Project Estimation in the Norwegian Software Industry – A Summary

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March 3rd, 2004.

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Executive Summary

This report provides an overview of the results obtained from a survey on project estimation in Norwegian software companies. The survey was conducted between February and November 2003. The main results are:

- We observed that 76% of the projects used more effort than estimated, while 19% used less. The average effort overrun was 41%.
- Average effort overrun was 67% in projects with a public client, compared to an average effort overrun of 21% for projects with a private client.
- Projects that used an incremental or evolutionary development approach had an average effort overrun of 24%, as opposed to the average 55% overrun for projects that used a waterfall-based development approach.

The frequency and magnitude of effort overruns found in this survey seems to be similar to results reported from surveys conducted in other countries in the past 20 years. The observed differences in effort overruns between private and public projects may be caused by differences in bidding procedures, level of client involvement or acceptance procedures.

In order to reduce the risk of effort overruns, software companies should:

- Focus on analyzing their own estimation performance, and invest in estimation improvement (for instance through experience databases or work breakdown structures).
- Differentiate risk buffers based on the type of the customer, development approach and the size of the project.
- Try to establish an “as close as possible” dialogue with the customers (e.g. through an incremental development approach).

All companies should analyse completed projects, in order to benchmark their performance. This allows for improvement efforts to be identified.

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1. Introduction

Accurate effort estimation is one of the most challenging tasks when developing software projects, as several surveys and case-studies have revealed during the past two decades [1]. Poor estimates may often lead to project complications which may cause delays, increased costs, decreased functionality or, in the most severe cases, project cancellation.

In order to improve estimation accuracy, it is important to get an in-depth understanding on which approaches that may be beneficial when industrial projects are estimated and conducted. This report describes a summary of some of the most important research results obtained in a survey as part of the BEST-Project. The survey was conducted in the Norwegian software industry between February and November 2003.

The BEST (Better Estimation of Software Tasks) project was started in 2000 at the University of Oslo, Norway. The goals of the BEST-project are:

- To produce industry relevant research results.
- To produce a comprehensive library of research papers and books on software effort estimation.
- To establish a stimulating and efficient work environment for researchers and master students interested in the field of software effort estimation.

This document is intended for practitioners in the software industry. Relevant research results, papers and information can be obtained from the projects web-site:

http://www.simula.no/~simula/se/bestweb/index.htm.

Previous papers published as part of this survey [2, 3] can also be found at this address.

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2. The Study

The goal of the survey was to obtain up-to-date information on estimation approaches and accuracy in the Norwegian software industry. We performed in-depth interviews with senior managers of 18 different companies, and project managers of 51 projects.

In order to ensure a representative sample, stratified random sampling [4] from the population of Norwegian software development companies was used. This is a reasonable approach, since we were going to investigate a limited number of companies and wanted to ensure that we had companies that represented different types of organizations, such as software houses developing products for the mass market, contractors who develop for clients and the internal development departments of large companies. We also wanted companies of different sizes, both small (<10 employees), medium (between 25 and 100 employees) and large (>100 employees).

The unit of investigation in this survey was either an entire company or a specific department (the latter in the case of very large organizations with more than 1000 employees). We will, however use the term company for our unit of research. The companies that participated had between 10 and 750 employees, with an average size of 141. Five of the companies developed projects to be used in-house, while two developed products for sale to the mass market, and the rest provided tailored solutions for public and private clients.

Each company submitted from one to four projects, depending on available resources for participation. For the specific projects, the mean effort was 3124.5 work-hours, while the median effort was 1175 work-hours.

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3. Results

In this section, we will mainly focus on *effort* estimation accuracy (measured in work-hours), although *schedule* estimation accuracy (measured in calendar days) will be discussed when appropriate. Out of the 51 projects in the survey, seven were omitted from the full analysis because they lacked clear documentation of estimated and/or actual effort. The manner in which we define an estimate in this report is presented in Appendix I. The formula used to calculate estimation accuracy is presented in Appendix II.

3.1. Project Performance

The senior managers in each company were asked about the outcome of their projects. In this survey, outcome was defined to be related to *estimation performance*, as in similar surveys [1], and not to, for example, economic success. They were asked to categorized projects conducted during the past year into three different categories:

(i) "Success" – delivered on schedule and on effort, with the required functionality[1] specified at the time of estimation.

(ii) "Challenged" – failure to meet schedule, effort or functionality requirements.

(iii) "Aborted" – projects that were either stopped or underwent major revisions.

The average response was 45% for "success", 49% for "challenged" and 6 % for "aborted". Note that these calculations are not adjusted for company size or differences in number of projects completed in different companies.

Of the 44 projects who provided the required data, two (5%) were aborted without being completed, and five (11%) were completed on time, on estimated effort and with the required functionality. The rest (84%) were challenged with respect to effort overruns, schedule overruns, functionality, or a combination of these. An overview is presented in figure 1.

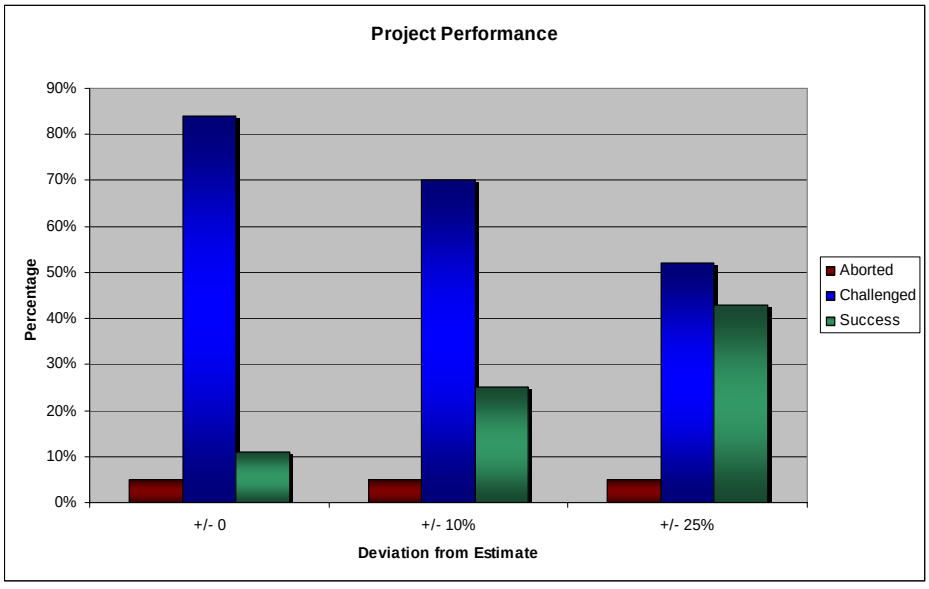

Figure 1: Project Outcome

[1] Delivered functionality was rated by the project managers, since we did not have access to the end users.

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Notice that Figure 1 uses different definitions of "Success" in the separate column groups, i.e., "Success" = no deviation from estimates of time, effort and functionality as specified, "Success" = maximum +/- 10% deviation, and "Success" = maximum +/-25 % deviation.

The senior managers described that there were almost as many "successful" projects (45%) as there were "challenged" projects (49%), and only 6% of the projects were aborted. On the other hand, through interviews with the project managers, we observed that only 11% were completed on schedule, on effort and with full functionality, while as much as 84% were "challenged". A potential reason for this is that a project that overruns its effort estimate or schedule estimate by a few hours or days will not be interpreted as challenged by the senior managers. If we define projects that are within +/- 10% of their estimates as "successful", the percentage of successful projects rises to 25%, while the percentage of challenged projects falls to 70%. If the success range is increased to +/- 25%, the percentage of successful projects is 43%, while the percentage of challenged projects is 52%. These results suggest that the senior managers on average have a too positive view on the success rate of their projects.

Moores and Edwards [5] have previously described that most managers are comfortable with a level of accuracy around +/- 20%.

3.2. Estimation Accuracy

An overview of the effort estimation accuracy for the projects is presented in Figure 2. Accuracy calculations are explained in Appendix II.

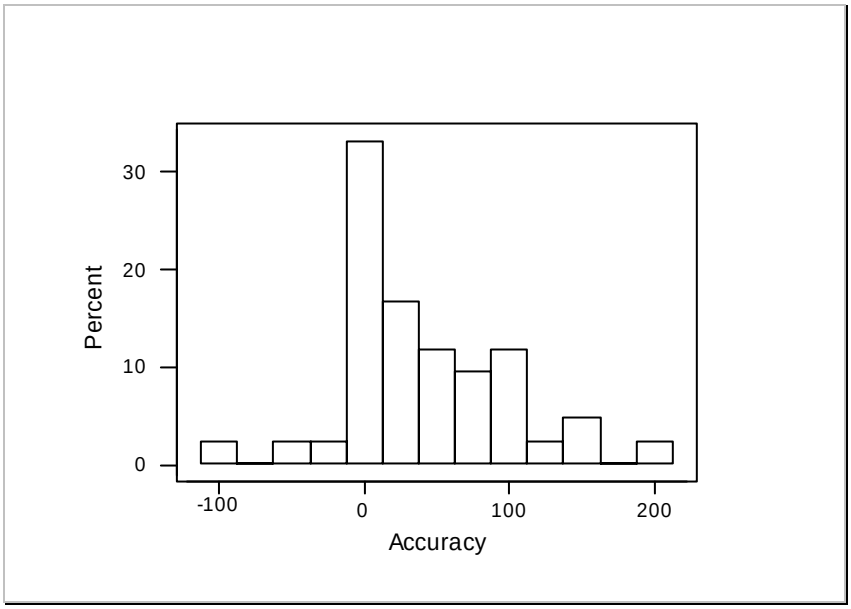

Figure 2: Project Effort Estimation Accuracy

The average effort overrun was 41%, while the median effort overrun was 21%. Mean schedule overrun was 25%, while the median schedule overrun was 9%.

We asked senior managers to provide us with their own assessment of the company's mean effort estimation accuracy. Responses ranged from 10% overestimation to 50% underestimation, with an average for all companies of 15.9% underestimation. This means that the senior managers on average may have a too-positive of a view on the estimation accuracy of their projects.

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3.3. Public vs. Private clients

Almost half of the projects in the survey were conducted for public customers. This reflected the responses from some of the senior managers who said they were increasingly seeking to obtain public clients. The companies used different bidding strategies in order to attract these clients, such as:

- Lowering their hour rates for the project.
- Providing a lower effort estimate to the client than what was believed to be most likely.
- Offering additional services.

However, the use of such strategies should not affect the estimation accuracy results described here; since we base our accuracy measures on the *most likely* estimates used internally by the companies (see Appendix I). Nonetheless, it seems as if projects conducted for public clients had more problems than those performed for private clients with respect to being completed according to the estimated effort. An overview is displayed in Figure 3.

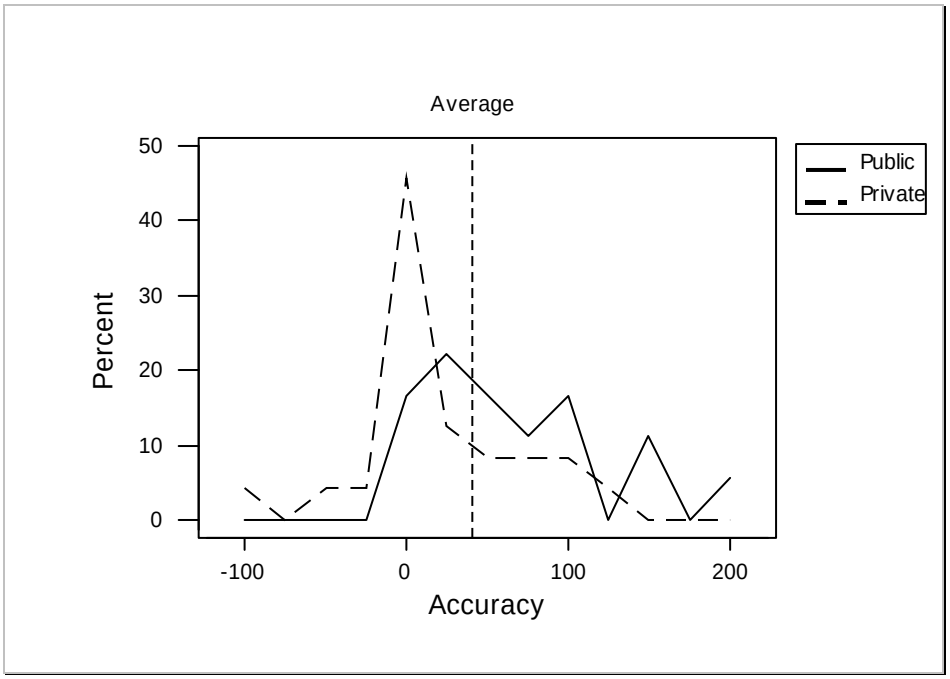

Figure 3: Accuracy of Public vs. Private Projects

The average effort overrun was 67% for projects that had a public client, while it was 21% for projects with a private client. When performing a statistical analysis (one sided t-test), the resulting p-value is 0.005, i.e. it is a very unlikely that the observation is coincidental. Corresponding median accuracy is 53% for public projects, and only 7% for private projects.

We investigated whether projects properties such as size, development method or delivered functionality may have caused this observed difference. If private projects were generally smaller, used an incremental or evolutionary development approach (see next subsection) or delivered less functionality, this may explain the observed difference in estimation accuracy. These project properties are listed in Table1.

	Actual Project Size (man-hours)		Development method		Delivered functionality (mean)
Client	Average	Median	Incremental/evolutionary	Traditional	
Private	3167	1043	46%	54%	103%
Public	3068	1368	44%	56%	110%

Table 1: Properties of Public and Private Projects

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As seen in Table 1, there were no differences in project size or choice of development method. There was a slight difference in delivered functionality, but not large enough to explain the differences in effort overruns. Nor was there any difference in other estimation related aspects such as choice of estimation method, or use of WBS or experience databases.

Perhaps there are aspects that lie outside the scope of our investigation that account for the observed difference? Possible reasons include:

- Public projects in Norway worth more than 200.000 NOK are subject to strict bidding procedures, and several factors in such bidding rounds may impact the estimation performance.
- Cultural differences between the public customers and private contractors may cause communication difficulties.
- Procedures in software acceptance by public clients may be complicated.

The project managers were also asked to provide general feedback on the possible reasons for the project outcomes. Typical responses from managers of projects with a public client were:

- Weak requirement specification.
- Difficult bidding process in public projects.
- The customer has devoted little resources for decision making.
- Extremely immature client.
- Client did not contribute.
- Requirement specification was incomplete.
- Long distance to client.
- Decisions took too much time.

3.4. Possible Benefits of Incremental and/or Evolutionary Development

The use of both incremental and evolutionary development methods has been advocated as means to facilitate more accurate estimation, when compared to traditional models such as the Waterfall model [6, 7]. Among the claimed benefits of incremental and evolutionary development is that use of these models enables tighter control of the development process [8]. This may allow a focus on developing core functionality, and less emphasis on what is often labelled as “nice to have” functionality. Thus, effort and schedule overruns that occur due to the development of unimportant or unspecified functionality, which could result from the use of other development models, may be avoided.

There were similar proportions of projects that mainly used an incremental or evolutionary approach, and those who used a waterfall approach.

Our results indicate that projects that are developed with an incremental or evolutionary model may be less prone to effort overruns than projects that implement waterfall development models. An overview is presented in Figure 4.

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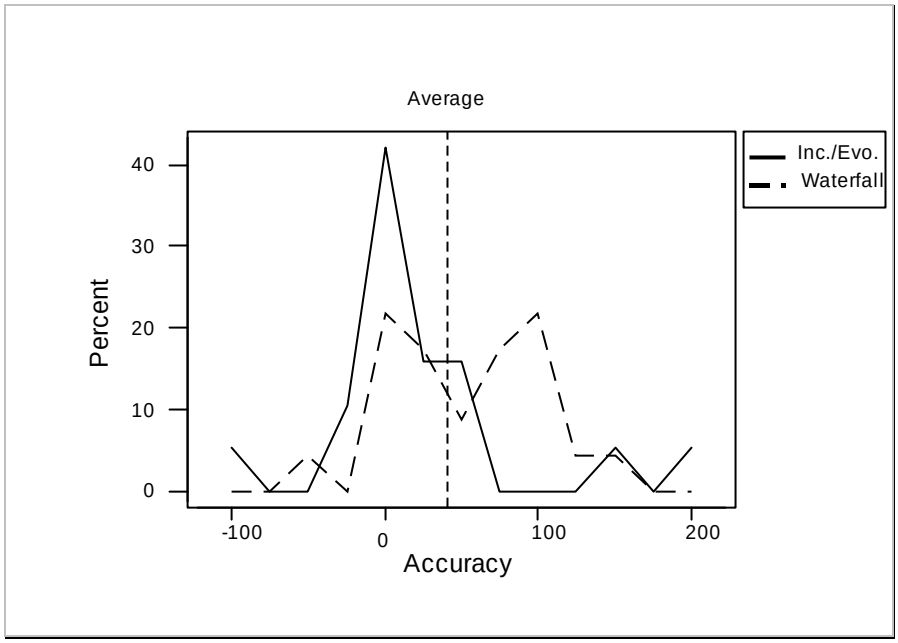

Figure 4: Estimation Accuracy by type of Development Model

Mean overruns in the incremental/evolutionary group was 24% (median overrun 1%), compared to the 55% overrun (median overrun 60%) in the waterfall group. When performing a statistical analysis (one sided t-test), the resulting p-value is 0.036, i.e. it is a very unlikely that the observation is coincidental.

A possible explanation for this observation is that the involvement of the customer is higher in projects that follow incremental and evolutionary projects. With higher customer involvement, errors and missing functionality can be detected earlier and at a lesser cost than during later acceptance tests.

3.5. How Does Project Size Affect Estimation Accuracy?

To see whether project size could affect estimation accuracy, we divided the projects into two equal halves, based on actual effort. Mean overruns for the large and the small projects were 52% and 30%, respectively, i.e., the larger the project the higher the average effort overrun.

3.6. In-house vs. External Projects

Out of the projects that were completed, 33% were developed in-house (internal), while 67% were developed on contract for a client (external).

We found no difference in estimation accuracy based on this differentiation.

3.7. Choice of Estimation Method

When asked about the kinds of estimation approach that were used in the projects, 13 of the companies answered that they relied 100% on expert estimation. Three of the companies used a combination of expert judgment and estimation models 100% of the time, while two companies sometimes used expert estimation and sometimes a combination of expert and models. Out of the five companies that used a combination of model and expert, four of the companies used use-case based estimation models [9].

Of the all projects we analyzed (including those who were aborted), 84% of the managers reported that they relied entirely on expert estimation, while 16% of the managers reported that they used a combination of expert estimation and estimation model. Out of these 16%, 14% stated that they relied

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on a use case-based estimation method tailored to their company's types of projects and historical data.

Based on our data, we could not find any difference in accuracy between those who used models in combination with expert estimates, compared with those who used expert estimates alone.

3.8. Use of Work Breakdown Structures (WBS) and Experience databases

There are some indications that use of predefined WBS for bottom-up estimation and/or experience databases may be beneficial. Out of the analyzed projects, 31% used a predefined WBS. Their average accuracy was 25% overruns, as opposed to the average 48% overrun of the projects that did not use a WBS.

When employing an experience database, this can either be formal (structured records stored in an available repository) or informal (stored in various formats and/or locations). There are indications that use of a formal experience database may be beneficial. Projects that were estimated with assistance of a formal database had an average effort accuracy of 4% overruns. The corresponding figure for both no database and informal databases is 46% overruns. However, one should note that few projects (12%) used formal experience databases, and this may have affected our results.

3.9. Reasons for choice of estimation method

In order to identify a possible rationale for the use of a particular estimation approach, the senior managers in each company were asked to rate several possible reasons for choosing estimation approach. Each reason had to be given a rating from one to five, where five was the maximum. A summary of the average ratings is given in Table 2.

Table 2: Reasons for choice of estimation methods

Reason for choosing method	Rating (1-5)
Market popularity	1.2
Review of other companies experiences	1.7
Lectures at universities/colleges/courses	1.8
Structured analysis	2.1
Thorough testing	2.7
Consultant advice	2.7
Estimator has had success with method	4.2

Out of all possible reasons, only one scored above average (3) on the ratings. This was that the estimator had had previous success with the method. A total of thirteen companies gave this reason the highest possible rating (5). The managers were also given the opportunity to describe important, non-predefined reasons for selecting an estimation method. Among the reasons provided were "using function point methods has shown to be inefficient" and "the method used is good for persuading senior management to approve a project"!

3.10. How important is effort estimation perceived?

When asked about how important effort estimation was viewed in comparison with other software development aspects, the senior managers provided free text responses. Of the eighteen companies, fourteen answered that estimation was very important, extremely important or most important.

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3.11. A Comparison with Previous Surveys

The surveys available for comparison with our data are mainly between ten and twenty years old. Despite this and other differences, such at programming platforms and communication technologies, our results are similar to those of the previous surveys. This suggests that the estimation performance of software companies has not changed much since the 1980s.

In this report, we include only previous research that has been subject to peer review, or in which the research method is, at least partially, described. For that reason, the frequently quoted CHAOS Report published by the Standish Group is excluded. We discuss the validity problems of that report in a separate paper [10].

Previous surveys were conducted by Jenkins [11], Phan [12], Heemstra [13], Lederer [14], Bergeron [15] and Sauer [16]. A summary of the surveys' results is displayed in Table 3.

Table 3: Previous surveys on estimation accuracy

Study	Jenkins	Phan	Heemstra	Lederer	Bergeron	Sauer	Moløkken
Year of study's first publication	1984	1988	1989	1991	1992	2003	2004
Location	USA	USA	Netherlands	USA	Canada	UK	Norway
Cost overrun	34% (median)	33% (mean)			33% (mean)	18% (mean)	41% (mean), 21% (median)
Projects completed over estimated effort	61%		70%	63%		59%	76%
Projects completed under estimated effort	10%			14%		15%	19%
Schedule overrun	22% (mean)					23% (mean)	25% (mean), 9% (median)
Projects completed after schedule	65%		80%			35%	84%
Projects completed before schedule	4%					3%	2%

As seen in the table, our results are similar to previous results, both related to frequency and magnitude of overruns. The results from the survey by Sauer, which showed improved accuracy, should be interpreted cautiously. That survey has methodological weaknesses, due to a self-selecting sample, obtained through a webpage.

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4. Recommendations

Our recommendations for software companies are that they should monitor and analyse the estimation related performance of their projects. When such knowledge exists, the companies can undertake measures, both to improve their own estimation accuracy and to properly handle risk and negotiations. More specifically, we advise companies to:

- Invest in estimation improvement, for instance trough WBS or experience databases. These elements have different pros and cons, and have varying effects in different companies. E.g., it is essential to note that even though the use of formal experience databases may be beneficial, they require constant (time consuming) updating of contents.

- Differentiate the need for risk buffers (contingency plans) based on size of project (small/large) and type of client (public/private). Such assessments should be based on past performance and may, for example, be incorporated into checklists or experience databases.

- Try to establish a *close as possible* dialogue with the clients (e.g. through an incremental development approach) in order to sort out ambiguities and resolve the needs of the end-users early.

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Magne Jørgensen received the Diplom Ingeneur degree in Wirtschaftswissenschaften from the University of Karlsruhe, Germany, in 1988 and the Dr. Scient degree in informatics from the University of Oslo, Norway in 1994. He has about ten years industry experience as software developer, project leader and manager in Telenor and Storebrand. He is now professor in software engineering at University of Oslo and member of the software engineering research group of Simula Research Laboratory in Oslo, Norway with many international publications on software cost estimation. Magne Jørgensen has supported software project estimation improvement work and been responsible for estimation courses in many software companies.

Thanks to all survey participants!

Thanks to Stein Grimstad and James Dzidek at Simula Research Laboratory for valuable comments.

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Appendix I: What is an Estimate?

Most previous research tends to treat a software estimate as a single fixed value. During the course of our research, however, we have noticed that software projects often have several estimates [17]. This aspect, and how this poses challenges to estimation models, has also been addressed by Edwards and Moores [18]. An overview of how one type of project *can* behave, is illustrated in figure 5 (Adapted from Edwards and Moores).

First of all, the estimate often changes over the course of a project, depending on the *stage* at which the estimate is made. For example, a project can have an early estimate (step 2), based on vague requirements (step 1), a planning estimate (step 4) based on a more detailed requirement specification (step 3), and one (or more) re-estimates during the course of development (step 6 and 7) if something unforeseen happens. These estimates, all for the total effort of the projects, may or may not be entirely different in magnitude.

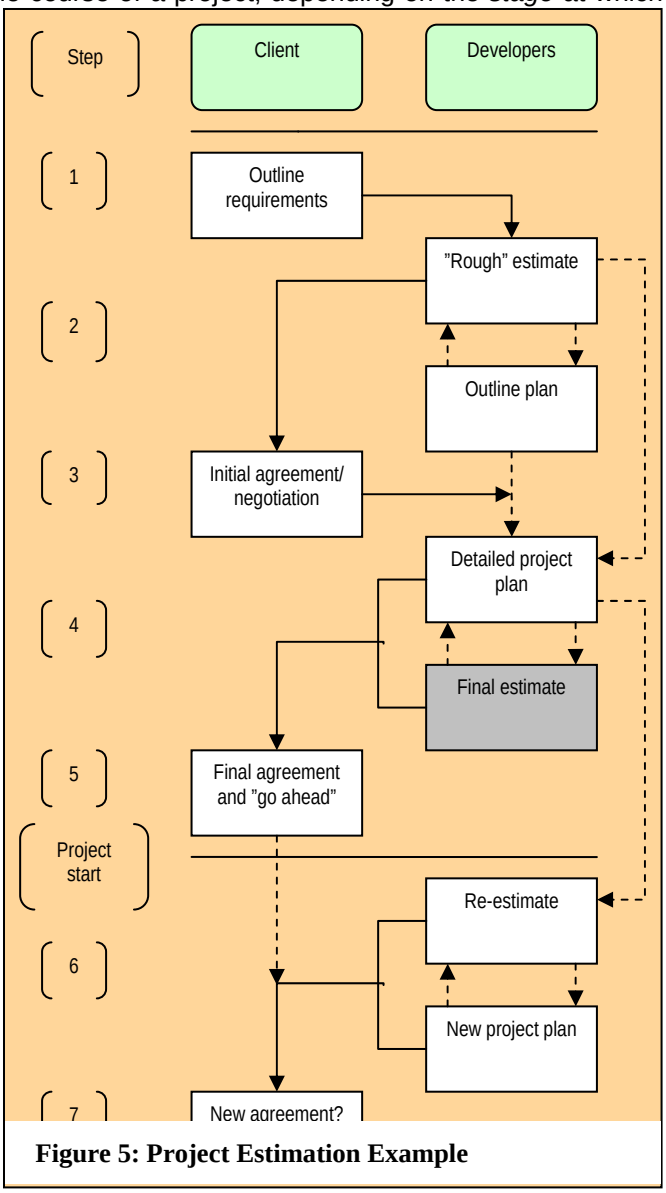

Figure 5: Project Estimation Example

Second, a very important factor is who the estimate is for, or communicated to. A single project may have two estimates at the planning stage: one that is used internally (step 4), e.g., for project managers, and another that is used externally, for clients (step 5).

When the goal is to investigate the estimation accuracy of actual software projects, as it is in this report, it is meaningful to use the *most likely* estimates, used by the developers internally, as our basis. This is instead of external estimates communicated to clients. The latter may be affected by factors that have nothing to do with estimation skill, such as market competition, or other financial aspects.

This applies whether the client is internal, e.g. another department in the same company, or an external customer.

In our survey, we collected data on all available estimates for each project. Some had only one, while others had as many as six different estimates. Nonetheless, this is not problematic when taken into account at the time of data analysis.

In order to investigate possible differences in estimation accuracy, it is important to compare the actual effort with the most appropriate estimate. For our purposes, this is the *most likely* estimate at the *planning* phase.

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Appendix II: Calculating Estimation Accuracy

Estimation accuracy, both related to effort and schedule, was calculated with formula (1):

$$Accuracy = \frac{(x - y)}{\min(x, y)},$$ x = actual effort and y = estimated effort. (1)

An effort estimation accuracy of -100 indicates that the project used half the amount of estimated effort, while an accuracy of 100 indicates that the project used twice the estimated effort. The same holds for schedule estimation accuracy. In both cases, an accuracy of 0 indicates that the project ended on target.