.

1.1 Problem

An important part of project planning is to estimate the required amount of resources, both time and cost, and lay out these in calendar time (PMI 2001). It is important to estimate in such a way that the estimates are realistic and can be trusted. If estimates cannot be trusted, management has no basis for a realistic decision regarding the time frame of the project.

CR has worked with process improvement together with different ABB organizations for several years. The general understanding CR has got from this cooperation is that the organizations' estimation processes do not work as well as one could wish and that many projects overrun their plans with increased costs as a result. CR suspects that the ABB organizations need to improve their estimation process, and has therefore introduced a project planning course which includes estimation recommendations. One recommendation in this course is that some characteristics, such as the size of the part to be estimated and the experience of the developers, should be considered when estimating, to facilitate production of more accurate estimates. Some organizations that have taken part in this training course have difficulties to adopt all ideas, for example the consideration of size.

As a result of the estimation process difficulties, CR believes that the estimates produced today are not good enough and that management perhaps does not trust the estimates and therefore makes unrealistic plans. With unrealistic plans the project overruns and resulting increased costs will most likely continue. Some kind of change

is necessary to improve the estimation situation, leading to more confident estimates and more realistic plans.

1.2 Background

Research has been conducted in the area of estimation, both within ABB and at external research institutes. Early research has focused on formal methods which, with the use of historical data of previous projects, predict the required effort through some kind of mathematical formula. Different estimation methods derive this formula in different ways, for example by the use of linear regression (Pressman 2005). This method requires that similar projects have been performed, measured, and documented, and that the estimation process not is altered, since process modification changes the conditions which underlie the derived prediction formula.

Some research has focused on less complex methods, mainly subjective expert judgment. An expert can be defined as a person with experience in the development domain. Experts may be more or less experienced and their judgments can be produced more or less structurally. Research has suggested several recommendations and techniques which, when used in the estimation process, indicate increased estimate accuracy as a result.

Due to the potential weaknesses in the current estimation practice and the insufficient supply of useful data from earlier projects within ABB, this thesis work focuses on finding a suitable, uncomplicated, but extendable estimation method to facilitate the beginning of an estimation improvement process. The work presumes the fundamental value that estimation accuracy is important for project success, advocated by the Capability Maturity Model Integrated (CMMI) (Chrissis, Konrad & Shrum 2003).

1.3 Problem Statement

With the problem at hand and given the stated background, we decided on the following problem statement.

> *Is there, for ABB organizations, a suitable method for estimation in project planning, which is superior to the current practice, extendable and easy to adopt?*

The question is answered through the following sub questions.

- Is there a need for such a method?
- Which requirements should the method fulfill?
- Which expectations are there?
- Are there such methods?
- How should the method be introduced?
- Which further steps are possible in the estimation improvement process?

1.4 Definitions and Abbreviations

To be clear with what the authors mean with key words used in the thesis, they are here defined (see Figure 1). Also, abbreviations used are stated (see Figure 2).

Term	Definition
Accurate estimate	An estimate close to the actual effort.
Effort	The amount of work time, e.g. person-hours or person-weeks, required for carrying out a certain task.
Estimate (noun)	An assessed value of the required effort.
Estimation	An assessment of the required effort for carrying out a certain task.
Estimation method	A thought-out method for how to estimate.
Estimation practice	How the estimation usually is performed.
Estimation process	A general course of events for the estimation.
Expert	Person with domain knowledge and some development experience.
Formal estimation method	An estimation method which involves more or less advanced mathematical formulas.
Inaccurate estimate	An estimate nowhere near the actual effort.
Management	Managers in general. Includes project managers as well as line management.
Successful project	A project where accurate estimates contribute to on-time delivery of planned functionality and quality.
Soft factors	Factors influencing the estimation indirectly.

Figure 1: Terms and corresponding definitions.

Abbreviation	Compound term
CR	Corporate Research
ASPI	ABB Software Process Initiative (project at CR)
LOC	Lines of code
FP	Function Point
PPB	Project Planning Basics (course held by ASPI)
WBS	Work Breakdown Structure

Figure 2: Abbreviations and their compound terms.

1.5 Thesis Outline

The thesis is organized as follows: In the next section, section 2, methods used in the thesis work are described. This follows by limitations to the thesis scope, stated in section 3. Section 4 summarizes related research, literature and ABB specific methods, while section 5 depicts the current estimation practice at the studied ABB organizations.

In section 6 we analyze and discuss the current estimation practice and related work. We underline main problem areas and give possible solutions. The analysis results in twelve estimation improvement measures described in section 7. An improvement method for how to realize the measures is presented in section 8. In section 9, a pilot of some of the measures is described.

Threats to the validity of the thesis work are discussed in section 10. Section 11 concludes the thesis work and in section 12 future work is suggested. References are listed in section 13, and in the glossary in section 14, terms and abbreviations are explained. The questions used in the interviews are given in Appendix A.

Section 2

Method

In this section we describe the methods used in the thesis work. Since the topic in this thesis is to improve the current estimation practice, the first step was to evaluate the current estimation situation, then explore related research to be able to suggest appropriate research results to apply.

2.1 Overview

When reviewing state-of-the-art, we chose to conduct a literature study of related research work. To examine the current estimation practice at ABB we used interviews with appropriate employees as the main information gathering method.

For the task at hand of receiving as deep understanding as possible of the current estimation practice, there were several possible strategies, but in the end, interviews were chosen over observations and questionnaires. One reason for this choice is our belief that interviews would be most effective since observations are time-consuming and questionnaires may have a low response rate and misunderstandings may not be detected (Robson 2002). Questionnaires may also lessen the involvement of the respondent (Cozby 2004). Another reason is that, as we had little knowledge about the estimation process, we wanted the possibility to ask subsequent questions based on answers given.

Interviews result in qualitative data which one can not draw statistical conclusions from. However, from qualitative data one can receive qualitative and comprehensive information which can improve the understanding of the current situation (Yin 2003).

When reaching thesis conclusions, these may be further validated through the launch of a pilot. Therefore we decided to conduct one.

2.2 Interview Design

We chose semi structured interviews (Robson 2002) since we wanted to: (1) use enough structure to ensure receiving answers to all or most of our questions in a relative short period of time but still (2) give the interviewed persons freedom to express and explain different aspects and thoughts in a relaxed manner. We chose only open-ended questions which give the interviewee more freedom in the answers (Cozby 2004).

As qualitative data was more important than quantitative, we decided that a selected sample of people, i.e. not a random sample, was justified and that the number of interviewees was enough considering the time aspect of this thesis. We chose to interview eleven relevant people, that is, people who were expected to have insight in the estimation process, within four different ABB organizations.

We also interviewed an employee at an external company, Prevas, since they claim to be “the fixed price specialist”. Offering customers fixed prices on their orders should imply knowledge on how to estimate project cost well, otherwise the company would end up losing a lot of money.

Most of the interviews were conducted face-to-face but since some of the respondents were situated in Malmö, we also performed telephone interviews. The drawback with telephone interviews is that the lack of visual may cause interpretation problems, i.e. face-to-face interviews can give additional clues to the answers given. However, telephone interviews also provide advantages common with those for face-to-face like a high response rate and removal of obvious misunderstandings (Robson 2002).

The time frame for the interviews was set to an hour. Less time would probably not have given us answers to all essential questions and more than an hour might not have been possible for the interviewees to spend. These opinions are also shared by Robson (2002).

To find relevant questions for the interviews we used brainstorming which resulted in a mind map (see Figure 3).

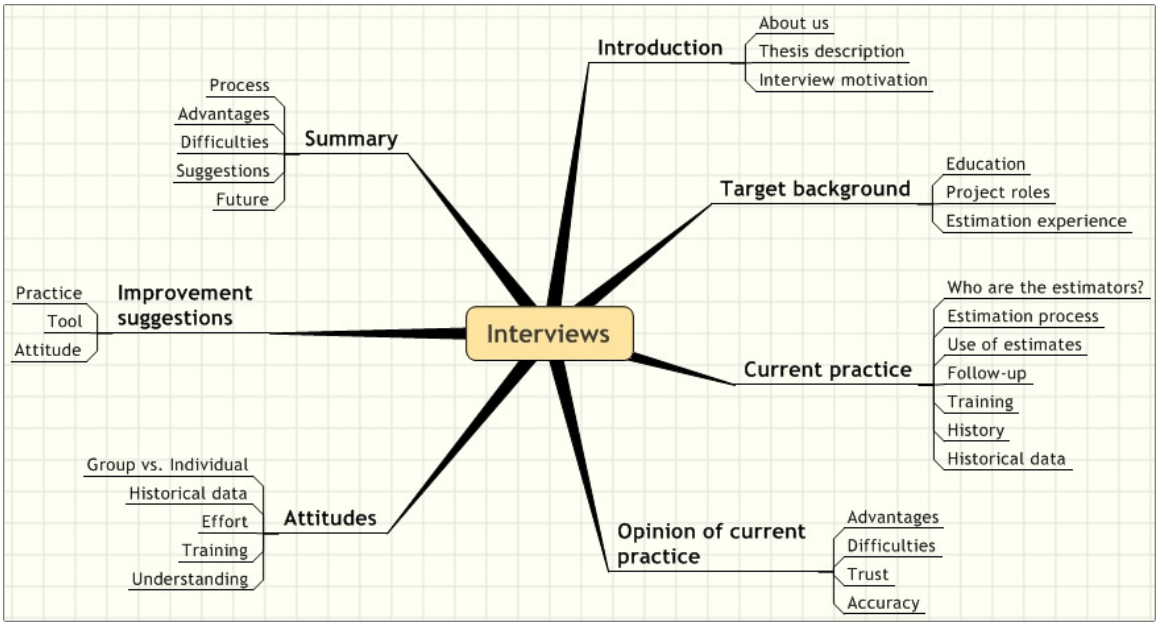

Figure 3: Mind map over main topics for the interviews.

Starting with this mind map, we formulated interview questions and when grouping them we received the following main subject areas:

- Types of project
- Current estimation practice
- Estimation education and experience
- Attitudes towards estimation
- Advantages and difficulties with the current estimation process
- Estimation follow-up

The interview material is found in Appendix A.

Section 3

Limitations

In this section we present the limitations of the thesis scope.

Due to the given background that the level of the current estimation practice at ABB may be low, we focus our investigation on methods that are less complex.

The thesis does not cover closely related problem areas such as resource management, calculations of expected project cost, or scheduling, i.e. the process where the estimated efforts are used to produce a schedule. Another strongly related issue is risk management, but as this subject is a large and challenging research area on its own, no more than brief connections are made in this work.

We have not investigated means to practically realize the outcome from the thesis work. That is, we will only provide thesis conclusions with recommendations and guidance to the realization of them; it is up to the organizations to decide on the detailed implementation.

No pilot project follow-up, in order to measure accuracy of the estimates and get an idea of the quality of the estimation method, will be conducted. The reason for this is that the pilot project will not have finished the development at the time of the finalization of this report.

Section 4

Related Work

This section is a summary of related work gathered through the literature study. First general topics are depicted, followed by a description of different estimation methods. Finally, expert based estimation is described in more detail.

4.1 Motivation for Estimation Improvement

Research show that there are several reasons for pursuing better estimation processes.

4.1.1 *Overruns very common*

Software development project overruns are very common; 60-80% of the projects overrun their plans (Molokken & Jorgensen 2003). According to the updated Chaos report (Standish 2001), not even a third of the studied projects finished on time and within budget, with all functionality originally specified. In addition to this, almost half of the projects were completed but had overrun its estimate and budget, and included less functionality than initially specified. The rest of the projects were not even completed, i.e. cancelled before completion or never implemented at all.

The report also discovered that the reason for unsuccessful projects was not lack of money or technology, but lack of management skills and support; the support from management affects the progress of a project and lack of management input may harm a project severely. Other important factors for project success, found in the study, are e.g. user involvement, project manager experience, and estimates reliability.

4.1.2 *Uncertainty*

We can not predict the future and therefore we can not expect estimates to be precise. Since many software development projects have high inherent uncertainty, we have to accept and assess the level of uncertainty instead of denying it or believing we can

remove all of it (Jorgensen 2005; Pressman 2005). Estimation is a risk factor but the risk can be reduced by using historical data and a structured estimation approach (Pressman 2005).

> *"It is the mark of an instructed mind to rest satisfied with the degree of precision that the nature of the subject admits, and not to seek exactness when only an approximation of the truth is possible." - Aristotle*
>
> (Pressman 2005)

4.1.3 *Need for a method*

An estimation method should be used during the estimation and the selection of this method should be made on the basis of the organization's needs (Lederer & Prasad 2005; MacDonell & Shepperd 2003). MacDonell and Shepperd (MacDonell & Shepperd 2003) also believe that an organization sometimes could benefit more from a somewhat less accurate but robust estimation method. This is especially true when the organization does not have the data required for calibration of a more accurate method to reflect local circumstances. Further they explain that project managers do not only want accurate estimates; they want to understand them as well, i.e. identify the background and motivation. Jorgensen (Jorgensen 2005) has found that small and simple changes to the estimation process can be enough to end up with more accurate estimates.

4.1.4 *The importance of accurate estimates*

Accurate effort estimates are important for the success of software projects, since they influence basic business decisions and are used when bidding, evaluating risks, determining project content, planning resources, and monitoring projects. Another reason for producing accurate estimates is that commitments to customers need to be met in order to not risk hurting the business. The estimates also affect software quality; too optimistic, i.e. too low, estimates lead to poor use of effort and more errors when programming (Taff, Borchering & Hudgins 1991; Jorgensen & Sjoberg 2001; Lederer & Prasad 1995; Kadoka, Cartwright & Shepperd 2001).

4.2 Factors to Consider when Estimating

Estimation activities need to be based on accurate facts, especially for a number of factors influencing the quality of the estimates.

4.2.1 *The trade-off triangle*

Estimating is challenging for several reasons and the first problem is that projects often must satisfy goals in conflict. A project has to deliver specified functionality within specified cost and time and with the desired level of quality (Stutzke 1996). These four goals make up the trade-off triangle (see Figure 4). According to Ambler (Ambler 2004), at least one of the triangle's corners must be allowed to vary, otherwise the quality will suffer. If all factors are exactly defined, it will lead to project failure since there is no space for the project team to manage the project.

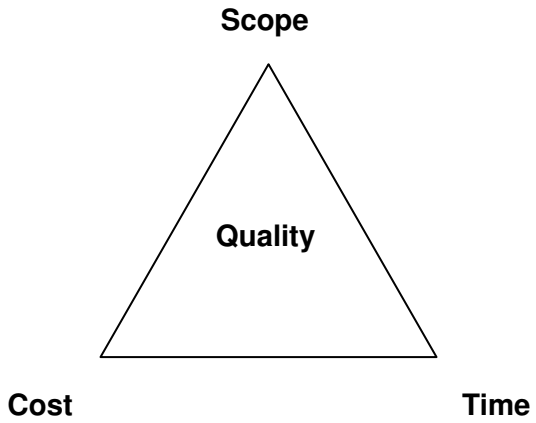

Figure 4: The trade-off triangle.

The problem is that different project stakeholders are more interested in one factor over the others. The financial department is more interested in the total project cost, the management is more concerned about the project schedule, the end users care mostly about the scope, and the software developers want to produce high-quality products. These conflicting goals complicate the estimation (Stutzke 1996; Ambler 2004). Ambler acknowledges the difficulty but says:

> *"Yes, it can be politically difficult to take an elastic triangle approach to development, but it's a lot easier than having to explain why you failed yet again."*
>
> (Ambler 2004)

Often it is management who controls all three corners of the triangle (McConnell 1996).

4.2.2 *Clear requirements important*

One difficulty, according to Stutzke (Stutzke 1996), is that estimates are needed before the project is well-defined. He explains that the more information becomes available, the greater possibility for accurate estimates and therefore more accurate estimates can be reached earlier in projects that involve improving existing code.

> *"An estimate cannot be more accurate than the accuracy of the data used to develop the estimate".*
>
> (Fairly 2002)

Pressman (Pressman 2005) reminds that you can not know how accurate the estimates are before project ending. He believes that the environment and the stability of the requirements affect the estimate accuracy. He also states that since unclear requirements imply higher risks, it is important that the project scope is fully understood and the requirements are clear, as early as possible. Modified conditions, e.g. changes in requirements, often occur after the estimation, which complicates the follow-up since the original estimates might not reflect the final project content (Taff, Borchering & Hudgins 1991).

4.2.3 *State the probability*

Together with the estimate, the probability for the estimate should be stated (Jorgensen 2004a, 2004b; PMI 2001). This uncertainty may, according to Jorgensen (Jorgensen 2004b), indicate how much time needs to be added to the contingency buffer, i.e. the

buffer for dealing with unexpected events in the project, and how likely it is that the business will end up losing money.

4.2.4 *Size*

Some literature recommends the usage of size when estimating, since the more there is to develop, the longer time it takes, and if one knows the size of the product to be built, one can better judge the effort required to build it (Pressman 2005; McConnell 1996; Humphrey 1995). Size refers to any countable outcome of a software project, such as lines of code (LOC) or function points (FP) (Taff, Borchering & Hudgins 1991; Pressman 2005). Pressman (Pressman 2005) claims that the accuracy of estimates is depending on how well the size is estimated and translated into human effort, and he believes that software sizing is the first major challenge.

> *"This step is by far the most difficult intellectually, which might be a part of the reason that people so often skip it."*
>
> (McConnell 1996)

The estimation of size is difficult since little literature tells how to do this; the estimation of size is "the real problem", and since most people estimate the effort directly it is suspected that people estimate with their own productivity level in mind (Taff, Borchering & Hudgins 1991).

4.2.5 *Conflicting estimation goals*

Political pressure is mentioned in many papers and defined as pressure from e.g. management or sales department. Political pressure exists in every organization and influences the estimates negatively in that it alters, most often lower them (Gray, MacDonell & Shepperd 1999; Molokken-Ostvold & Jorgensen 2004b, 2005; Jorgensen 2004a; Jorgensen & Molokken-Ostvold 2004a; Lederer & Prasad 1995; Molokken & Jorgensen 3003).

It is a possibility that reasons exist for estimators to have goals other than accuracy in mind when estimating, thereby providing unrealistic estimates. In addition, these hidden goals may be in conflict with other estimators' hidden goals. It is also a fact that planning, estimation and bidding often are mixed up (Jorgensen 2004a, 2005). According to Jorgensen, the terms *bid*, *planned effort* and *most likely effort* are in conflict with each other since they have different estimation goals. He explains that the impact of this conflict should be avoided or at least reduced by identifying estimation goals different from accuracy. If most likely effort is defined as the median value of a probability distribution, the chance for the actual value to not exceed the estimate is equal to the risk of exceeding it, i.e. a 50% probability estimate. When planning, one may want higher certainty than 50% and may therefore add a buffer to get the planned effort. The bid, or *price-to-win*, should be based on the most likely effort but is not an estimate in itself; it is only a number to get the contract (Jorgensen & Sjoberg 2001; Jorgensen 2004a).

4.2.6 *Available work time different from calendar time*

There is a difference between actual time available for work and calendar time; available work time is the concentrated time it takes to finish an assignment while calendar time is the total elapsed time from start to end (Fairley 2002; Wyzocki & McGary 2003). Several activities are carried out in an ordinary work day, which are not associated with work, e.g. mail correspondence and telephone calls to family members (Cornelius 2004). Out of a full work day, only 75% is regarded to be available for work *if not interrupted* (Fairley 2002; Wyzocki & McGary 2003), interruptions extend the calendar time even further;

> *"Every time a worker is interrupted, it takes more time to get up to the level of productivity prior to the time of the interruption."*
>
> (Wyzocki & McGary 2003)

Multitasking is another factor which reduces focus and efficiency. Multitasking may result from the custom of executing projects by priority; customers are demanding and want to see progress which has the effect that employees aim to keep as many customers satisfied as possible (USCRC 2005).

If the actual available work time is not taken into consideration the probability for overtime and project overruns increases (Fairley 2002). Adding more resources to get more productive time does not seem to be the solution; more resources do not always result in shorter calendar time. In fact adding too many workers may increase the calendar time (Wyzocki & McGary 2003).

4.3 Improving Estimation

Three perspectives on what to consider when making an attempt to improve estimation is described: how to increase project control, how to overcome resistance to change, and how to use increased follow-up to facilitate change.

4.3.1 *Lack of project control*

Lederer and Prasad (Lederer & Prasad 1995) found that ineffective project management is the major cause for project overruns. However, the general opinion among information project managers and professionals in their study was that project overruns are due to customers' poor understanding and change of requirements. Lederer and Prasad recommend re-evaluating the attitude towards customers along with paying more attention to management control issues such as careful examination and follow-up of estimates, to improve the estimate accuracy.

4.3.2 *People fear changes*

Managers must lead the way to improve the estimation and when introducing changes it is important to be aware of human factors (Chroust 2002; Stutzke 1996). Chroust express it quite clear:

> *"Psychology asserts that an individual exposed to an unknown/changed environment exposes a certain amount of fear which in turn seems to be one of the major reasons for objecting to the introduction of new technology".*
>
> (Chroust 2002)

Chroust thinks that, when introducing a new method, it should be discussed and criticized openly and proper adjustments should be made before the method is launched.

4.3.3 *Follow-up*

To be able to adjust an estimation method to produce more accurate estimates, it is important to take historical data into consideration (Fairley 2002). Historical data, in this context, is records of previous projects and their results, which may consist of information about project attributes or durations of different activity categories (PMI 2001).

It is not possible to decide if an estimate was accurate on the basis of a comparison with the actual value. A small deviation does not necessarily mean that the original

estimate was correct; more information need to be considered, e.g. conditions, assumptions and the uncertainty of the estimate (Jorgensen & Sjoberg 2001). Since the estimates depend on the original requirements it is necessary to update the estimates when the requirements change, by re-estimating periodically and as events occur (Fairley 2002; Stutzke 1996).

4.4 Estimation Methods and Theories

Estimation is challenging and organizations are different, therefore several estimation methods and theories exist. The most common ones are described here.

4.4.1 *Function point analysis (FPA)*

When measuring size, FP is an alternative to LOC (Hill, Thomas & Allen 2000; Humphrey 1995). Function point analysis was invented by Albrecht at IBM in 1979 when he defined five basic functions: inputs, outputs, inquiries, data files, and interfaces, which are calculated, weighted and summarized to a total number of function points per category. These are translated into effort estimates with the help of historical data on development cost per function point (Humphrey 1995). The method needs calibration to fit the organization (Hill, Thomas & Allen 2000).

The main advantages are that function point analysis is a well-documented method usable in the early requirement phases, and that the estimates are based on a large body of historical data. Disadvantages are e.g. difficulties with the calibration to fit different organizations and the counting of an existing product's function points directly (Hill, Thomas & Allen 2000; Humphrey 1995).

4.4.2 *Regression Methods*

According to Pressman (Pressman 2005), many formal estimation methods are derived by regression analysis of data from past projects; it can be explained generally with the following formula:

$$E = A + B * (e)\text{^} C$$

Here, the variable E represents the effort, A, B and C are constants derived from the historical data through the regression analysis, and e is the estimation variable, e.g. LOC or FP. Many methods can, after calculation of E, adjust it to fit project characteristics, such as complexity and staff experience.

One disadvantage is that regression analyses are sensitive to extreme values (Humphrey 1995). Further, these estimation methods are based on limited empirical data and are therefore only useful for similar projects and development environments. In addition to this, regression methods need to be calibrated to fit local needs (Pressman 2005).

4.4.3 *Case based reasoning (CBR)*

To use case based reasoning, or *estimation by analogies*, when estimating involve prediction by finding similar cases, or projects, to compare with (MacDonell & Shepperd 2003). The similarity with each project is evaluated by looking at several features, e.g. the number of interfaces, the development method, the application domain, the size of the functional requirement specification and the programming language (MacDonell & Shepperd 2003; Shepperd & Schofield 1997; Kadoka, Cartwright & Shepperd 2001). When having found similar projects with known effort values, these can be used to derive an effort estimate for the present project (MacDonell & Shepperd 2003).

Case based reasoning has the advantage that it can be used in circumstances where more formal methods can not be used, e.g. at a very early stage of a project (Shepperd & Schofield 1997). Case based reasoning is also more robust than regression methods when it comes to extreme values (MacDonell & Shepperd (2003); Kadoka, Cartwright & Shepperd 2001). A disadvantage is that it is difficult to collect historical data and to identify which features to choose for the comparison (Kadoka, Cartwright & Shepperd 2001).

4.4.4 *Expert based estimation*

Expert based estimation refers to the consideration of experts' opinions (Hill, Thomas & Allen 2000). The estimation is performed by one or several persons, who are experts in some meaning, e.g. have domain knowledge or experience of similar development (Hill, Thomas & Allen 2000; Jorgensen 2004a; PMI 2001). Using their experience, the estimators assess the effort needed for the work unaided, i.e. using gut feeling, or by more structured approaches with defined processes and supporting historical data (Jorgensen 2004a, 2004c).

An advantage with expert based estimation is the fact that the method is applicable early, i.e. in the beginning of the development process when the requirements are vague (Hill, Thomas & Allen 2000). It is also more flexible when it comes to the input required and the time spent working on the estimates (Jorgensen 2004c). Some difficulties affecting the quality of the estimates are the distinction between real experience and the expert's subjective view and the expert's ability to remember everything relevant from earlier projects (Hill, Thomas & Allen 2000). Lack of visibility and repeatability are two other drawbacks (Gray, MacDonell & Shepperd 1999).

Expert based estimation is subjective, but all estimation methods are subjective in some aspect, e.g. when determining inputs to a method (Hill, Thomas & Allen 2000; Gray, MacDonell & Shepperd 1999). Formal methods are typically less flexible and more complex than expert based estimation and formal methods need to be calibrated with historical data to fit circumstances in the organization (Jorgensen 20005; Fairley 2002). A major advantage with expert based estimation is that it does not require historical data (Hill, Thomas & Allen 2000; Höst & Wohlin 1998).

Expert based estimation is the most common estimation method used today and research has found no evidence for formal methods being superior to expert based estimation (Jorgensen 20005; Passing & Shepperd 2003; Gray, MacDonell & Shepperd 1999; Molokken-Ostvold & Jorgensen 2004b, 2005; Jorgensen 2004a, 2004c; Molokken & Jorgensen 2003).

> *"Select simple methods unless substantial evidence exists that complexity helps |…| One of the most enduring and useful conclusions from research on forecasting are that simple methods are generally as accurate as complex methods." - Armstrong*
>
> (Jorgensen 2004a)

A further study of expert based estimation is depicted last in this section.

4.5 Combination of Methods

Some literature recommends using more than one estimation method, at least two, with complementary strengths and weaknesses (Jorgensen 2005; Stutzke 1996). Their estimates can be combined simply by calculating the average or by weighting the estimates, but since it is hard to determine the weights the average is recommended as

the most robust approach (Jorgensen 2005). MacDonell and Shepperd (MacDonell & Shepperd 2003) advice organizations to first investigate if there is a superior estimation method that can be used and otherwise use a set of different estimation methods.

4.6 ABB Specific Methods

To clarify the estimation situation at ABB, we describe the ABB gate model, which all projects within ABB are supposed to follow, and the project planning course given by ABB Corporate Research.

4.6.1 *The ABB Gate Model*

The ABB Gate Model is used to make projects' progress visible in the organization. The model is divided into three different layers intended to be used at different organization levels. Among other things, the model increases project control and improves the communication within and between projects.

The model defines eight gates, from G0 to G7 which are spread over a projects lifecycle (see Figure 5), and four employee roles with specific purposes.

Gate	Gate name	Purpose
G0	Start Project	To start the project with budget and allocated resources
G1	Start Planning	To allow detailed planning to start due to stable requirements
G2	Start Execution	To get commitment from all project stakeholders
G3	Confirm Execution	To confirm that all known technical risks are resolved
G4	Start Introduction	To allow market activities to start as well as piloting
G5	Release Product/Solution	To release the project results to the market/organization
G6	Close Project	To do a follow-up on the project and close it
G7	Follow-up on Project Results	To evaluate the product/solution

Figure 5: Gate names and corresponding purpose.

A gate is a business decision based on e.g. project benefits, status and risks, where the possible result is either continuation, with or without changes, or termination of project. The roles hold a meeting where the decision is to be made after presentation of the different roles' meeting preparations. To make a well-founded decision at G2, the requirements should be estimated and a realistic project plan created (ABB 2003).

4.6.2 *Project planning basics (PPB)*

ABB Project Planning Basics Course (PPB) is a two-day-course which includes the most important parts of project planning, e.g. risk analyzing, estimating, scheduling, and budgeting. From now on when we refer to PPB in this thesis, we refer to the estimation part of PPB.

The course uses the term *Planning Package* for all deliverables that should be estimated. The input to a group estimation session should be the Work Breakdown Structure (WBS), Planning Package Descriptions, experienced personnel, and earlier estimates, if available. Updated Planning Package Descriptions, including size, effort, duration and other cost elements, is the output from the estimation.

The course recommends using the *Probability Method*:

1. Estimate the minimum size (min) of the Planning Package and use the lowest value anyone in the group comes up with.
2. Estimate the maximum size (max) of the Planning Package and use the highest value anyone comes up with.
3. Estimate the most likely (mostLikely) value of the Planning Package and reach an agreement on it by discussion.
4. Calculate the average size as follows:

$$average = \frac{min + 3mostLikely + max}{5}$$

Estimation of effort:

1. Multiply the size by a productivity factor to get the effort in man hours.
2. Agree on duration (lead time) for the Planning Package.
3. Add calculated values and motivation for these to the Planning Package Description.

The added information in the Planning Package Descriptions are used in coming project planning steps e.g. for making the budget (SECRC 2005).

4.7 Expert Based Estimation in Depth

As previously stated, expert based estimation refers to the consideration of experts' opinions. The estimation is performed by one or several persons, who are experts in some meaning. They should have domain knowledge or experience of similar development (Hill, Thomas & Allen 2000; Jorgensen 2004a; PMI 2001).

4.7.1 *How to estimate?*

The project content, or scope, must be understood before estimation can be performed (Pressman 2005). The estimation starts with a description and decomposition of the project scope into smaller work packages, i.e. a WBS, then one or several experts estimate the time needed for each work package to be developed by using their experience. Jorgensen (Jorgensen 2005) thinks that one should estimate as late as possible because the estimation requires much information; the more information at hand, the more accurate estimates may be produced. Early, rough estimates may have an anchoring effect on subsequent estimates, preventing estimators to make a correct judgment when more information becomes available (Jorgensen 2005). Before a final estimate is made, project complexity and risks should be reviewed (PMI 2001; Pressman 2005).

The estimation process can generally take two approaches: bottom-up, where activities described in a WBS are estimated and summarized, and top-down, where the project is compared with similar projects and estimated as a whole (Jorgensen 2004a). Jorgensen recommends the use of both, but independently of each other to avoid anchoring effects. He also found that the bottom-up approach should be used if the estimators do not have experience of, or access to, very similar projects (Jorgensen 2004a, 2004c).

The estimation can be carried out individually by one or several experts or in estimation groups in several different ways (PMI 2001). To increase the accuracy, estimates coming from several experts with different knowledge and backgrounds should be combined and there are various possibilities for this combination. One is that several experts meet and agree to a common estimate. Another approach is that the project

manager combines the individuals' estimates by taking the average or weighting them according to the experts' level of competence, but since it is hard to determine which expert gives the best estimate, the average is recommended. Using the average of several experts' estimates increases the accuracy in the final estimate (Jorgensen 2004a, 2005; Höst & Wohlin 1998).

4.7.2 *Who should produce the estimates?*

The more development experience, the greater probability for accurate estimates (Taff, Borchering & Hudgins 1991). Project Management Institute (PMI 2001) recommends that the person, or group of persons that are most familiar with what to develop, should estimate or at least approve the estimates. Taff, Borchering, and Hudgins (Taff, Borchering & Hudgins 1991) recommend that the estimators, when using several, should have different backgrounds and experiences.

Jorgensen (Jorgensen 2005) points out that expertise in knowing how to develop something is not the same thing as expertise in knowing how much it will cost or knowing the uncertainty in the effort estimate. He thinks that one should interpret estimation expertise as experience from very similar projects, not from general software projects. He also found that there was no connection between knowing how to develop and knowing how much effort is needed (Jorgensen 2004a, 2004c).

An organization has two alternatives; either people who are likely to be a part of the project estimate, or the organization can have estimation groups who only estimate and do not participate in the development. People in such groups may have fewer tendencies to be influenced by personal or political issues; however, such groups can be difficult to organize (Molokken-Ostvold & Jorgensen 2004b). There is higher uncertainty and higher over-optimism in an estimate when the producer is not involved in the project (Jorgensen & Molokken-Ostvold 2004a).

If persons who are likely to participate in the development estimate, the following advantages are reached (Molokken-Ostvold & Jorgensen 2004b; Fairley 2002):

- The work to be estimated can be clarified; requirements, assumptions, and misinterpretations can be discussed.
- The group will feel ownership of and commitment to the project.

One disadvantage with not having independent estimators is that persons with high interest in the project, e.g. project managers, may provide unrealistic estimates in order to get their project approved (Molokken-Ostvold & Jorgensen 2004b).

4.7.3 *Group estimation*

Molokken-Ostvold and Jorgensen (Molokken-Ostvold & Jorgensen 2004b) state that using humans when estimating makes the estimation subjective and the estimates are affected by the persons' biases. Generally, people are biased towards over-optimism. To reduce these biases, Molokken-Ostvold and Jorgensen suggest estimating in groups, which they through their study found to produce less optimistic estimates than the individuals alone.

A major problem when estimating is forgotten project activities to include in an estimate (Fairley 2002; Molokken-Ostvold & Jorgensen 2004b). It is believed that estimating in groups should decrease this problem since more people should remember more things and also find better similarities with previous projects (Passing & Shepperd 2003; Molokken-Ostvold & Jorgensen 2004b; Jorgensen 2004c).

A groups' jointly produced estimate is close to or better than the best individual estimate (Taff, Borchering & Hudgins 1991). Molokken-Ostvold and Jorgensen (Molokken-Ostvold & Jorgensen 2004b) even found that the group estimate is better than taking the average of the individuals' estimates and consider a possible reason for this being the discovery that an unstructured group discussion around the estimates, leads to more things remembered. Group estimation results in discovery of problems, increased confidence in the estimates, and higher and more general acceptance associated with them (Taff, Borchering & Hudgins 1991). Passing and Shepperd (Passing & Shepperd 2003) agrees with this and chose to describe group discussions as an "effective support for human estimators". They also mean that it leads to production of new knowledge and improvement of estimation accuracy.

Molokken-Ostvold and Jorgensen (Molokken-Ostvold & Jorgensen 2004b) also brings forth other valuable group aspects such as motivation and information sharing and suggest that these aspects may have lost research focus due to the skepticism towards effort estimation in groups. There are two terms rising from group estimation, whose effects are stated by some researches to be negative for the estimation: *group polarization* and *choice shift*. Group polarization is referring to the individual shift in opinion between before and after the group discussion. Choice shift is the difference between the group result and the average of the individuals' judgments. Molokken-Ostvold and Jorgensen consider the skepticism, but dismiss it as possibly arising from misinterpretation of other research areas like psychology.

Structured versus unstructured groups

When working in groups there are a lot of different approaches (Lennéer Axelson & Thylefors 2005), from groups without any structure to highly structured groups. The Delphi technique is a structured approach to make group discussions more effective. There is no face-to-face contact, but anonymous interaction in several iterations leaded by a moderator (Molokken-Ostvold & Jorgensen 2004b). Turoff (Turoff 1971) explains that the Delphi technique provides a meaningful group communication structure by saving time and providing means for anonymity and feedback. He also states that the goal of Delphi is not to reach group consensus but to discover differences of opinion within the group. This non-consensus goal is also stated by Rowe, Wright and McColl (Rowe, Wright & McColl 2005), who add that Delphi reduces the pressure on humans to adapt to the majority; however, they did notice that the minority decision is drawn towards the majority decision even though the majority is wrong.

A variation of Delphi is the less structured Wideband Delphi; a mixture of Delphi and unstructured groups. The main difference is that the persons involved meet face-to-face to solve the task (Molokken-Ostvold & Jorgensen 2004b). In Delphi-like groups, accuracy increases when the participants receive some kind of feedback, statistics or motivations, between iterations (Rowe, Wright & McColl 2005).

Molokken-Ostvold and Jorgensen (Molokken-Ostvold & Jorgensen 2004b) believe that unstructured groups can be used to reduce individuals' optimism. They found individual estimates to be, on average, less optimistic after group discussion with other experts than before group discussion. The suggested reason for this reduction of optimism is that participants may have been influenced by arguments and additional information presented during the group discussion.

4.7.4 *Checklists*

A checklist is a reminder of important activities and aspects not to forget when estimating and can be a valuable support since experts easily forget activities which results in too low estimates and underestimation of the required effort for unexpected

events. Checklists may even bring a novice up to an expert's level. Humans are inconsistent, they give different output for the same input and checklists may increase the consistency. A potential by-product is that checklists can be a way to include and pass on estimation experience (Passing & Shepperd 2003; Taff, Borchering & Hudgins 1991; Jorgensen 2004a).

4.7.5 *Soft factors*

Chroust (Chroust 2002) explains that a significant part of why it is difficult to introduce changes depends on soft factors. A person's impression of a change influences the result more than e.g. how the quality or the work time is affected by the change. The problems are related to social and emotional issues and there are many aspects of how developers perceive the introduction of changes. One aspect is that much of their experience and know-how becomes out-of-date leading to loss of knowledge advantage and possible "guru"-status.

When estimating the experts are influenced by political pressure and they also tend to be over-optimistic when predicting own performance; mixing wishful thinking with realism (Molokken-Ostvold & Jorgensen 2004b; Jorgensen 2004a). However, the over-optimism in some estimates does not necessarily need to be over-optimism, but instead management's pressure on the estimators to lower estimates which may have been realistic (Molokken & Jorgensen 2003).

Anchor values, e.g. early indications on the required effort or initial values outspoken in a discussion, strongly affect the effort estimates. This implies that the rough estimates produced early may strongly affect the more detailed estimates (Jorgensen & Sjoberg 2001). There are also indications on that experts' judgment is strongly impacted by irrelevant information even when the estimators know the information is irrelevant (Jorgensen 2004a).

Estimators may decrease or increase estimates to satisfy personal goals, such as wanting or not wanting to include a certain part in the product (Taff, Borchering & Hudgins 1991). Also, different company roles can have different goals when estimating (Molokken-Ostvold & Jorgensen 2005). There are short-term goals, e.g. getting a business contract or showing personal competence by giving a lower estimate, and long-term goals, e.g. producing accurate estimates to be sure there is enough time for high quality development. When the feedback on estimation accuracy is limited, the short-term goals tend to be dominant.

Accusations for inaccurate estimates should be avoided together with increase or decrease of estimates due to pressure from management or customers (Lederer & Prasad 1995). Estimators sometimes worry about making commitments when providing estimates, but it is managers who give commitments when required, not developers (Taff, Borchering & Hudgins 1991). Separation of estimates and commitments is recommended since estimates often are overruled by commitments obligated by outside forces (Fairley 2002).

Another factor contributing negatively is Parkinson's Law (Jorgensen & Sjoberg 2001):

> *"Work expands so as to fill the time available for its completion"*
> (Parkinson 1958)

People adjust their level of effort to complete a task so that the task is completed when required, not earlier. Also, project environment stress not being late, but it does not promote delivering early. Early finishes are often punished instead of rewarded; the

estimate was apparently too high and future estimates might be decreased (USCRC 2005).

4.7.6 *Uncertainty assessment*

Different estimates result in different projects; high priority on cost together with incomplete requirements leads to adjustment of the work to fit optimistic estimates while high priority on quality together with complete requirements leads to overruns when estimates are too optimistic (Jorgensen & Sjoberg 2001). Over-optimistic estimation, i.e. underestimation, happens all too often and it occurs when the requirements are unclear, or the task is complex or large (Hill, Thomas & Allen 2000; Jorgensen 2005; Molokken-Ostvold & Jorgensen 2004b).

One should always state motivations for an estimate together with the confidence level, assumptions made and affecting risks (Jorgensen 2005; PMI 2001; Stutzke 1996). To facilitate the documentation, standardized templates should be used (Fairley 2002). It is important to distinguish between certainty and precision; a decimal number resulting from mathematical calculations may give the impression of a high certainty (Jorgensen 2005; Fairley 2002).

Using intervals

An estimate is always the *probable* value of the required effort; the uncertainty of an estimate should be indicated with a range of possible values, i.e. an interval (Jorgensen 2004a; PMI 2001; Höst & Wohlin 1998). Intervals may be produced through estimation of the minimum and the maximum value of the required effort so that they correspond to an interval with e.g. 90% probability that the actual value is captured (Jorgensen 2004a).

Jorgensen (Jorgensen 2004b) explains that how the task of assessing the effort uncertainty is formulated, has a strong impact. In his study, he found that since a wide estimate interval implies higher uncertainty, estimators tend to produce very narrow intervals in order to seem competent. It was also revealed that managers do evaluate these estimators as more skilled. The traditional framing, i.e. asking for an interval with 90% probability to include the actual effort, leads to over-optimism and too narrow intervals (Jorgensen, Teigen & Molokken 2004; Jorgensen 2004a, 2004b). Other explanations for this tendency may be poor statistical knowledge, conflicting underlying estimation goals, overestimation of own skill, and anchoring effect from the most likely value on the minimum and maximum values (Jorgensen 2004a).

Better is to ask for the probability of the actual effort value being more or less than some given values. An alternative is to use the minimum and maximum values given by applying rules-of-thumb, e.g. 50% and 200%, on the estimated most likely effort. This framing leads to greater realism since the estimator does not have to produce the interval, only state the uncertainty in it (Jorgensen, Teigen & Molokken 2004; Jorgensen 2004a, 2004b). Also, as it is difficult to imagine percentages, i.e. to separate between e.g. 70% and 90%, rules-of-thumb may be very useful (Jorgensen, Teigen & Molokken 2004).

When judging estimates, it is important to note that high confidence is not equal to high expertise and, generally, people tend to be highly over-confident (Jorgensen, Teigen & Molokken 2004; Rowe, Wright & McColl 2005). The level of confidence stated often reflects the time spent working on the estimate, not the actual confidence (Jorgensen 2004a). In a study by Jorgensen, Teigen and Molokken (Jorgensen, Teigen & Molokken 2004) they found that when estimators say they are 90% confident, their estimate interval included only 60% of the actual effort values. Project managers

reward over-confidence by estimators, since narrow intervals make their planning easier (Jorgensen, Teigen & Molokken 2004).

Calculations to Assess the Uncertainty

From the shortest time (min), the most likely time (modal), and the longest time (max) an approximated mean time can be calculated by the following formula, when assuming an approximated beta distribution:

$$mean = \frac{min + 4 * modal + max}{6}$$

A beta distribution can be left skewed, right skewed or symmetric. In the symmetric case, almost all of the probability distribution will be within three standard deviations (s) from the mean leading to that one-sixth of the range of the interval is a reasonable approximation for the standard deviation (David 1998a, 1998b), i.e.:

$$s = \frac{max - min}{6}$$

The above approximation formulas are empirically derived, not theoretically. There is no theoretical argument supporting the weight of 4 instead of 3 or 5 in the mean formula (David 1998b).

The project manager should add time to the mean value to get a planned estimate. How much time that needs to be added, depends on project risks and how confident the project manager wants to be (Jorgensen & Sjoberg 2001). For symmetrical bell shaped distributions one can say that 70% of the probability distribution will be within one standard deviation, 95% within two and approximately 99% within three (Ruckman 2002).

4.7.7 *Follow-up*

Generally, estimators tend to explain accurate estimates by factors they can control and factors related to experience or skill, while inaccurate estimates are explained by external factors such as changes in scope (Jorgensen, Teigen & Molokken 2004; Jorgensen & Molokken-Ostvold 2004a). It is easy to blame external factors if no follow-up is performed or if it takes a long time before it is performed (Jorgensen, Teigen & Molokken 2004). When no feedback is received, people tend to produce over-confident intervals and the short-term goals win over the long-term goals (Jorgensen, Teigen & Molokken 2004; Molokken-Ostvold & Jorgensen 2005). For project management, it is valuable to know about any systematic biasing effects and the direction and magnitude of them, since the effects in that case can be counteracted and adjusted for. If project management knows which modules are usually misestimated, they can easier judge the risks and take appropriate measures, such as extending the project's contingency buffer (Gray, MacDonell & Shepperd 1999).

To improve the estimation accuracy, projects need to be followed-up so that estimation accuracy can be evaluated and estimation feedback, such as how accurate the estimates were and why they were not more accurate, can be provided to the estimators (Jorgensen 2004a; Molokken-Ostvold & Jorgensen 2005). Such historical information should later be used when estimating to apply a more analytical approach and to reduce the influence of human and situational biases (Jorgensen 2004a; PMI 2001; Pressman 2005).

Section 5

Current Practice

This section describes the estimation practices at the four studied ABB organizations, here called A, B, C and D. The information was gathered through the interviews with mostly project managers at different levels. Also, the estimation practice at an external company is described.

5.1 Estimation Context

The projects' structure and type of work are presented together with project organization and project priorities. The objective is to present the estimation context since it may affect the estimation practice.

5.1.1 *Project structure*

The organizations run larger projects divided into smaller sub-projects which are distributed between different development sections depending on the subject area. The larger projects involve around 70-100 persons and the smaller sub-projects around 10-30 persons. Project managers exist at different levels, where the sub-project managers are more involved in the detailed estimation and planning. Generally, the projects run for half a year up to one year and are carried out roughly in three phases: planning, implementation and completion. Usually, the development teams are not defined until the implementation phase.

5.1.2 *Type of work*

The development is mainly adding functionality to, or improving, a mature and well-known base product. In other words, the foundation for the development is well-known, and the work to be performed can be either well-known or completely unknown.

The projects' similarity with earlier projects varies. Some projects are similar both in size and content, others are similar in size, but not in content, and others are

completely different. For example, the projects at organization C are quite different, while at organization A, the projects are similar to each other both in content and size. Also, within the same organization the projects differ a lot; one of the interviewees from organization D participate in projects which are similar to each other, while another interviewee from the same organization judges projects to be completely different. In other words, the extent to which projects are similar varies both between and within the organizations.

5.1.3 *Project priorities*

Directives from management affect the projects. If a project is running late, management has to prioritize project aspects to be able to meet the plan. In general, project cost is not as important as other aspects. In most cases, the time of delivery is most important, but sometimes other aspects, such as quality or functionality, are also very important. To be able to deliver a delayed project at the predefined deadline, the organizations usually reduce the functionality, add more resources to the project or work as much overtime as possible. It may be difficult to cut in project scope, and to add extra resources is not possible when all resources already are busy. The project teams receive assignments and resources and have to do the best they can with that.

The time plan is an instrument used to control the work, but often the project does not turn out the way one had planned. One of the interviewees explains the hassle of making an accurate time plan:

> *"En plan är inaktuell dagen efter att den är klar."*
> *("A plan is out of date the day after it has been finished.")*

When a project is running late at organization A, and the delay is large they have to move the deadline. Sometimes they use two deadlines, one real and one known as "late delivery". Functionality, on which other projects are dependent, has to be finished at the real deadline and other functionality can come in later.

One project manager at organization B explains that the deadline is a requirement like all other requirements; they are only wishes and can be discussed. They receive a deadline and plan the project on the basis of that. If the plan becomes too expensive to fulfill, they discuss the possibility of developing during a longer period of time. The project team can be pressured to finish within the planned time; it depends on the steering-group for the project. He means that it is a question of management maturity. The estimation conditions have been changed during the last years. Earlier, the time of delivery was very important, which lead to much overtime. After that, people had a tendency to overestimate to reduce the risk for having to work overtime. Today, the deadline still is important, but not as much as before.

5.2 Estimation Practice

How the organizations are carrying out the estimation today is described; how they plan the projects, who is estimating, how they produce the estimates and any strategies for estimation improvement.

5.2.1 *Planning procedure*

Effort estimates are needed early because they are used when planning. Generally, due to the limited information available in the early project stages, a rough estimation is done first leading to a rough plan. One of the interviewees says that the estimates are more like wishes of the amount of effort needed, than realistic expectations. As more information becomes available, the estimates and plans are refined and become more detailed. The planning process is iterative for a period of time.

Typically, the project managers on the different organizational levels are responsible for the planning associated with their level. They generally estimate and plan together with experienced developers. The main project manager is responsible for the overall planning of the whole project.

The market aspects are mostly managed by a product office or product management. They estimate roughly and determine a set of requirements suitable for the current market and hand this set over to the project management to investigate more carefully. Project management estimates and matches the requirements with available resources and thereafter produces a plan to meet the deadline established by product management. Sometimes the rough estimates are simply adjusted when estimating in more detail. A project manager explains how they try to adjust the rough estimates which are fairly accurate, even though they can be quite wrong too. Discussions are held with different people when trying to find out how much work the scope will require.

Sometimes, on the basis of the investigation and the produced estimates, either some areas are removed from the project scope or the possibility of moving project deadline is discussed in a negotiation process between project and product management. One of the interviewees explains it as a battle between the product management and the project manager.

5.2.2 *Who is estimating*

In general, there are no formal requirements on the estimators. It is implicitly understood that it should be persons who give accurate estimates and have knowledge about what to be estimated. It usually results in persons with different knowledge and experiences, but that is nothing the organizations think of specifically. Some of the interviewees say that they use available developers; others say that they use seniors but also less experienced, however, they have to be acquainted with what to develop otherwise they can not contribute. The majority of the respondents say the organizations use the same people for the rough and detailed estimation, but it is not an issue the interviewees have reflected on.

One of the interviewees explains that one problem is that very experienced persons usually estimate, but the same people do not always develop. Another says that they usually estimate with a very experienced person in mind. A third interviewee says that they estimate for a medium experienced person.

5.2.3 *Producing estimates*

None of the organizations use any special estimation process, except for some parts of the organizations that more or less follow the recommendations in PPB. As with the project plan, they first produce rough estimates and later more detailed estimates. There is some uncertainty regarding whether or not the estimators have knowledge about or access to earlier estimates. Some of the interviewees do not know, and others say that they use the same people for all estimation.

None of the interviewees report using the size factor in the estimation. A few says that some estimators may be using size indirectly when estimating, but not explicitly, even though PPB, which they should follow, recommends it. One of the interviewees says he does not believe that they think in terms of size and complexity, at least they do not have any templates for it.

At organization B, when they have received a common understanding about the project scope and the requirements definitions, they break down the functionality in more

detail. They hold several breakdown workshops to define activities, e.g. design, code and test activities, and estimate the effort needed for them. Using their experience they estimate in groups with support of a modified version of the Wideband Delphi technique. They estimate individually once, instead of three times, and for larger tasks than Delphi recommends since they have so many activities, around 1000. If there are great differences among the estimates they discuss the difference. They use the lowest minimum effort estimate, the highest maximum, and the most likely effort estimated by the developer if that person is present. The project manager is often the moderator during these group meetings and is also documenting.

At organization D, they perform the feasibility study on the function level and the result is used when producing the rough estimates. Sometimes estimating is easy because they know approximately what to implement. They use their experience which gives them an effort value. This value is multiplied with *pi* (π) to make room for tests etc. The person estimating has to go around and ask people to get estimates. No method exists for reviewing estimates from earlier projects other than consulting your own memory. The detailed estimation is more of an adjustment of the earlier rough estimates than making new estimates.

One of the project managers at organization A explains that they hold a project planning workshop where they follow PPB, but they also work before and after this workshop. It is often an iterative process, since the requirements may not be fully understood. Although the requirements should be understood at that point in time, they work iteratively quite a long time afterwards.

In projects at organization C, the project teams often have much experience in their field so they can classify functions according to types to make the estimation easier. They explicitly take the complexity factor into consideration when estimating but not size. A developer says that the project managers distribute the functions and then he is expected to comment on the completed time plan. The earlier you are involved the more you can influence, but it is mostly comments to completed proposals and the managers do not always listen. The management has produced rules-of-thumb for the distribution of time for activities associated to one project part, e.g. design, documentation, programming, and test. The distribution is presented in terms of percentages of the total time for that project part. However, the respondent thinks that the time for documentation is too long and the time for testing is too short.

Since estimates are developed based on experience, no supporting tools are used when estimating, except possibly Excel.

5.2.4 *Uncertainty*

Most of the interviewees explain that they assess the uncertainty of the estimates indirectly through the use of minimum-maximum intervals. The uncertainty is acknowledged by adding buffer time corresponding to the width of the interval to the project plan.

At organization B, they use a slightly different strategy. When estimating they use statistical theories and assume that the estimates follow a normal distribution. Afterwards they add one or more standard deviations to reach a final estimate with higher confidence. The estimated most likely value is given to the developer and the remaining time in the final estimate is added to the buffer.

5.2.5 *Historical data*

In general, there are no historical data to be used during the estimation. Most of the interviewees do not know of any historical data, possibly there is some kind of historical information in old project reports. However, documentation has not been prioritized and the respondents do not think that people look at the data afterwards. A project manager at organization D explains that the type of documentation produced consists of conclusions drawn in general project team meetings on why projects were late. At organization B they have collected data from one project, which they sometimes use for support in the estimation by comparing if the estimates produced are reasonable. But the data is difficult to use because they change a great deal in the process between projects.

Some of the interviewees have the opinion that they should have access to some kind of data to support the estimation. They also believe that the gathering of historical data needs to be improved, but think it may be difficult to document well. One of the interviewees says it is possible if the management prioritizes the collection and use of it. Some of the interviewees think that spending time to save data relevant for a historical database might feel justified, if it does not cost them too much. Reporting is not popular among the developers; they only want to develop software, and the project managers' main focus is the amount of time left in the project.

Almost all of the interviewees, those at organization D being the exception, report that they can not really follow up the projects since they are writing their work time on whole projects and not project parts; it becomes impossible to compare and draw conclusions. Also, these time reports can not be used to build a historical database for the same reason. At organization D they write their time on different project activities, e.g. development, test, project management, and bug-fixing, but they still do not use this time data for follow-up or when estimating.

5.2.6 *Estimation follow-up*

The estimated effort values are not followed up during the projects to evaluate their accuracy. Though, in general, continuous follow-ups of the amount of time left in a project are conducted on a weekly basis according to some of the interviewees, and more sporadically according to other interviewees. These follow-ups are performed by reviewing the current amount of time put into the project and thereby evaluating how much time there is left. However, as one of the interviewees says, not all people do it even though they should.

When a developer begins a new task, or realizes that the current task will take longer time than estimated, he or she reviews the estimate for that task. This kind of re-estimation is done individually by the developer who simply adjusts the estimate if necessary. No other method exists.

After project ending there is no follow-up of the accuracy of estimates either. One project manager explains that they perform a general follow-up of projects by evaluating what went well and what needs to be improved. They also compare the total actual project time with the estimates' total, but he judges this comparison not to be very good since they do not consider the changes to the original requirements that have been done. Another manager says that although they are following the ABB Gate model, which states that a follow-up should be done after project closing, they do not conduct one. After project closing, at G5 (see 4.6.1), nothing happens because another project has already started. There is no time for follow-ups. One manager adds that this lack of follow-up is why he has no idea of how accurate the estimates are.

5.2.7 *Education and training*

The current estimation education is depicted. Also, the interviewees' opinions about what is needed in the future are presented.

Current education and training

In general, the employees have not received much estimation education. Everyone in development projects at organization A has attended PPB and one of the project managers emphasizes that they *should* be using PPB-techniques when estimating. At organization B, some have attended PPB but they still use their own estimation method. They have run a compressed version of PPB where they went through the most important material, but it mostly concerned planning. A project manager at organization C says that some persons, including him, have been educated in project planning by external consultants. Another manager has attended the PPB course, but says that everybody has not done that. Some has attended it, while others have not had the time yet. At organization D the employees receive no training.

One of the project managers at organization B says that they do not teach estimation, but he himself teaches the people who are going to estimate with him. He thinks that it is enough if they know how to perform the estimation, while the theory behind is not necessary to have knowledge about.

Future education and training

One interviewee says that the kind of project planning that the PPB course recommends has been enforced by project management. Management has chosen that way of work and believes in it, but he thinks that more practice is needed if they are going to follow PPB. Another interviewee thinks that PPB is enough for project members, but for project managers a course dealing with estimation in more detail is needed. One interviewee thinks that if you are about to introduce some new estimation method, more education and motivation is needed for experienced estimators. They think it is important that persons with experience in the processes are involved and can help them during the days when they plan the projects.

The interviewees agree to some extent that workshops are appropriate for teaching new work procedures, but it is not enough. The principal point is to introduce new work procedures practically; otherwise it is difficult to learn. Larger changes demand workshops with practical examples and time for the participants to try themselves. Some of the interviewees suggest education distributed in time, since you need time to practice and reflect upon the new things, e.g. through exercises in-between the occasions.

One of the interviewees means that there has to be key persons to lead the way, and entice the other persons into education and seminars. The change will then come by itself. It would be good if some experienced person from outside can come into the project team and help practically, or if someone in the group can learn and then teach the others.

Another interviewee thinks that everybody has to improve their estimating. They probably need to be educated in estimating, but there are probably not so many tools for such things. It may be more about experience, to have made something similar earlier. He could accept introduction of new estimation theories if they are effective, however, he believes they may be too general.

One respondent would appreciate new work procedures which do not require any education. When it comes to the daily way of work, one should understand the new

procedure after a two-hour-presentation. Other things might demand more education, e.g. if you are about to change the requirement specification to something else. He thinks it is difficult to decide which way of education is better because all education steals time from other things. Another interviewee points out that if they receive any education material to read, there is no time to read it on working hours.

5.3 Time Aspects

There are some time aspects concerning the estimation practice. The amount of time needed for estimation is depicted together with the interviewees' associated opinions. Also, their views on the available work time and time for reporting are described.

5.3.1 *Time for estimation*

The time frame for the estimation is different between the organizations; anything from a few days up to two months is possible. They also associate estimation with different activities. At organization A, it is a matter of one or a couple of days to plan and estimate, partly depending on how well the participants have prepared themselves. At organization B, the process of decomposing the project into activities and producing the effort estimates requires around two weeks.

However, at organization C the planning and estimating lasts for two months and at organization D, it takes one month for the team members to familiarize themselves with the project and produce estimates.

Some of the interviewees think they could use more time when estimating and planning, that it is stressful today. One interviewee says that if one evaluates the result, they could spend more time on the estimation in order to produce more accurate estimates.

One respondent means that after they have decomposed the work and identified activities, the estimation can be performed quite easily. The estimates will not automatically become more accurate by simply spending more time on the estimation; the benefit is perhaps that you recognize activities you otherwise would have missed. For one person it may take one day to go through and estimate all activities, but if more people are involved, more time is needed. It is up to each project team to allocate time needed to manage the estimating and planning. If you do not produce a good plan it is easy to blame it on too little time for planning.

According to a developer at organization C, the time frame usually is reasonable and he says that the first mistake one can make is to not specify the requirements in a clear way. The time needed for the estimation can range from a couple of hours to several days, depending on how well he knows the function to be estimated. Both project managers within the same organization think they ought to spend more time on exploration of the requirements and the initial estimation; the better you understand the requirements, the easier the implementation phase can be carried out.

One of the interviewees thinks that the time required for the estimation is reasonable, but it is a lot of time and it is taken from other work. They would like to discard functionality early so that they do not have to spend unnecessary time on exploring and estimating parts that later will be removed from the agenda. The product management could perhaps do a better job by giving them less functionality to begin with. He says that less time spent on the exploration and estimation might be desirable, but it would not be a good idea because they still want to produce high-quality requirement specifications.

5.3.2 *Available work time*

Most interviewees explain that they estimate in man weeks, which corresponds to one week of full time work for one person. They define a man week to be around 32 hours and not 40 due to multitasking and other factors. One of the interviewees says that the number of hours often is lower; for experienced people it can even be as low as 25 hours. Another interviewee is not convinced that this is the best way of thinking because if you plan for 32 hours, other managers can insist on using one of your resources the “extra and free” eight hours. He claims this happens every week.

At organization D they say that a man week equals 40 hours. However, one of the project managers has introduced that every person is 80% effective except for key persons who may be only 60% effective, since they have other obligations such as taking care of external resources.

One man week equals 40 hours at organization B, and when estimating they ask themselves; “how long does it take if one can work 100% and without disturbances?” After that they plan on the basis of 32-hour weeks, but one project manager does not think that people are disturbed that much; in reality they may work 38 hours at least. He thinks that extra time disappears if people feel they have time left, e.g. people may take extra long breaks. In the ongoing project they have a different technique; they plan on the basis that people work 100% and then add time buffers at regular intervals for correction.

At organization C they define a man week as 40 hours and they make plans accordingly but with only one task at the time to reduce multitasking.

5.3.3 *Time for work time reporting*

One project manager says that he would like to report work time on different project parts. The possibility exists in their current time reporting system and they have tried to report work time on different functionality. However, the user interface became very complicated and due to this the time reporting took too much time. Today they report on whole projects instead. They have also tried to use Excel, but two parallel time reporting systems are not appreciated. Another manager explains that they use an administrative system to report their time identifying the projects, in which it would be possible to report time in more detail. Management has not supported the idea of a more detailed reporting because they think it will be too complicated, and the project managers refuse to have two time reporting systems.

Another interviewee says that he would like a tool that does not require a course to learn, that is easy to use. To report time today is difficult and takes too much time. He writes down his time every day in an own Excel sheet, and then transfer this to the real reporting system once per month.

5.4 Factors Affecting the Estimate Accuracy

According to one project manager an estimate is accurate when the actual effort is within 10% of the estimated effort. When the estimates are accurate it is generally because they use the same people in project after project, i.e. the estimators have experience of similar projects.

Another manager says that an accurate estimate means passing G4 on time. The early estimates which are produced at G1 may vary from 50% to 100% and he thinks that this is a good judgment. He believes that the estimates produced today are accurate. However, he also says that the projects always exceed their budgets.

Other reasons given for accurate estimates are: participation of many experienced people in the project and few recently employed, the project manager is experienced, they are building on an existing product, and the feasibility studies and requirement specifications are well done. A project manager says that all estimators in his projects have had a good understanding and have appreciated his interest in estimation.

One of the interviewees gives an example of accurate and inaccurate estimates:

> *The estimates for the recent sub-project turned out to be accurate due to the fact that the estimating project members had been working in the same area before and they have a well defined development process. However, the estimates for the whole project were a disaster because other sub-projects were not completed when they were supposed to. Their sub-project was supposed to finish last, but was completed first, which lead to that they had to go back and spend a lot of time adjusting for changes in other sub-projects. Inaccurate estimates arise from lack of acknowledgment of dependencies between sub-projects or lack of attention paid to project risks.*

When the project time plan fails, the common belief is that not enough time was spent on making good judgments when planning, that it was due to unexpected difficulties in the project, or that someone made a mistake. Other possible reasons given are: poorly performed preparatory work, pressure from management affecting the plan in different ways, and underestimation of the complexity. One project manager explains that you have to accept that you can produce inaccurate estimates.

5.5 Political Factors

Political factors such as trust, pressure and over- and underestimation, which may influence the estimation, are described.

5.5.1 *Trust in estimates*

In general, the interviewees trust the produced estimates and also believe that other people trust the estimates. However, some of the project managers report being aware of the fact that estimators may under- or overestimate and the managers deal with this in different ways. Some talk to the estimators and ask for motivations for unusual high or low estimates, and then accepts the estimates. Others know the estimators well enough to be able to tell who is optimistic and who is pessimistic and therefore simply adjust the estimates accordingly. Some rely on that too high and too low estimates will even out in the end.

The given reasons for the trust in the estimates are that several persons acquainted with what to develop have been involved in the estimation and sometimes even management. Also, they claim that their organizations have a good organization culture which includes trust.

One project manager says that he trusts the produced effort estimates, but knows they can differ with around ± 20% from the actual effort values. He guesses that his manager has opinions about the estimates, but tries not to think about it, because in the long run he is the one who has to take the consequences for inaccurate estimates. Another project manager says that management sometimes questions the estimates and that he has to defend them, but points out that it is one of his tasks as project manager.

5.5.2 *Pressure*

Everyone knows about the fact that management wants everything to take as short time as possible and that political factors to adjust the estimates in some direction do exist. Though, it is up to oneself to communicate why the estimates look the way they do, and what happens if they are decreased, e.g. that by decreasing project buffers the insecurity will increase. A project manager says that if he agrees to something, he has to fulfill it later. The pressure affects people differently. You have to be firm and determined; otherwise you do not get the resources you want.

An interviewee at organization A says that the final project plan, before G2, should be inspected and accepted by the people who are going to follow it, i.e. the project team. This *should* be done, but is not always the case. One difficulty can be that it often is a senior developer who has estimated and when a junior developer then is to comment the estimate, it can be difficult for that person to contradict the more experienced person. He also says that sometimes, management has decided that something should be a part of the project and forces it into the project plan without any estimation or re-planning.

A developer at organization C thinks that his superiors do have opinions about the size of his estimates because the deadline is the most important factor. If he presents a larger estimate than expected, the related functionality will not be included in the product.

One respondent at organization B does not believe that estimators feel a pressure to deliver low estimates since they do not strive for low estimates. Low estimates imply that the project plan will not hold and when he thinks that an estimate is too low, the estimator has to explain the reason for it being low.

A project manager at organization C says that because of the working climate, no one thanks you if your project develops according to the plan; it is more rewarding if you present an over-optimistic plan which later fails, than to be realistic and produce a plan that does not fail. The project manager is concerned about this.

Another project manager says that since there is a deadline to meet one does not always have the possibility to add margins to the estimates. One of the interviewees explains that they estimate by making

> *“erfarenhetsmässiga bedömningar kryddade med managements förväntningar”*
> *(“experience based judgments flavored with management’s expectations”).*

Sometimes they know that the estimates are not realistic and will not be met, but have to use them anyway and later the plan indeed fails.

5.5.3 *Over- and underestimation*

None of the interviewees evaluate estimators’ development skill based on the estimates they provide, i.e. they do not consider a developer giving lower estimates to be more competent. However, they have different opinions of whether or not other people do it.

The project managers at organization A have various opinions about whether the developers think about political factors when estimating or not. One manager does not believe the developers think about such factors and he neither believes that they underestimate to be considered more competent; since they estimate in groups, such

estimates should disappear anyway. Another manager believes that both over- and underestimation exist in his development section. He himself thinks that people generally underestimate and he is absolutely sure that there exist political factors which influence people to estimate in one or the other direction. His opinion is that one should overestimate rather than underestimate. Project delays are not good since it affects many other development sections due to the numerous dependencies between them. The third manager at organization A also believes that political factors exist. He admits that he himself overestimates the effort for requirements that he feels are unnecessary to develop. Or, if he wants to implement a certain requirement he can give a lower estimate for it. He does not think about lowering his estimates to be considered as more competent, or that other people do that. The fear may exist among some people, but he does not think that it should be like that. He does know that some are afraid that the estimates they give are turned into commitments and that they *have* to meet them. He tries to counteract such tendencies.

At organization C, the interviewees think that political factors exist which affect the estimators to modify the estimates in some direction. They think one can either underestimate to be considered more competent or overestimate to be sure to be able to deliver on time. One of the managers even says that a large portion of the estimation is to be familiar with the estimating persons and to know if they overestimate or underestimate. Another interviewee says that he knows that if he overestimates a feature, that feature will not be included in the project scope, and if he really wants to develop another feature he underestimates. He thinks that most people overestimate, but it depends on the person. Some people may be afraid of having to work overtime and therefore add time to the estimates.

5.6 Estimation Conclusions

How the estimation works today and future improvement prerequisites are described. Advantages and difficulties with the current practice are depicted together with improvement suggestions and the respondents' opinions of the estimation accuracy.

5.6.1 *Advantages*

One interviewee at organization B says that the project scope breakdown into small activities gives them fast feedback if they have estimated correct or not. The group estimation where everybody estimates independent of each other is a good way to acknowledge everyone's opinion, to reduce the risk that people affect each other, and to reduce the risk of seniors with their higher status getting more weight to their estimates. If taking the most likely value from the developer, when that person is participating in the estimation, that estimate becomes something of a commitment.

Other advantages are received when letting the developers estimate the parts they are going to implement, because then they know how to focus the breakdown. One of the respondents at organization A also believes that estimation in groups leads to consideration of more opinions.

5.6.2 *Difficulties*

One difficulty is that the requirement specification may be incomplete when the project begins. Also, new requirements are hard to handle if the project does not receive more time or resources. Another difficulty is to get time for estimation, as it is difficult to get time for documentation.

One project manager explains that it is easier to estimate smaller parts but at the same time it is difficult to break down the requirements. With too large parts, they underestimate. They need routines for the breakdown.

One of the interviewees explains that it is complicated to use the size and complexity factors when estimating because the group needs to have the same starting point to be able to discuss these factors; what a large or complex activity really implies is very individual. He claims that often the estimation is not the hard part, but the identification of what to do. They also forget things to consider when estimating.

5.6.3 *Improvement suggestions*

The interviewees have some improvement suggestions regarding the estimation. One interviewee says they want to increase the predictability for knowing when projects will finish, and this means a clearer process is needed together with more training. Another interviewee feels that it might be a good idea to know how the estimation really works, and what an estimate should include, e.g. testing and technical documentation.

One thought at organization A is that it often takes equally long time to produce e.g. a project specification or quality plan, independent on the type of project. An idea is to use this knowledge by having rules-of-thumb when estimating such parts. It is also desirable to have the opportunity to see motivations for the estimates and to have at least some key person that has knowledge in estimation techniques. Another reflection is that the estimation could be improved with the use of historical data; the estimation could take less time. One manager says that they need better means if they are to have historical data documented.

One interviewee feels that it would be good to have more support from templates when estimating, today it is completely up to the project manager. Another interviewee thinks that they should use checklists when estimating to remember all parts to be estimated. A third interviewee has noticed that he always ends up with quite a lot of paper on the side of the project; this is a thing that could be improved. For example, he keeps the estimates to his current project on several places.

5.6.4 *Estimation accuracy*

To sum up the estimation situation at organization A, one manager's opinion is that the estimation works fairly well today, but they receive a too large scope of requirements from the product management which results in unnecessary work since the scope usually is cut by half. The main reasons for project delays are that resources are working on other projects or that they are busy with support errands when they should work on the project in question. Developers often work on two or three projects simultaneously. Another manager says that you only need to look at his current project to realize that they have to improve their estimation practice; they are extremely late, over 1000 hours. This is partly because resources have been working with support but that is not all; the estimates *have* been wrong as well. Finally, another manager at the same organization thinks that they may need a better technique for estimation, since the estimation does not work satisfyingly well today. Generally, they need to improve their estimation. They are late at some deliveries but have not learned from that, i.e. they have not investigated why they were late. They are quite good at estimating and planning but do not manage to include all circumstances. If the plan is kept, they ask themselves if the quality of the delivered product was good enough.

At organization B, the interviewees agree on that they generally produce accurate estimates. However, one manager has experienced that people may have had critical knowledge, but not said anything until too late.

Although one interviewee at organization C says that the estimates in the current project feel generally accurate, two of the interviewees are agreed on that their

estimation skills need to be improved. One respondent says that the estimates feel quite bad and that one should be able to produce better estimates. A possible reason for the estimates being unsatisfactory is that they might not be familiar enough with the functionality and tools. Today, it works out in the end because some parts take longer time and some shorter. If an estimate is accurate it is due to a great deal of luck.

Due to earlier complaints at organization D, they have placed demands on the product office to give them clearer requirements. It has improved, but to what extent is difficult to say. One manager says that in one part of the project the estimates produced by the associated key person usually are accurate, but in another project part the estimates produced by the key person are too optimistic. The project got delayed a lot in the beginning because of quality issues and that the two key persons were absent at the same time.

5.7 External Organization

Prevas is an IT company with head office in Västerås. They describe themselves as:

> *"Prevas, the fixed-price IT project expert, is a project-oriented, hi-tech IT company. Prevas offers consultancy services, products and customer support to organizations developing products with a large IT component or needing to streamline or automate their production and operations. Delivery reliability, quality and fixed price are characteristic of Prevas' solutions."*
> *(Prevas 2005)*

Prevas carry out both running and fixed-price projects but we have focused on the latter. A general picture of the company and their attitudes is given. Also, their estimation practice, facilitating factors and difficulties they recognize are presented.

5.7.1 *Project structure*

Projects appropriate for the fixed-price strategy are well specified projects which Prevas has full control over. Also, the technology is often well known and the assignment fully understood. The interviewee says that compared to projects at ABB, the projects at Prevas are small and short in duration. They estimate in man weeks which equals 40 hours from a cost perspective, but they know that people are not always 100% available.

5.7.2 *Estimation practice*

At the offer stage they estimate the projects roughly and in later stages the estimates become more detailed. They conduct a feasibility study in which technical persons estimate the work to be performed. The project inherits the rough effort estimates.

One person, or two if it is a large project, breaks down the work and estimates in more detail. They try to generalize the project parts to fit one of the categories: simple, medium, and complicated, and then use standard times when estimating the effort. They estimate the minimum, maximum and most likely amount of time needed for each part. They indicate the risk for overrun for each estimate as low, medium or high and based on this they categorize the project as a low, medium or high risk project.

5.7.3 *Estimation attitude*

The interviewee does not think that estimators are considered to be more competent when providing lower effort estimates, but he knows that salespersons and engineers have different goals when estimating.

Prevas has defined a good estimate as one that meets the project budget. This means that as long as the actual effort is smaller or equal to the estimated effort, the estimate was good. However, as soon as the actual effort exceeds the estimated, the estimate was not good enough.

5.7.4 *Facilitating factors*

The feasibility study is important when defining the project and getting customer commitment. They review the effort estimates carefully since the estimates lay the foundation for the offer. They are also very clear with the customers' expectations on Prevas as a supplier, it is absolutely necessary that they know exactly what to develop and also when and how changes in the project are to be treated.

They separate the commercial budget and the project budget, where the commercial budget addresses the customer and the business, and the project budget relates to the project locally. Any positive or negative additions to the commercial budget do not impact the project budget since the project budget should reflect realism; thereby the additions neither affect the effort estimates. Additions may be increases in the customer price to make a profit, or decreases to get an important contract. Also, they have to make additions for the risk they take by offering a fixed-price deal. The respondent thinks that they are clearer with these kinds of matters and have more sense of money than larger organizations, such as ABB.

They report time on activities instead of the whole project, which means that the project managers can follow up the estimates. To be able to compare, they use some standard activities together with project specific activities. The interviewee says that they perform follow-up on how the project went, but that it could be improved. They use and measure three key values: delivery reliability, guarantee work, and an overall grade on how good they performed. The results indicate that over 90% of the fix-priced projects are delivered on time, the amount of guarantee work is around 2% of, and their overall grade of performance is eight on a ten graded scale.

The interviewee recommends the use of checklists in the estimation work. Checklists can be used at different stages, e.g. when bidding, planning, and closing projects. He thinks that it is very important to have clear project endings; they use a checklist in the end that is more extensive than the one in the beginning of projects. One reason is that they want to be able to update a project after closure independent of the involved persons, i.e. using the same developers should not be a requirement since they can be busy with other projects.

5.7.5 *Difficulties*

At Prevas they save the effort estimates and the actual effort values, but it is difficult to compare these in the end due to changes in the project scope. Also, the activities they report their work time on are too rough for them to be able to follow up satisfyingly.

Section 6

Analysis and Discussion

We analyze and discuss the current estimation practice at the ABB organizations. We draw parallels between the current practice and related work, highlight problem areas and discuss possible solutions. The result is twelve measures for how to improve the estimation.

6.1 Discussion of Current Practice

This part aims to present the authors' general picture of the estimation situation at ABB. By discussing the current estimation practice, prerequisites and needs are identified.

6.1.1 *General picture*

None of the organizations seem to have a clearly stated estimation method to be used. This neglect has more or less resulted in an estimation practice where everyone estimates to the best of their ability, and gut-feeling appear to be the most common approach. Gut-feeling may not be the best foundation for estimates and to improve the estimation somewhat, they try to get more opinions by either estimating in small groups or by asking other people for advice.

The persons selected to estimate are the persons who are available, even though the interviewees claim it should be people who produce accurate estimates. Often it is the same people estimating the rough and the detailed estimates. Generally, they do not seem to have given this issue much thought.

6.1.2 *Management*

Since there is no estimation method required, the project manager plays a big role in the estimation. The manager's estimation knowledge, demands on the project team, way of handling the negotiation with management, trust in the estimates and attitude

towards the estimation highly affect the project team's estimation practice and performance. If the project manager for example thinks that follow-ups are not that important, it is not very likely that the project team will conduct follow-ups on their own or carefully prepare input to any follow-up. Also, as some interviewees have mentioned, we believe it is the project manager's responsibility to defend the estimates when negotiating with management. He or she has to be prepared for a discussion and bring motivations for the estimates in order to convince management. If having estimated in a more structured manner, one has a more stable foundation for defending the estimates.

With today's practice, many project managers report the need of knowing if the estimators are pessimistic or optimistic, i.e. are over- or underestimating, to be able to adjust the estimates accordingly. This seems to be a very unstable and ineffective way of producing accurate estimates.

One project manager said he is only interested in how much time is left in the project, not how much time has been spent. This could imply a too strong focus on project deadline in addition with management not being enough interested in improving the estimation and learning from experience. By evaluating the amount of time spent in a project, it may be possible to make decisions about forthcoming re-estimations; knowing that one project part has overrun its estimate may provide useful information about the estimates of other project parts. Management may not prioritize estimation efforts due to insufficient knowledge about the effects.

6.1.3 *Follow-up and education*

According to our definition of follow-up, which is in accordance with research's, i.e. to evaluate estimates' accuracy and associated reasons, none of the organizations conduct follow-ups of estimates, neither continuously nor at the end of projects. However, this is not surprising if our suspicion that management does not prioritize estimation is correct.

Some of the interviewees mean their project teams do perform follow-ups. Nevertheless, they are only comparing the total actual effort with the total estimated effort, probably due to their time reporting system in which they only report time on the whole project, and not on project parts or activities. This comparison is probably very misleading since, at the end of a project, the estimated total effort usually does not reflect the final project scope. During project development more information becomes available and changes are made. These changes need to be well documented to enable follow-up in the end. Also, the time plan needs to be revised and in order to this, re-estimation is needed. Re-estimation means estimation all over again with inclusion of the extra information, not only adjusting the original estimates. The organizations have nothing stated about how to handle new information, changes and re-estimation. Sometimes changes and new information are not handled at all. The re-estimation that is performed today is simply an adjustment of the old estimate, often done by the developer before starting to work with the corresponding task.

When following up in the end of a project, all information documented needs to be considered, not only the original effort estimate and the actual effort. One needs to explore occurrences during the project that made the original estimate, at G2 (see 4.6.1), differ from the actual. This knowledge helps improving the estimation and planning of the next project.

Historical data is data from previous projects collected and saved for some purpose, e.g. in to improve the estimation which this thesis focuses on. To be of any use, we

claim the data moreover has to be easy to extract, preferably from some logically designed database with search capabilities. Since the purpose is to use the data over time to improve the estimation, it also has to be easy to expand and improve the database. With this classification, we have the opinion that historical data does not exist within ABB (we do not count the data at organization B or the information existing in old project reports). For the same reasons as it is difficult for the organizations to perform follow-up today, it is hard to draw conclusions and to build a historical database. Organization B which comes closest to an attempt of establishing a historical database does not use the data when estimating. Another reason given for not having a database is that project documentation has not been prioritized. The work with historical data can not begin until activities such as documentation, re-estimation and follow-up are prioritized.

It is possible that increasing estimation knowledge can solve these problems, i.e. by introducing more education, both for project teams and management. Today the interviewees feel they do not receive enough education; some of them do not even remember what was said during the PPB course. However, it is inevitable that the time reporting system has to be altered.

The lack of follow-up means it is not possible for the interviewees to have any opinion about whether the estimates are accurate or not. They should only be able to tell when the total project estimate was inaccurate, i.e. when the plan or budget is overrun. Nonetheless, some of the project managers believe their project teams produce rather accurate estimates. This makes us consider the possibility of them referring to the most recent estimates, which recently have been adjusted to fit the plan. However, we are more interested in producing accurate and reliable estimates during the project planning before G2, i.e. where the information available is not comprehensive but estimates still are very important.

In addition to not having the prerequisites for follow-ups, the interviewees also report not receiving enough time from management for conducting follow-ups and that project closings due to this are not performed as well a they should. One can always discuss if this is true or if the project manager are not demanding more time. In either way, it is something which has to be improved if management wants more accurate estimates to be able to produce more reliable plans and budgets.

6.1.4 *Attitudes and political pressure*

We believe the attitudes and political pressure within the organisation have large influence on the estimates. The estimation attitudes are visible in the reasons given for accurate and inaccurate estimates. The respondents tend to credit the project team when estimates are accurate and point out external factors and misfortune with an attitude of indifference when estimates are inaccurate.

It appeared that when the estimates are inaccurate it also depends on pressure from management affecting the estimators in different ways; they may produce accurate estimates to begin with, but management pressure makes estimators lower the estimates unrealistically. One manager also says that one has to accept that inaccurate estimates may be produced. We agree on that one has to accept it, however, it must not be a reason to let go of estimation control, believing that you can not produce accurate estimates. Instead, let it be a reason to assess the uncertainty of the estimates, leading to knowledge in advance of which estimates have high uncertainty.

The interviewees have the opinion that the estimation works just fine, but on what basis do they claim that? What are the criteria for accurate estimates? An explanation given

is that estimates are accurate when the project is not delayed too much, i.e. not as delayed as last time when the project was extremely delayed. Another explanation given is that they at least have implemented all important requirements. We do not think these are appropriate explanations; if they had estimated and planned to implement a set of requirements, but only implemented the most important ones, their estimation and planning did not work fine since they could not fulfil the plan.

What does a good or a bad estimate mean? Does the definition differ from accurate and inaccurate estimates? Is a good estimate obtained when several estimators spent enough time on the estimation, when one has estimated in an excellent manner or when the project manager is satisfied? It is important to be clear and agree on what a good or accurate estimate means, and what a bad and inaccurate estimate means. One of the interviewees says that an accurate estimate means passing G4 on time. We do not agree since, to be able to pass G4 on time they might be forced to remove planned functionality due to e.g. inaccurate estimates. To be able to state that the estimates are accurate, one needs to compare them carefully with the actual effort values together with any influence from events during the development. We think that the only aspects of interest are whether the estimate was accurate or not, how accurate it was and why it was not more accurate. Therefore we suggest that good estimates are the same as accurate estimates.

We believe that the failure of project plans is so commonly accepted within ABB organizations, that it is considered enough if the most important requirements have been implemented. Also, they seem to be satisfied as long as the current project is not as delayed as the previous project. We strongly recommend that estimation follow-ups are performed and focus given to the accuracy of the estimates and reasons for why they were not more accurate; otherwise one can not learn and improve. Because there are no demands on the project teams to evaluate why the estimates were inaccurate or how inaccurate they were, the estimators know their performance is not going to be evaluated: they do not have to spend time producing qualitative estimates. Further reasons for the belief that the estimation works fine may be lack of knowledge of better estimation approaches and the opinion that it is all about predicting the future which is known to be impossible.

The political pressure is most visible in the constant deadline focus. Generally, the respondents think when projects not being late the estimation worked fine, but say the projects still cost more than expected. According to the respondents this seems to be like it should. The focus on the deadline has appeared to be the superior focus which overrides all other aspects, such as the costs. We suspect this attitude is not long lasting for the organization and therefore the goal of the estimation should be reconsidered and clarified. The prominent focus on deadline, we believe, affects the estimators when estimating. The estimators might feel it is no point in producing qualitative estimates when management has already decided on the project delivery date and expected content of the product. If the estimators' primary goal is not to provide management with accurate estimates, other goals, such as producing not *too* large estimates than management wants, may appear. Management must want realistic estimates and be willing to reduce the scope of functionality if necessary.

Some interviewees say as much as half of the initial functionality received from product management is abandoned after their estimation. If the estimators know half of the functionality will not be included in the product, they might not be motivated to spend time on producing qualitative estimates. They feel it is unnecessary work. Product management therefore should try to reduce the requirement scope as much as possible before handing it to the estimators, to save time and increase the motivation leading to more accurate estimates.

6.1.5 *Comparison with external company*

In our opinion and to our knowledge, the external company Prevas seems to be better at estimating than any of the four ABB organizations. The reason for this is not very surprising since there are a lot of differences between them. Main differences, between Prevas and ABB organizations, affecting the estimation practice are:

- The projects carried out at ABB organizations are larger, i.e. run for longer time and include more team members, than the fixed-price projects at Prevas. Smaller projects should be easier to organize and thereby easier to estimate.
- Prevas only offers fixed-price deals for projects that fulfill a number of conditions, these are: fully understood assignment, well-defined project, and well-known technology. Also, Prevas has full control of the whole project. These conditions are most often not fulfilled in projects at ABB. This difference implies that Prevas should be estimating with requirement specifications of higher quality than those that projects at ABB have to base their estimates on, which lowers the project risks. Furthermore, projects at ABB are often sub-projects to larger projects, and have dependencies to other sub-projects, meaning that one project team does not have full control.
- At Prevas, the project teams report time on different activities instead of on the whole project. They use both standard activities and project specific activities and from the time reports they can follow and have control of the project. After project ending, they produce three key values to measure their success. We believe these measures forces the projects to estimate well in order to receive satisfied customers.

These were the main organizational differences, but there are also differences in the estimation attitude:

- Since projects' profitability is dependent on the estimates, they review the early estimates carefully before leaving an offer to the customer. They separate the project's budget from the commercial budget, to gain realistic project plans and be able to control any profit more directly. This mean the estimators know that the goal of the estimation is accuracy, which we think implies more realistic estimates.
- At Prevas accurate estimates are estimates that make the project meet its budget. They do not use definitions such as "within 20% of the actual effort". Every project budget overrun is considered to be an overrun, no matter of the size. We mean this awareness on project costs is reasonable and the clear distinction of what is expected motivates the estimators to produce more qualitative estimates.
- Prevas applies clear project endings to be able to re-open a project without being dependent on the same project team or specific persons. Clear project endings also involve follow-ups and conclusions. At ABB they seem to rush from one project to another, not prioritizing project endings.

6.1.6 *Conclusion*

All respondents within ABB organizations want to improve today's estimation practice, even those who claim their estimation is rather good. They probably know that their estimation practice is not well-founded enough, but may not see any ways to improve. However, some general suggestions on how to improve have appeared during the interviews, which we have embraced.

During the interviews the respondents only referred to the current project or the project before. This suggests a present time orientation in which the current project has their

focus, and their estimation practice is based on the previous project's estimation practice, i.e. they do not have any general thought-out estimation method. Local conditions and the project manager seem to have high influence.

Our conclusion is that the level of estimation maturity is too low for introducing any advanced estimation method. It is a too large step and the chances are big that the employees would not appreciate and adopt the method. A thought-out, structured, but at the same time uncomplicated estimation method is needed.

6.2 Current Practice and Related work

Our own discussion supported by related work and conclusions drawn from it. This section includes a comparison of the current practice and the related work, as well as a discussion and conclusions.

6.2.1 *General discussion*

We decide to concentrate our work to expert estimation. First of all, the level of estimation maturity at ABB today is too low to introduce an advanced formal method. This low level of maturity seems to origin from too low estimation priority and too little estimation knowledge within the organizations. Second, even though some research argues that expert estimation is non-transparent, inconsistent and uncertain due to the subjectivity involved, it is still the most commonly used estimation method and much research on ways to perform expert estimation in a good and structured manner exist. Third, all methods are subjective in one way or another and there exist no evidence today that formal methods result in more accurate estimates than expert estimation. Fourth, formal methods are less flexible and need to be calibrated with environment specific data. We are looking at four different ABB organizations and therefore need a more general method to suit them all. Finally, historical data does not exist at the organizations and expert estimation does not require it. Due to the low level of estimation maturity, we do not expect any large process change to work, leading to our decision to introduce an estimation improvement process in small steps.

A major difficulty with estimation is that initial estimates are usually needed long before the project scope or even the project team is decided. This means that rough estimates have to be produced early and are thereby based on very loose foundations. These estimates can only be used for what they are intended, i.e. to make very rough decisions about project content, cost and delivery date. When the rough estimates are used as a starting point for later estimates, which is often the case at ABB, it is very likely that the uncertainty associated with the loose foundations will be inherited into the more detailed estimates due to the anchoring effect.

Different estimates result in different projects; too low estimates may either result in project overruns or reduced project scope, and too high estimates may lead to lower productivity or a project scope larger than intended. The more information that is available when estimating, the more accurate estimates may be generated. It is therefore important to define and understand the project scope to reduce project risks. We recommend management to postpone the rough estimation as far as possible and spend the time improving the feasibility studies instead. For the same reason, it is important to produce a high quality requirement specification before using it for the more detailed estimation.

Management has a big impact on the success of projects and we believe that some of the problems above can be reduced if the management's project control is increased and the priorities are stated. Also, management must lead the way in this estimation improvement process.

6.2.2 *Expert estimation*

As stated earlier, estimation deals with predicting the future which, at least the authors of this thesis think, is impossible. This impossible situation still has to be solved and we mean there are no excellent prediction methods, only methods more or less suitable for the situation and ways to get around the drawbacks.

The drawbacks with letting experts estimate are dependent on the fact that humans are subjective and may be biased in their estimation. Furthermore they are inconsistent in that they provide different outputs for the same input and may suffer from memory loss. If the estimation is not well documented, the process is not repeatable and loses transparency. The main advantages of expert estimation are that it is flexible, does not require historical data, and is easy to implement.

One needs to define who should be used as expert, but different opinions exist on this subject. Some research recommends a narrow definition of experts; experts should be people with experience from very similar projects. Other research recommends diversity; using persons with different backgrounds and experience. There may also be a difference between people with knowledge in estimation and knowledge in what to develop. A possible solution to this could be to use people with knowledge in the domain and educate them in estimation, thereby reducing that issue.

Another decision is whether people in the project team or people who are not going to develop should estimate. It is believed that when the development team is used the result will be useful discussions leading to a common understanding of what to develop; misunderstandings can arise and clarifications be made. Also, the team will feel a commitment to the project and be motivated to both estimate and develop well, and as stated above, experience should give more accurate estimates. The disadvantage is that persons with high stakes in the project, i.e. other goals than estimating accurately, can affect the estimates, either directly or by exercising pressure on the project team. The advantage of having outside people estimating is that they have no personal interest in the project and therefore may be more objective. However, this is more difficult to organize due to practical issues and one will not benefit from the possible advantages of using the development team.

Many of the interviewees seem to have the opinion that the estimators have to be familiar with what to develop, or even know how to develop, otherwise they can not contribute. However, due to practical issues, the reality is that most often one has to make use of those employees who are available.

A question we have asked ourselves is: it is possible that estimation success, and the closely related project success, is more dependent on the persons involved than other characteristics? That is, can it be that the estimation practice is less important than choosing people who are positive towards estimation and have a greater understanding for the causes and effects of estimation? Probably this is the case, but we still face the fact that project managers must use people who are available for the estimation, leading to the need for a more structured and thought-out estimation method as support when estimating.

6.2.3 *How to reduce drawbacks*

To make the estimation more repeatable and reduce the risk associated with inconsistent humans who rely on their memory, checklists are a possible tool. According to research, a checklist also reduces the estimation effort and can equal estimation novices with experts. However, a major drawback is that it is not unlikely that usage of a checklist makes the estimators relax and confident on that nothing is

forgotten because they believe the checklist is complete, meaning that they may not think for themselves and creativity may disappear. The checklist has to be created and extended over time using experience from earlier projects. Humans are able to recognize unexpected events or factors that a checklist based on earlier projects can not. This means that a checklist may be dangerous as the only tool when estimating. Nevertheless, an excellent by-product from using checklists is that they include and pass on experience. The solution as we see it is to use checklists, but not directly in the estimation. Instead, they can be used to check the estimates afterwards to ensure no important aspect is forgotten.

Other means to reduce expert estimation drawbacks is to always provide motivations with estimates and furthermore document assumptions and risks. Templates can support the documentation and make it easier, something some of the interviewees also mentioned.

6.2.4 *Estimation prerequisites*

First of all, to provide a more stable and confident base for the estimates, estimation should be done as late as possible to give more time for the feasibility studies and the production of a high qualitative requirement specification. A good understanding of the scope lowers the project risks.

Second, one has to declare the goal of the estimation, since planning, bidding and estimation are often mixed up. When bidding, one has to sell the project, i.e. may have to lower the price (often by lowering the estimates) to get the deal. On the other hand, when planning, one has to add some extra time to the estimates in order to be prepared for unexpected events or estimation errors. The goal of estimation should be nothing but accuracy; afterwards one can use the estimates for different purposes. We believe this separation may be one of the reasons that the estimation at Prevas seems to be more successful than at ABB. Also, according to interviewees some developers are afraid that their estimates are turned into commitments. We agree with research saying an estimate should not be a commitment and therefore recommend clarity in this issue.

As mentioned earlier, the anchoring effect may affect the estimation negatively and rough estimates should thus be separated from detailed. However, sometimes the organizations use the same estimators for both detailed and rough estimation meaning that the estimators have knowledge about the rough estimates when estimating the detailed. This should be avoided, since information influences people even though they know it is irrelevant. If it is practically impossible, the detailed estimation must not be based on the rough estimates.

It is not possible to draw general and truthful conclusions, based on the interviewees, about the type of development performed at the four ABB organizations. The only thing certain is that the projects are at least not *very* similar to each other. This leads us to believe that strategies as top-down will be impossible to use (besides the fact that historical data does not exist) and the only realistic strategy is to estimate using a bottom-up approach, using a WBS as they do today. It is important to separate the WBS work and the estimation, to increase the control of the estimation process, i.e. the WBS work need to be done before estimating.

6.2.5 *Soft factors*

We have defined soft factors as factors not directly related to the estimation but still highly influencing it. Since soft factors not are related to the estimation, these factors

may easily be neglected. One large soft factor is political pressure; another is the consideration of available work time.

Even though the managers we have interviewed have different opinions if political pressure on the estimators exists or not, we believe it does. Political pressure from e.g. management and sales can have different sources and exist in every organization, so even at ABB. Political pressure raised from the same source may have different effects on different roles or different personalities. In the context of estimation, political pressure may result in hidden conflicting goals, e.g. developers might lower their estimates to seem competent or to satisfy the project manager and project managers might increase theirs to be certain to deliver on time or lower them to satisfy management. One solution, among others, to these hidden goals is to follow up the estimates. When follow-ups are conducted, the focus on estimation accuracy is likely to be increased.

Organizational priorities when projects run late are another aspect that results in political pressure on the estimators. If cost is not important, one negative consequence of project overruns is eliminated leading to less focus on accurate estimates. A strong focus on deadline affects in that one strives to fit the estimates to the delivery date; accurate estimates are not the main priority. Interviewees report on occasions when management forces things into a project without any estimation or planning. When something is forced into a project, priorities obviously do not lie on budget or quality.

Depending on the unit used when estimating, a soft factor may be the consideration of expected amount of available work time. If estimation is done directly in man weeks, one has to know the amount of effective work time available in a week. If estimation is done in man hours, it becomes more of a planning and scheduling issue, but it still needs reflection. In either case one has to account for time loss due to interruptions and multitasking. Most interviewees seem to be aware of this work time reduction, but we do not think they really have understood the extent and the reasons. Inspired by Cornelius (Cornelius 2004) we quickly calculated the amount of expected work time available when writing this thesis. We ended up with 32 hours a week and still we have only taken non-work related factors, e.g. minutes before and after breaks, and private phone calls, into account. There should also be time losses due to interruptions. As we got as a result as low as 32 hours when not considering interrupts and this is the least amount any of the organizations use, it leads us to believe that the organizations need more knowledge in this area.

While it is important not to be over-optimistic during estimation in order to meet project plans and budgets, it is also wise not to exaggerate the estimates, by e.g. buffer on every estimate, due to Parkinson's Law which states that the time available will be used and added buffers have no effect. It is better to estimate for accuracy and leave it up to the project manager to add time buffers to the project plan, invisible for the developers.

Another soft factor is the fear associated with introduction of changes. This fear may cause new work processes to be discarded by developers even though they may be superior to the current practice. To handle this we recommend being cautious when trying to improve the estimation practice. Educate the estimators and let them have influence; it is them who are going to do the work. Discuss the way of work and acknowledge any criticism. We believe satisfied employees mean a great deal to the overall improvement work.

6.2.6 *Combination of experts*

Some research suggests estimating by combining techniques with different strengths and weaknesses, e.g. top-down and bottom-up or expert estimation and formal methods. Since the top-down approach is not suitable for the ABB organizations and formal methods are too advanced this type of combination of estimation techniques has not been considered. There is, however, one other form of combination: combination of expert estimators by estimating in group. Group estimation is an estimation technique that combines different experts' backgrounds, knowledge and opinions, some being optimistic and some pessimistic. Estimation in groups has the possibility to reduce biases and hidden goals. It may also help the estimators remember more aspects, create new knowledge within the group, and increase the confidence in the estimates.

When it comes to working in groups, there are many aspects to consider, such as the number of participants, a structured or unstructured approach, need of a group leader, and goal of the work; e.g. if consensus is wanted or not. Research has shown that estimation groups striving for consensus estimates often reach a group estimate that is better than the average of the individual estimators'; it could even result in a better estimate than the best person's estimate since more aspects can be revealed in the group. Other research does not recommend consensus since variations and differences in opinions should be the aim. Also, psychological aspects affect, leading to pressure on humans to conform to the majority and a consensus which is not more than a compromise where the strongest person has influenced the most. We believe that in reality it may take too long to reach consensus on every estimate and more opinions may be acknowledged if the average of the individuals' estimates is used instead.

Some interviewees believe that the estimation only takes more time if many people are involved. This leads us to believe that if they are going to estimate in groups, which we recommend, the groups need some kind of structure as support. Also, they say the amount of time needed depends on how well the involved people have prepared themselves.

To get structure but not consensus, the Delphi technique is an effective tool for group work. However, Delphi is probably too strict to be used in real groups and this is why we shift our focus to a modified Wideband Delphi. This technique probably fits the ABB organizations very well, since it is not very strict but still offers some structure. Also, organization B is already using a modified version of Wideband Delphi. The main benefits of using Delphi-like techniques are that accuracy increases with feedback, the likelihood of people affecting each other is reduced, and assumptions, motivations and misunderstandings are brought up. Also, the anchoring effect is reduced when focusing on clear and objective motivations and the fact that the estimators estimate before hearing any estimate proposal. We believe in giving feedback face-to-face, because of the opportunity to ask resulting questions.

Given the prerequisites at the ABB organizations, we advocate the following:

- The group estimating should consist of the project members, since it increases the involvement and gives the group a common picture of what to develop.
- Individual preparation before the meeting is included in the process to save time.
- We believe the project manager due to his/her role is familiar with leading a group; therefore we suggest the project manager should act as moderator, i.e. coordinate and document the meeting. If he/she documents, it shows the

importance of doing it. In addition, it may be a good idea not to delegate something that is considered to be boring.
- We recommend two iterations since iteration is an effective way of reflecting on the estimates while three, as some literature advocates, is too time-demanding.

6.2.7 *Intervals and uncertainty*

Research suggests estimation to include more than simply giving an estimate; one should also asses the uncertainty in the estimate in order to indicate the risks associated with it. Usually, this uncertainty judgment seems to be made by estimating in intervals, i.e. to estimate the minimum, maximum and most likely effort; if the interval is wide it reflects higher uncertainty. The project planning course PPB recommends this, which has resulted in that some of the interviewees use it too. An alternative to ask the estimators for an interval including the most likely effort is to create an interval from most likely effort based on rules-of-thumb and then ask the estimators for the probability, i.e. a percentage for the actual effort ending up in this interval.

There are at least two drawbacks with these estimation probability assessments. The first is that percentages are difficult to assess, separate and interpret. The second is that research has indicated that estimators tend to be over-confident, i.e. the confidence in the interval does not match the actual rate of estimates ending up within its interval. One reason for this may be that narrow intervals make planning easier for project managers, therefore they tend to reward estimators based on interval width. This implies that there is a reason for the estimator to provide an incorrect, i.e. a too narrow, interval. Another reason for the over-confidence may be that if the most likely value is estimated first, the minimum and maximum values are anchored at the most likely. However, if estimating the minimum and maximum values before the most likely we believe the most likely value will be anchored by the interval, resulting in placement of the most likely near the middle without further consideration.

Most interviewees say they only handle the uncertainty in their estimates indirectly by estimating in intervals and evaluating these intervals. We think this evaluation as the only strategy is probably not very good since the project members have to analyze the intervals every time they look at them, which easily may be forgotten. Also, this handling of uncertainty seems to be implicitly understood, i.e. nothing is stated about it and everyone uses an individual estimation process. One can start off the uncertainty assessment by evaluating the intervals, but one should also state the uncertainty more directly. One example is to state the risk for overrun of the estimate, like Prevas does by categorizing the risk as low, medium or high from the interval. Organization B assesses the uncertainty by calculating an expected value from the interval and with the help of statistics they produce several estimates with different confidence.

We do not think that any of these strategies are good enough due to the stated drawbacks, e.g. the over-confidence issue and the difficulties with percentages. We agree that it is more wisely to use rules-of-thumb when producing intervals than to let the estimators themselves estimate the intervals. We suggest a combination of the strategies; the estimators should work in groups, using our modified Wideband Delphi, to reach a most likely effort value which together with rules-of-thumb gives an interval. One should start with a 50-200% interval, since the most likely effort often is underestimated. Inspired by organization B's estimation practice and supported by statistical theories, we suggest this interval is used to calculate estimates of certain confidences. To assume that the possible actual values follow an approximated beta distribution seems realistic and the errors associated with the approximations made are defended by the fact that these are substantially smaller than the errors built-in in the

estimates. The reason for making several final estimates available is to make clear that management needs to make a choice of how certain the estimates should be.

The most likely value should be given to the developer, since it is the value the group has produced and if more time is given it will probably be used, as discussed earlier. The remaining time in the final estimate is added to the buffer.

A logical detail, which research point out, is that one should avoid expressing estimates or approximated numbers with high precision since it gives an impression of exactness and certainty. We suggest only using whole numbers and not decimal numbers when estimating.

6.2.8 *What the estimates reflect*

It is important to define what the estimates are regarding, e.g. which unit is used, if calendar time or effective time should be considered, what kind of risks, and which activities should be included. If the estimators only estimate the programming activity for a project part, the project manager later needs to add time for the remaining activities related to the project part, such as specification writing, design and test, e.g. by using rules-of-thumb of the kind existing at organization C. Due to the interviews revealing an uncertainty regarding what an estimate reflects, we believe this need to be reflected upon and clearly stated.

Another aspect in need for consideration, which the interviews have indicated, is the productivity factor; different developers work in different rates and this affects the estimates. Also, sometimes it is not yet decided who is going to develop which part, therefore it is important to, before the estimation, define what the estimates should reflect; if the estimators should estimate with a medium or very experienced developer in mind.

6.2.9 *Size*

The larger module to develop, the more time is required. This is the relation between size and time according to research and it should not be very surprising. Some research even claims that the accuracy of the effort estimates is affected by how well the size is estimated and translated into effort. However, research also acknowledges that software sizing is a major challenge and some even claim the judging of size being the real problem. PPB recommends the use of size when estimating, while the interviewees report on difficulties with estimation of size as well as translating the result into effort estimates. It is hard for estimators to agree because they do not have the same frames about e.g. what is small and what is large? When estimating they are probably thinking in terms of size although they claim they are not, but they may not have understood what we mean by size. There are different levels of using size in estimation; counting LOC requires some historical data and a more disciplined estimation method, while mere usage of size as a comparison only demands a common basis for the discussion. One of the interviewees mentions the difficulty of using historical data when conditions have changed; one part that required much time before might not require as much time today due to new development techniques. However, he sees another possible use of the size factor; if part A takes x time and part B is double the size of A, part B should take 2x time.

Some of the interviewees point out that one can not only consider the size factor; the complexity factor is more important. We agree and believe an alternative to size could be estimating the complexity and include the size as a parameter. However, more work is needed in this area.

We have chosen to not recommend using size or complexity explicitly when estimating. We see it as an estimate definition issue and it is up to the estimators to decide on this. Due to the great resistance we have observed in the organizations, we think it is easier for them to start considering size and complexity when having implemented a more structured estimation process.

6.2.10 *Estimation follow-up*

One of the interviewees means that it is more rewarding to produce an over-optimistic plan which later fails than a realistic plan based on higher estimates which indeed is met; they are not rewarded for keeping to the plan. This is not surprising since follow-ups are not conducted, meaning that inaccurate estimates will never be discovered and it is possible to seem competent and please management by providing low estimates. The high acceptance of project overruns augments this tendency.

The fact that requirements may change or be discarded makes it harder to follow up. Estimates reflect the original requirements; if these change, so will the estimates. Also, a small difference between estimated effort and actual effort does not automatically imply that the estimate was accurate; more information is needed to draw a conclusion, e.g. changes and assumptions made. To keep the estimates up to date we recommend re-estimation periodically and when changes to the requirements occur. To be able to re-estimate and track an estimate, careful documentation of every estimate is important. However, we recognize that many of the interviewees report documentation not being very popular among developers. We believe that as they are not used to documenting, it is difficult to know what to write since the motivations are obvious for themselves. To get used to motivating estimates, guidance and clear directions from management are needed, e.g. templates and examples together with education and training.

Most of the interviewees mean they need more education and training, while some of them do not see any use for it, probably because they do not know of any better way to estimate. It may be easy to blame low performance on lack of education, but most of the interviewees do realize they need education and training to be able to improve the estimation process. In addition, they have opinions on how to improve the education, e.g. with more practical exercises both during and in-between training opportunities.

As mentioned, an advantage with expert estimation is that it does not require historical data, but the use of historical data may improve expert estimation in the future. However, due to difficulties such as how to categorize the data and what data to be saved, together with the general lack of time and developers' resistance towards documentation, more work on how to establish an easy-to-use historical database and the inclusion of it in the estimation procedure is needed.

6.2.11 *Management*

As stated earlier, we believe management has a big impact on the success of projects. Research even claims that ineffective project management is the major reason for overruns. Some examples of bad management with respect to estimation and project planning are: demanding accurate estimates without providing time or means for estimation, setting an unrealistic deadline to be met, not controlling that the estimation work is performed in a good manner and not following up the accuracy of the estimates are.

Even though all interviewees think a developer is not evaluated as more skilled when providing lower estimates, research claims that managers do tend to consider them as more competent. In addition to wanting to be considered more competent, there seem

to be other reasons for estimating inaccurately. During the interviews it became clear that an important part of the estimation, for project managers, is to know if estimators are optimistic or pessimistic. Estimators may also purposely over- or underestimate depending on if they want a certain part included in the product or not. Results from the interviews point to that some project managers trust the estimators, while other project managers do not trust them and adjust the estimates. This is of course not good and even becomes dangerous if project managers think that persons overestimate when they are really underestimating or the other way around. The communication is not as good as it should be, however, it is a challenging subject. We recommend project managers to not simply increase or decrease estimates as they sometimes do today.

Since project closure does not seem to be prioritized at ABB today, we recommend that time for project closure should be prioritized. Clear project endings lead to more focus on follow-up and the possibility of later re-opening the project independent of project members.

6.3 Main Problem Areas with Solutions

The analysis and discussion of current practice and related work has resulted in eleven problem areas. Each problem area is presented below together with the solution and a rationale for it. The numbering is not to be confused with priorities; it is solely a way to refer to the problem areas.

1	**Problem:**	The estimates are of varying quality.
	Solution:	Evaluate the current estimation practice and begin an estimation improvement process. Learn from experience from earlier projects.
	Rationale:	Improving the estimation process and taking advantage of experience increase the likelihood of producing accurate estimates. However, introducing changes requires insight in today's practice and its shortages as well as employee attitudes. Small changes can make a big difference; therefore necessary modifications should be introduced in steps.
2	**Problem:**	Lack of structured estimation process; the estimation is mainly based on gut-feeling or guesses.
	Solution:	Apply a structured estimation process.
	Rationale:	Structure may result in a more analytical approach which reduces the guessing.
3	**Problem:**	Management influences the estimation to a large extent.
	Solution:	Increase estimation structure and project control. Be aware of the soft factors and clearly state expectations on the project team.
	Rationale:	Increased structure and control decreases the subjectivity. Awareness of different factors influencing the estimation helps in counteracting them.
4	**Problem:**	Lack of rationale for estimates; it is too easy to increase or decrease the estimates.
	Solution:	Require motivations for every estimate. Document motivations, assumptions, and conditions.
	Rationale:	A motivation requires more effort which may result in more carefully produced estimates. No motivations make the estimate rely on human memory; assumptions made are easily forgotten. Motivations also assist in the negotiation with management.

5	**Problem:**	Neglect of the uncertainty in estimates; no appropriate measures taken.
	Solution:	Formulate the uncertainty in every estimate by using intervals.
	Rationale:	Formulating the uncertainty of estimates makes it possible to take measures, e.g. add associated buffers to the project plan.
6	**Problem:**	Individual biases influence estimates. An important part in the estimation for project managers is to judge estimators and adjust the estimates accordingly.
	Solution:	Combine several estimates and use rules-of-thumb in the estimation.
	Rationale:	When combining estimates, individual biases become reduced. Rules-of-thumb may decrease the effect of soft factors.
7	**Problem:**	Estimation goals other than accuracy are accentuated.
	Solution:	Educate employees in estimation and specify the goal of the estimation. Inform estimators that competence is not evaluated on the basis of estimates produced. Hide management's expectations on the project plan. Follow-up on estimation accuracy.
	Rationale:	Knowledge about different estimation goals and the effects of inaccurate estimates may lead to realistic estimation. If the estimators do not know about what kind of numbers management expects or wants, this pressure is reduced. Short-term goals win over long-term goals if follow-ups are not conducted.
8	**Problem:**	Early, very rough estimates most likely influence detailed estimates.
	Solution:	Do not let the estimators know about the earlier rough estimates.
	Rationale:	If not knowing about earlier estimates one can not get influenced by them.
9	**Problem:**	No control of relation between project progress and project plan. No knowledge about estimation accuracy.
	Solution:	Follow up the projects continuously and after project closing.
	Rationale:	Continuous follow-up increases the control of how the project is going and measures can be taken earlier. Follow-up after project closing may give valuable knowledge about the estimation accuracy.
10	**Problem:**	No consideration of what to include in an estimate.
	Solution:	Define what an estimate should reflect. Use a checklist.
	Rationale:	A common understanding of what kind of estimate is wanted improves the consistency and accuracy. A checklist helps ensuring that no activity which should be included in the estimate or important aspect to be considered is forgotten.

11	**Problem:**	Low estimation priority. Estimation inaccuracy and project overruns are widely accepted.
	Solution:	Define the estimation goal. Prioritize estimation by e.g. setting off time not only for the production of estimates, but also for estimation education and training, feasibility studies, documentation, and project closures.
	Rationale:	Priorities require goals to be met. Estimators need time to produce documentation needed in order to improve the estimation further. If not prioritizing estimation, one can not expect estimation success.

6.4 Resulting Estimation Improvement Measures

From the suggested solutions twelve measures have been derived. These are briefly presented here showing the correspondence with the problem areas described earlier (see Figure 6). The measures are presented in more detail in the next section, Section 7: Estimation improvement measures.

	Problem 1: The estimates are of varying quality	***Problem 2:*** Lack of structured estimation process	***Problem 3:*** Management influences the estimation	***Problem 4:*** Lack of rationale for estimates	***Problem 5:*** Neglect of the uncertainty in estimates	***Problem 6:*** Individual biases influence estimates	***Problem 7:*** Estimation goals other than accuracy	***Problem 8:*** Early estimates influence later	***Problem 9:*** No control of relation between progress and plan	***Problem 10:*** No consideration of what to include in an estimate	***Problem 11:*** Low estimation priority
WHO TO ESTIMATE											
Measure 1: Use experts' judgment	■	■									
Measure 2: Hide previous estimates	■		■					■			
WHAT TO ESTIMATE											
Measure 3: Define the estimates	■									■	
Measure 4: Define the goal of the estimates	■	■	■			■	■	■		■	■
HOW TO ESTIMATE											
Measure 5: Combine opinions structurally	■	■		■		■					
***Measure 6*:** Estimate with intervals	■	■			■						
Measure 7: Use checklists	■	■				■				■	
Measure 8: Document estimates	■	■		■	■	■	■				■
HOW TO INCREASE PROJECT CONTROL											
Measure 9: Follow up the projects	■					■	■		■		■
Measure 10: Learn from experience	■					■					■
Measure 11: Think about the soft factors	■		■			■	■	■			
Measure 12: Improve management's control	■		■			■	■	■	■		■

Figure 6: Correspondence between measures and problem areas.

Section 7

Estimation Improvement Measures

After a thorough investigation the following twelve estimation improvement measures have been derived. These measures address project teams with a project manager leading the way. The twelve measures are organized into the following categories and are described throughout this section.

Who to estimate

Measure 1: Use experts' judgment
Measure 2: Hide previous estimates

What to estimate

Measure 3: Define the estimates
Measure 4: Define the goal of the estimates

How to estimate

Measure 5: Combine opinions structurally
Measure 6: Estimate with intervals
Measure 7: Use checklists
Measure 8: Document estimates

How to increase project control

Measure 9: Follow up the projects
Measure 10: Learn from experience
Measure 11: Think about the soft factors
Measure 12: Improve management's control

7.1 Who to Estimate

It is important to think through and define who should estimate.

Measure 1: Use experts' judgment

Use experts' judgment. Experts are persons who have domain knowledge and some development experience. Through the feasibility study important knowledge is received and should be used.

Measure 2: Hide previous estimates

The estimators should not have knowledge about previous estimates. People are influenced by information even though they know it is irrelevant. Due to this, it is preferable that different people estimate the rough and detailed estimates, and that they do not have access to earlier estimates.

7.2 What to Estimate

It is important to think through and discuss what the estimates are regarding and what the goal of the estimation is.

Measure 3: Define the estimates

State what the estimates are regarding.

- Whether or not size and complexity should be estimated.
- If time is estimated: Which time unit is used, man weeks or hours? Be clear with the difference between calendar time and effective time.
- Which activities should be included in an estimate? Only programming or also detailed design, and unit testing, etc.?
- Which experience level, of the person who is going to develop, should be estimated for?
- Which risks, if any, should be considered in the estimate? None or risks of a certain type? One alternative is to only estimate work visible (afterwards the project manager adds time for risks).

Often the distribution of time of related activities, such as design, programming, and testing, are the same in projects. It is wise to make use of this knowledge by only estimating the time needed for programming a part and from this estimate and with the help of rules-of-thumb derive the time needed for other activities.

Measure 4: Define the goal of the estimates

Separate estimation, planning and bidding processes. Estimation, planning and bidding are easily mixed up, but are indeed separate processes with different goals and therefore must be distinct. Bidding affects the estimating negatively in that it strives to lower the estimates to fit the price or delivery date the customers or sales are looking for. Planning affects the estimates because it involves resource and deadline discussions. The only goals for estimation must be realism and accuracy.

An estimate should be a realistic estimate of how much time is needed for one particular part. This means that it can not be anything other than an estimate, i.e. an approximation. It can not be a commitment due to the associated insecurity.

7.3 How to Estimate

To improve the accuracy of the estimates, it is important to combine opinions structurally, estimate with intervals, use checklists and report the estimates.

Measure 5: Combine opinions structurally

Combine several experts' opinions in semi-structured group meetings. More people remember more things. Diversity is good; people with different knowledge and experience think of different aspects. Preferably the group that is going to develop should meet and estimate, but be aware of the number of people; it is wisely to avoid being too many. If the project members estimate together, it increases the involvement and gives the group a common picture of what they are going to develop. Misunderstandings and unclear things are found early.

It is important to acknowledge that this process does not strive for a consensus. The group estimate should be the average of all estimators' estimates, to reduce biases and over optimism.

Due to group dynamics and to save time, a semi-structured process should be followed. A moderator is needed, e.g. the project manager, who coordinates and documents the estimation meeting.

7.3.1 *Estimation process*

A. The individuals should prepare themselves by e.g. reading the related requirements and reflect upon earlier experience in similar projects.
B. The moderator gathers the group to a meeting and starts with a discussion around what the estimate should reflect (the minimum, maximum or most likely value) and what this means.

   For each work package to be estimated:
   1. The most involved person presents the part to be estimated and the others are given the possibility to ask questions.
   2. Discuss insecurities, misunderstandings and difficulties.
   3. Each person gets time to estimate individually under silence and then writes the estimate on a note.
   4. The moderator gathers the individuals' estimates and presents them anonymously.
   5. A structured dialogue follows where each person in turn has the opportunity to comment, give their assumptions and ask questions around the estimates.
   6. Finally, each person estimates individually once more.
   7. The moderator documents the assumptions and insecurities together with the final individual estimates.

   If more work packages are to be estimated, repeat steps 1 – 7.

C. After the meeting the moderator combines the individual estimates into one final group estimate, per work package, by taking the average of the individual estimates.

Measure 6: Estimate with intervals

Estimates cannot be precise; some uncertainty has to be accepted.

> *"It is the mark of an instructed mind to rest satisfied with the degree of precision that the nature of the subject admits, and not to seek exactness when only an approximation of the truth is possible." - Aristotle*

To take the uncertainty of an estimate into consideration one should estimate an interval, i.e. estimate a minimum and a maximum value in addition to the most likely value. From the interval one can derive an expected value, the standard deviation, and a final estimate with a certain confidence. Also, the interval can be used to determine the size of the related buffer time.

We recommend the use of rules-of-thumb when estimating intervals, e.g. the minimum value as 50% and the maximum value as 200% of the most likely value. These numbers only serve as a starting point, and should later be adjusted to fit the organization.

From the most likely (modal), minimum (min) and maximum (max) values the expected value (E) and standard deviation (s) are derived through the following formulas.

Expected: $$E = \frac{min + 4 * modal + max}{6}$$

Standard deviation: $$s = \frac{max - min}{6}$$

Then one has to decide which confidence is needed, 70% or 95%, to calculate the final estimate using one of the following formulas.

Final estimate: $f = E + s$ *gives a 70% confidence, or*
$f = E + 2s$ *gives a 95% confidence*

Since most likely is the estimated most likely value and due to Parkinson's Law, "work expands so as to fill the time available for its completion", it is wise to plan with the most likely value and add the remaining time, given by the following formula, to the project buffer.

Buffer time: $$b = f - modal$$

After the calculations, be sure the derived numbers are expressed only in integers, i.e. whole numbers without decimal numbers, since it otherwise can be an illusion of security. Subsequently, document the derived numbers.

Measure 7: Use checklists

An excellent way of ensuring that no essential activities are forgotten in the estimation process is to use a checklist. When creating the checklist it is important to consider which activities should be included in an estimate and aspects important to remember. However, it is difficult to create a complete checklist which covers every aspect at once; it needs to be improved over time.

It is dangerous to use the checklist too early in the estimation process, i.e. to *only* rely on the checklist because it can not cover everything that need to be considered. It is important not to use the checklist until in the end of the estimation, as a control of that nothing has been forgotten.

Measure 8: Document estimates

When documenting estimates, a standardized template should be used to facilitate the handling of estimates. Standardized templates make it easier for those who do not like to document. When creating the template, focus should lie on simplicity. It is not only the estimate that needs to be documented; at least assumptions, the confidence level, affecting risks, and involved people in the estimation must also be included.

It is important to motivate the estimates for several reasons. One can not solely trust individual persons' memories when it comes to understanding the estimates. Motivations help when negotiating with management and make sure all conditions and assumptions are available when re-estimating. It will also help the discussion when estimating, resulting in estimates more worked upon. Sometimes estimates may be produced for specific developers and if this is not stated and the developers are changed, no re-estimating will occur and the estimates become invalid.

7.4 How to Increase Project Control

Increasing the project control can be done in many ways, here are some approaches presented. Improvement of project control is an important step towards better estimates.

Measure 9: Follow up the projects

Follow-up of projects facilitate improvement. Follow-up should be performed continuously to increase the control of the project and to re-estimate if necessary, and after project closing to improve the estimation of future projects.

7.4.1 *Follow up continuously*

Continuous follow-up should be performed to keep track of the estimates during the project, preferably on a weekly basis to increase the chance of getting early warnings of potential problems. If any project condition or other assumptions have been changed, re-estimation is necessary. If not re-estimating, one does not have any defense against project overruns. This weekly follow-up also functions as a common status-check of the project as a whole. To be able to follow up on a weekly basis it is important to break down the work carefully, therefore the WBS work is very important.

Time for continuous follow-up has to be prioritized. Every project member should want to know in time if discarding functionality or moving the deadline is necessary.

7.4.2 *Re-estimate*

Re-estimation refers to a process that aims to review the estimates and alter them due to changes in project conditions to receive trust in the plan. Re-estimation could involve an entire new estimation process or merely adjustments of the estimates, partly depending on the possible impact of changes. The most important thing to consider is *why* the conditions were changed. It is absolutely necessary to answer this question to be able to know the impact of the changes. Dependencies could be of major importance to be able to decide the amount of damage.

7.4.3 *Follow up after project closing*

If using historical data is an objective in the organization, follow-ups must be done and the required data stored. But even when historical data is not an objective, follow-ups are still important to be able to learn from experience from earlier projects in order to improve the estimation process. However, to only compare estimated effort with actual is not enough; a small variation does not necessarily mean that the estimate was good. Therefore it is necessary to record the uncertainty of the estimates, motivations, and events during the project and reasons for them to be able to perform a qualitative follow-up after project closing.

If preparations to the follow-up are made as a part of the estimation process, the chance for it being done effectively is increased. Also, it is probably easier preparing when having everything at hand.

Measure 10: Learn from experience

Learning from estimation experience is necessary to improve the estimation. Education in estimation is very important, not only for the one who is responsible for the estimation, or for the estimators, but for all involved persons, e.g. management, since they direct or indirect use and influence the estimates. An understanding for the theories used, statistical expressions and surrounding factors is to prefer. When educating, it is important to let the participants practice with realistic examples.

Measure 11: Think about the soft factors

There are a lot of factors influencing the estimation process indirectly. Here are the most important ones to be aware of.

7.4.4 *Underlying conflicting goals*

Persons with different project roles, e.g. management, salesmen, project managers and developers, may have other goals than accuracy in mind when estimating. These goals may result in too low or too high estimates depending on the goal in focus. It is necessary to be aware of the different goals to be able to counteract them, but despite such awareness one may still be influenced by them.

Apart from different roles having different objectives, there are mainly two types of goals: short-term goals and long-term goals. Short-term goals usually result in over-optimistic estimates and if estimators know that there will not be an evaluation of the estimates in the end, the short-term goals are likely to win over the long-term goals.

A typical short-term goal may for the developer be to indicate competence or to satisfy the project manager by providing lower estimates. Another is for the salesman to get the business contract or for the developer to get the opportunity to develop a specific part and thereby decreasing the corresponding estimate to ensure it is included in the plan. Political pressure highly exists and affects the estimates.

Long-term goals include ensuring that there is enough time for development, prioritizing quality and successful deliveries, or making the organization profitable in the long run.

7.4.5 *Available work time*

Available work time affects estimating, planning and scheduling. According to research, 75% of a work week, or 30 hours a week, is the amount of time available *if not interrupted*. This number is reduced even more if productivity is lower than 100% due to e.g. multitasking or interruptions.

7.4.6 *Reactions to changes*

When introducing changes such as a new work procedure, there are many psychological factors not related to the work procedure affecting the introduction, e.g. different versions of fear. These factors are presented in more detail in the thesis report and should be considered.

Measure 12: Improve management's control

Management control issues, such as project control by comparing estimates and actual performance, and careful examination of the estimates are very important for accurate estimates. Directives from management highly affect the project. It is important that the managers are aware of their powerful influence.

The project manager plays a big role in convincing and negotiating with management or other stakeholders. The project manager also needs to inspire the project members and to be aware of the existing conflicting goals and political pressure as well as working for eliminating these. It is important to prioritize time for estimation and documentation. The project manager's attitude towards the plan, deadline, budget, and quality plays a major part. The project manager needs to respect the developers' opinions; they are the most involved ones and should be worth listening to. It is important not to evaluate the estimators on the basis of the estimates they produce.

Lowering or increasing the estimates should be avoided. The project manager is responsible for the project buffer; he/she can add or remove them leading to an increase or decrease in the security of the plan. He/she should not give away the buffers by giving more time to the developers, since time received tend to be used.

Management expectations affect the estimates. It is important to be clear with the expectations on the project team, e.g. what to deliver and how to handle changes, and also with the project content; the feasibility study and requirement specification are very important. Management should consider postponing estimation until necessary, i.e. prioritize time for the feasibility study and the requirement specification. This will, among others, increase the project understanding, lower the risks of anchoring effect from too rough values and increase the accuracy of the estimates.

Time for project closure should be prioritized. It is important to have clear project endings to be able to follow up carefully and later re-open the project independent of project members.

Section 8

Estimation Improvement Method

A method for how to realize the estimation improvement measures is described. All of the measures are important; however, the authors neither expect nor recommend ABB to implement all concurrently. The reason is that many small but simultaneous changes may result in a larger conversion than ABB is ready for. Therefore, the measures have been developed independently and can be implemented in steps; small changes make a big difference.

8.1 First Step

The first step in the estimation improvement method is to explore the organization's current estimation process for any similarities with the improvement measures. If any measure is almost implemented, begin by implementing that measure completely.

8.2 Following Steps

When the first step in the method has been carried out, choose a suitable number of new measures and implement these. Repeat this procedure until every measure has been implemented. During this process, it is very important to follow up and evaluate every measure to be able to make adjustments if necessary.

8.3 Priority

As the measures are independent of each other, it is possible to implement them in any order. However, to facilitate the estimation improvement process, the measures have been prioritized according to importance and the amount of effort required realizing them (see Figure 7). See also Figure 6 in section 6 for correspondence between the measures and the stated problem areas.

	LITTLE EFFORT	MORE EFFORT
PRIORITY 1	*Measure 1:* Use experts' judgment *Measure 2:* Hide previous estimates *Measure 3:* Define the estimates *Measure 6:* Estimate with intervals *Measure 7:* Use checklists	*Measure 5:* Combine opinions structurally *Measure 8:* Document estimates *Measure 9:* Follow up continuously *Measure 11:*Think about the soft factors
PRIORITY 2	*Measure 4:* Define the goal of the estimates	*Measure 9:* Follow up after project closing *Measure 10:* Learn from experience *Measure 12:* Improve management's control

Figure 7: Priority versus required effort.

Section 9

Pilot

To receive feedback on our work and, especially, on our estimation improvement measures, we conducted a pilot at Corporate Research. The goal was to teach a project team in our estimation measures and then let them estimate their project on their own using these. Due to time limitations, there was no intention to follow up the team's own estimation in the purpose of evaluating estimate accuracy; only to evaluate the experience of performing estimation as we recommend.

The pilot consisted of a workshop to train the project team in some of our estimation improvement measures, followed by launch of the project team's estimation on their own. This section includes a short description of the pilot project, the workshop and an evaluation of the pilot.

9.1 Description of Pilot Project

The pilot project was a project carried out at CR consisting of a project manager, and four developers, two of whom from CR. The project goal was to develop a communication module for enabling remote access to an electric meter. It had an expected duration of a year and was one of the larger projects this team had carried out. The work consisted solely of new development.

When we conducted the pilot, the project was in a second planning stage, meaning they had more specified requirements, a decreased scope and a more detailed design than at the first planning stage. This implied that the team was not estimating from scratch, rather performing re-estimation which is somewhat different.

9.2 Workshop

When introducing a new way of work, education and training is essential. We decided that a workshop was the best approach to train the pilot team, since it is commonly

used and includes opportunities for education, practical exercises with guidance and questions. Out of the twelve estimation measures we chose to use the following five in the workshop:

Who to estimate

Measure 1: Use experts' judgment

What to estimate

Measure 3: Define the estimates

How to estimate

Measure 5: Combine opinions structurally
Measure 6: Estimate with intervals

How to increase project control

Measure 11: Think about the soft factors

The reason for this selection is mainly that number 1 and 3 are easy to start with, nevertheless we expect them to make a significant contribution to the estimation improvement. Measures number 5 and 6 were chosen for providing valuable practical exercise with guidance. Measure number 11 gives important awareness. Of the remaining estimation improvement measures, some are easy to learn without explicit training, while others are difficult to try out directly since they need preparatory work from the organization. Also, by choosing these five measures we included all of the estimation measure categories.

We held the estimation workshop for three hours with the three project members at CR. The workshop opened with a presentation of the five chosen estimation measures and the motivations behind them. The rest of the measures were mentioned briefly and the participants received a document, including all the twelve measures, to read on their own.

To familiarize everyone with the practicalities of our estimation process we introduced a small and really simple exercise from real life. The drawback of using this simple exercise turned out to be that the estimates felt very inaccurate since we had the correct actual value to compare with. However, evaluation by measuring accuracy was not an objective. The benefit was that the exercise was simple enough for the participants to be able to concentrate on the estimation process. Also, even though the resulting estimate was not very accurate, the participants could draw conclusions from the estimation work, e.g.:

- Everyone has to share everything they know to the other estimators, if the estimate is to be as accurate as possible.
- Other people affect your opinion.

Then it was time to launch their project estimation with our measures, which was conducted by letting them estimate some of the deliverables in their WBS by themselves. Since there were only three project members present we let the project manager act both as moderator and estimator, to get a better average, although it may not be optimal for the estimation process. During the process we gave them guidance, observed the group and made useful notes.

The workshop ended with a summary, concluding questions and an evaluation. After the workshop the project team estimated the rest of their WBS by themselves.

9.3 Pilot Evaluation

An evaluation of the workshop, performed by both the pilot team and the authors, together with an evaluation of the pilot project's own estimation work is presented.

9.3.1 *Evaluation of workshop by pilot team*

The evaluation was made first by an open discussion summarizing the workshop, and then by using an individual questionnaire. The result exceeded our expectations. The pilot team reported to be satisfied with the way of estimating and will continue using the estimation process in this project and in future projects. They appreciated using a more structured method and state they are going to think about the affecting soft factors.

As there were only three participants in the workshop, we thought they may assess the estimation process as being too heavy, i.e. including too much overhead, but that was not the case. Instead all of the participants reported positive reception of the more structured way of work since the estimation turned out to be more effective. In the previous estimation session conducted, it had been easy to get stuck in the discussions, which takes unnecessary much time.

They admitted never believing in the minimum and maximum values they used before (by recommendation of PPB), since they felt it was something completely unfounded. Now it is clearer regarding what to estimate.

In validation of this team evaluation, one should remember the special conditions: it was a re-estimation process, with well defined requirements and design, and only three persons estimating who also were interested and open-minded towards new work procedures. They had never estimated projects earlier, so they had only the first project estimation to compare with.

9.3.2 *Evaluation of workshop by authors*

Our observation of the group estimation is that the pilot team easily learned and adopted the ideas and the estimation process. It also gave valuable indicators to clarifications needed in the process.

When the team started off by defining the estimates, it was immediately obvious that the team members had different opinions about certain aspects, e.g. which activities code review and testing included. It required some debates before agreeing but they seemed to really appreciate the definition of what the estimate should reflect. The presentation of each part to be estimated was also rewarding. It resulted in discussions and questions about what that part included, even though they already had a good design of it.

We realized it is possible for the project manager to join the estimation if he/she does not have any motives of his/her own. However, it should be easier to run and coordinate the discussion and concentrate on the documentation, if this is the only focus, especially if the team is larger than three persons.

It was easy for the pilot team to skip the second estimation iteration because they already were somewhat agreed on the effort and no new factors had come up during the discussion. However, it is important to iterate twice to be sure enough reflection is made upon each estimate.

The discussions were valuable since it resulted in assumptions, uncertainties and clarifications; however we noticed it is important to not withhold information during the discussion.

9.3.3 *Evaluation of project estimation*

An evaluation of the project estimation was done by an informal interview with the project manager. He reported that the estimation was more effective than last time. It had gone well since the work breakdown was well done, they had a good design, and a common picture of what to develop; they reached a common understanding quickly.

As we were concerned about the second iteration in the estimation process we wanted to know how they had handled this during the estimation on their own. However, the project manager said they had performed the second iteration for every estimate. Also, he had trust in the estimates

The project manager wants to follow up the estimates, and have therefore asked his developers to record the actual effort values. But he believes this is going to be difficult; to keep track of and record actual values, since there is no tool for it. He admits that it all comes down to being disciplined, which is hard; if nothing is requested, nothing will be done.

Section 10

Threats to Validity

The section includes a discussion regarding different types of threats to validity of our results. The different methods are discussed and analyzed.

We have to establish the fact that the objective summaries of related work and current estimation practice still are subjective in some sense, since the summaries include filtering and choice of information to use.

The interviewees in the ABB organizations were selected for their insight in the estimation practice at ABB; they were not a probability sample. Statistical conclusions can not be based on a selected sample (Robson 2002), however, drawing statistical conclusions was never the goal. The purpose of the interviews was to understand the current estimation situation in order to make suggestions for improvement of it.

The selection of interview targets resulted in one developer and ten managers at different organizational levels, all active in the estimation of their respective projects. This distribution of roles was not an active choice and the risk that project managers present a different picture than developers was considered. It is also possible that the interviewed persons are a finite group of people, more familiar with and have more knowledge about estimation in general, than the typical ABB employee; hence, the estimation in their projects may be superior to other projects an not reflect the true ABB estimation practice. However, based on the provided responses, which imply a lot of shortages in the current estimation process; we still claim ABB is in need of estimation improvements and we expect other projects to have an estimation practice level equal to or lower than the one presented here.

In general, surveys using respondents are affected by the respondents' memory, knowledge, experience, and enthusiasm. Also, respondents might answer in a way to appear better than they actually are (Robson 2002). However, we found several

examples of honesty and reflections in the interviews, which may imply that most information received, is correct and not politically correct.

The interview questions were based on related work, along with our own ideas about possible factors influencing the estimation. Although the questions were formulated in advance and in agreement with interview recommendations (Robson 2002) we did not always ask the questions exactly as they were formulated since we held semi-structured interviews. Also, as we are no professional interviewers we may have affected the interviewees by wording or intonation. Overall, we do not believe these shortages influenced our interpretation of the current estimation practice at ABB.

The summary and analysis of the current practice turned out to be challenging since the interviewees provided answers with varying level of detail. This may depend mainly on two things: first of all, the respondents express their organization and way of work in different terms, and second, the interviewees' backgrounds and impressions of our knowledge in the area may have affected their wording. Another possible reason is language translation; the interviews were conducted in Swedish. However, details were not our focus, but the overall practice and attitudes.

When drawing conclusions that one of the four organizations carries out something in a certain way, it is based on information from the interviews held at that organization, which is answers from two or three persons. No further investigation has been done to verify whether the information is correct or valid for the whole organization. The same reasoning is applied when making statement about ABB in general; these statements are solely based on the interviews conducted at the four organizations.

Robson (Robson 2002) recommends audio taping the interviews to obtain a permanent record and to be able to concentrate on the interview. However, we decided not to. One motive for this is that we wanted an informal atmosphere and we believed that a tape recorder could have hindered that. Another motive is that we had the opportunity to perform the interviews with both authors present; it was possible for one of us to concentrate on interviewing and for the other to record the interview by taking notes. To increase correctness, we chose to send a summary to all the interviewees. This gave them the opportunity to correct statements if necessary, and us confidence in our perception of their estimation practices.

Section 11

Conclusion

Main conclusions drawn from the thesis work are presented in this section. The problem statement for the thesis was:

> *Is there for ABB organizations a suitable method for estimation in project planning, which is superior to the current practice, extendable and easy to adopt?*

This question was answered through the following:

- *Investigation and analysis of the need for improvement and what kind of improvement is suitable.*
  The investigation made it clear that a need for estimation improvement exists, since no thought-out estimation method is used within ABB. The estimation consists mainly of gut-feeling and guessing. Projects cost more than planned and time plans are seldom met. The estimation maturity is low, leading to the conclusion that no complicated or advanced improvements are adequate. Introducing expert group estimation is a suitable part of an estimation improvement, since it is uncomplicated and does not imply a large difference from today. Also, many other aspects exist which can improve the estimation, e.g. reflection of what the goal of the estimation is and what an estimate should reflect.

- *Investigation of the readiness and a proposed method for how to start an estimation improvement process.*
  Due to the general lack of time and the low level of estimation maturity, improvement in small steps is the most suitable approach. Therefore we propose twelve estimation improvement measures together with an improvement method for how to implement them.

- *Increased understanding of surrounding factors and their influence on the estimation.*
  Attitudes, psychological aspects, and political pressure highly exist and influence the estimation negatively, resulting in e.g. a too strong focus on deadline. An increased awareness of these factors together with suggested measures will reduce the impact of them. Also, management needs to increase their control of project performance and re-evaluate some priorities. If giving more priority to feasibility studies, requirement specifications, estimation, documentation and follow-up, this will lead to less project plan and budget overruns.

- *Proposal of further work and future steps to take in the estimation improvement process.*
  Usage of historical data in the estimation may increase the estimation accuracy. However, the establishment of an easy-to-use historical database and an approach for how to use it need to be investigated further. The use of size or complexity when estimating might also be a future improvement step, but more research is needed in the area.

- *A first try-out of the proposed estimation method.*
  A workshop was conducted at Corporate Research, in which a pilot team tested some of the estimation measures. The result exceeded our expectations, which promises well for estimation improvement at ABB.

The thesis work has resulted in a method for estimation, which will improve current practice and is easy to adopt. It also provides a base for future improvements.

Section 12

Future Work

Here are possible next steps and areas which need further investigation described.

One possible further improvement when having realized all of the estimation improvement measures may be introduction of another method with other strengths and weaknesses to complement the suggested estimation improvement method. Though, the possible benefits from such an introduction need to be investigated further, to know if realization of this combination is worth the extra effort required.

Using historical data may assist the estimators to improve the accuracy in their estimates. However, we claim there are some issues to be solved before historical data can be expected to be used successfully. First, the creation and use of historical data requires follow-up, both continuous and after project closing, as well as careful documentation of these. Second, which data to save depends on the intended use and the estimation process; as mentioned earlier, recording effort estimates and actual efforts is necessary, but not enough. Other useful things may be uncertainties, motivations and, to add traceability, names of people involved in the production of the estimates. Third, to be able to collect historical data, the time reporting has to be split on different project parts or activities. Fourth, it is important that the historical database is easy to use since it otherwise can be time consuming and ineffective. Due to the importance and with respect to the difficulties of establishing an easy-to-use historical database, it may be a suitable assignment for a future master thesis or internship at ABB.

To improve the estimation, estimators need to be trained specifically in estimation. This may be done in assistance of an estimation expert and the use of historical data so that comparisons between estimated values and actual values can be made directly. Through this training the estimators can discover mistakes they repeat and learn how to counteract them. However, this approach to estimation training within organizations

needs to be investigated further since it may not be a very realistic approach, given the time aspect.

Some literature recommends consideration of size and/or complexity before estimating the required effort to produce more accurate estimates. One approach to this may be to judge the size and complexity by using some predefined scales. Since the size and complexity of a task are two separate things, two separate scales may be used; however, this strategy requires a method for combination of the two scales. Better is to use a scale for complexity and include the size factor when assessing the complexity. One possibility is to use a scale with an even number of grades (to force the estimators to make a decision), e.g. 1-4 where 1 is not complex and 4 is very complex. When a decision is made, translation of the grade into effort may be done using the historical database.

Project overruns do not only depend on the accuracy of the estimates, but also on how the estimates are managed. Estimates are also used for scheduling, planning of resources, and the amount of buffer time to include in the plan according to the stated risks and uncertainties. Interviewees report on difficulties with risk management which is a huge research area closely related to effort estimation. Therefore, we suggest further investigation in areas other than estimation in order to reduce project overruns; accurate estimates are not enough to obtain successful deliveries of projects.

Section 13

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Appendix A

Interview questions

The material used at the interviews is presented. The language is Swedish since the interviews were conducted in Swedish. Due to the restricted interview time, one hour, the questions marked with (▪) have lower priority and may have been excluded during the interviews.

Intervjuschema

Intro

För att personen vi intervjuar ska veta varför vi genomför intervjun och förstå syftet med denna så att svaren blir så givande som möjligt.

Om oss

Anna Lindvall och Camilla Lindström. Läser datateknik på Chalmers med inriktning mot systemutveckling. Gör nu vårt examensarbete på ABB AB, CR i ASPI-gruppen med Stig Larsson som handledare.

Beskrivning av examensarbetet

Vi tittar på tidsestimering i planeringsfasen av mjukvaruprojekt. Med ordet estimering menar vi den process som leder till estimat, dvs. tidsuppskattningar, för olika projektdelar.

Motivering för intervjun

Vi genomför intervjuer som en del av informationsinsamlingen. Syftet är att få så mycket kunskap som möjligt om hur estimeringssituationen ser ut på ABB. Informationen kommer att sammanställas och vi kommer att dra paralleller mellan det vi får ut och genomförd forskning inom området. Ju mer vi vet om hur ni estimerar idag desto mer underlag har vi för att kunna föreslå ett sätt att förbättra estimeringen på lång sikt.

Vi kommer inte att använda namnen på de personer vi intervjuar i vår rapport. Om du vill kan du få ett exemplar av rapporten när den är klar. Vi kommer också att göra en presentation av examensarbetet som du är välkommen till.

Vi kan skicka en sammanfattning av det vi pratat om idag, som du får kommentera om du vill, så att vi inte har missuppfattat något.

Personens bakgrund

För att möjliggöra eventuella slutsatser senare.

Utbildning

- Vilken typ av utbildning har du i huvudsak? Teknisk eller icke-teknisk?

Tidigare roller

- Vad har du tidigare haft för roller i (mjukvaru)projekt, på ABB eller andra företag?
- Hur lång erfarenhet har du från mjukvaruutveckling?

Estimeringserfarenhet

- Träning/Kurs/Lång erfarenhet?

Hur estimerar man idag?

Vi vill veta hur man estimerar idag och hur de uppfattar sin estimeringsprocess för att vi ska kunna veta hur man kan estimera bättre.

Om projekten

- Hur stora projekt? (man weeks)
- Vad för slags utveckling? Nytt eller förbättringsarbete? Hur mycket återanvänding?
- Hur stor skillnad mellan projekten?
  - Typ av utveckling
  - Teknik
  - Komplexitet
  - Kalendertid
  - Kostnad
  - Programmeringsspråk
- Vilka planerar projektet?
- Hur arbetar de i planeringsfasen?
- Hur skriver ni er tid? (på projekt, aktiviteter, eller annat?)

Estimeringsprocess

Vilka

- Vem estimerar? (person som också ska utveckla, utomstående? Hur många?)
- Vad krävs för att en person ska kunna estimera?
- Använder ni personer med skilda kunskaper, erfarenheter, kompetenser?
- Är det lätt att hitta rätt folk till estimeringen? (primära, sekundära)

När

- När estimerar ni? (vilka skeenden? Först en tidig uppskattning och sedan en mer detaljerad estimering?)
- Hur lång tid tar det?
- Estimerar ni mer än en gång? Hur många gånger?
- Hur skiljer ni mellan de olika estimaten? Vilka är det som utför dem?

Hur

- Hur estimerar ni idag? (bottom-up, top-down, finns någon modell?) Varför?
- Tar ni hänsyn till storlek och komplexitet? Olika utvecklares kompetens/erfarenhet?
- Tas estimaten fram genom någon form av grupparbete? Varför/varför inte?
- Följs Project Planning Basics (PPB)? Varför/varför inte?
- Tar ni idag fram osäkerheten i estimatet? I så fall hur? Hur används det?
- Vad har ni för definition på estimat, dvs. vad avser ett estimat, hur mycket inkluderas i det? (t.ex. risker)
- Är 1 man week = 40 h? Hur tänker ni med övertid?
- Används verktyg?
- Hur omestimerar ni? (när villkor/krav ändrats)
- Känner den som estimerar till tidigare framtagna estimat?
- Vem är det som ansvarar för att estimera för ändrade krav? För risker?
- Adderar projektledaren tid till estimaten? Varför? (för att minimera risker, planera för ändrade krav eller för att kunna ha önskad säkerhet/tillit till estimaten)

- Minskar projektledaren estimaten? Varför? (för att möta trycket uppifrån eller pga konkurrens)
- (Tror man generellt att estimerarna under- eller överestimerar?)

Användning av estimat

- Varför estimerar ni?
- Till vad används estimaten? (schedulering, prioritering, motivering för chefer?)
- Finns politiska skäl att ändra estimaten åt något håll?

Uppföljning av hur ”korrekta” estimaten blev i slutändan

- Görs kontinuerlig uppföljning av estimeringen idag? När?
- Görs återkoppling av estimaten efter projektets slut?
- Får estimerarna del av den? (Får de feedback på sina estimat?)
- Hur dokumenteras uppföljningen?
- (Vad antecknas vid estimering? Vad ”redovisas för chefen”, dvs. hur motiveras estimaten?)

Historisk data

- Finns det någon historisk data? Varför inte?
- Vilken typ av data? Hur är den lagrad?
- Används den? Är det lätt? Ger det resultat?

Träning

- Lär man ut estimering? Hur? Behövs det? Bra/Dåligt?
- Tränas ni i estimering? Hur? Behövs det? Bra/Dåligt?

Estimeringshistorik

- Blir det ”bra estimat”? Varför/varför inte? Om det blir bra, varför? Hur bra?
- Blir det ”dåliga estimat”? Varför/varför inte? Om det blir dåligt, varför? Hur dåliga?

Åsikter om dagens metod

Det är möjligt att vi redan fått svar på dessa frågor.

- Skulle du säga att estimeringen fungerar (tillräckligt bra) idag? Hur vet du det?
  - Känner du att du vet tillräckligt mycket om vad som ska utvecklas för att estimera okej?
- Hur bra känns dina estimat?
  - Hur följer du upp om estimaten var bra/ok/dåliga? Skulle du vilja det?
  - Hur kan man komma ihåg resultatet av en uppföljning och förbättra estimeringen till nästa projekt?
  - Är det någon annan som följer upp estimaten, tror du?

Fördelar

- (Går fort, enkelt?)

Svårigheter

- (Metod/tool/trust/resurser?)

Trust

- Hur mycket litar du på estimaten? (%?)
- Litar andra på estimaten? Vilka?

Attityder

- Tror du att din överordnad bryr sig om hur stora estimat du presenterar?
- Vad händer om du/någon uppskattar att det kommer ta mycket längre tid än vad management tror/hoppas?
- Uppfattas de som ger lägre estimat som mer kompetenta?
- Om estimeringen man gjort visar sig vara felaktig och man inte kommer att kunna hålla den ursprungliga planen, vilket av följande bli lidande: budget, deadline, funktionalitet eller kvalitet?
- Vad är den allmänna uppfattningen när planen spricker? Är det ett ”misstag”, är utvecklarna för långsamma, chefen för dålig eller har någon estimerat helt fel?
- Vad anser du?

Historisk data

- Skulle du vilja använda det om det fanns?
- Är du villig att spara undan det?

Tid

- Vad tycker du om tiden det tar? Rimlig?

Träning

- Behöver ni bli bättre på att estimera?
  - Behöver du tränas i att estimera?
  - Behöver andra tränas i att estimera?

Förbättringsförslag

Vi försöker undvika att föreslå lösningar men vill ändå undersöka behovet av förändring.

Metod

- Finns det behov av förändringar i estimeringsprocessen?
- Förväntningar på ett arbetssätt? Krav?

Verktyg

- Finns det ett behov idag?
- Vilka förväntningar finns?

Egna idéer?

Attityd till förändring

- Hur vill ni tränas i nya arbetssätt?
  - Workshop
  - Material att läsa på egen hand
  - Längre kurs (flera dagar, antingen ihop eller utspritt)
- Känner ni till CMMI? Är det ett mål att uppnå högre nivåer inom CMMI? Vilken nivå?

Summering

- Vi skickar en sammanfattning.
- Får vi återkomma om vi behöver klargöra något eller har kompletterande frågor? Telefon eller mail bäst?