Investigating Intentional Distortions in Software Cost Estimation - An Exploratory Study

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Abstract

Cost estimation of software projects is an important activity that continues to be a source of problems for practitioners despite improvement efforts. Most of the research on estimation has focused on methodological issues while the research focused on human factors primarily has targeted cognitive biases or perceived inhibitors. This paper focuses on the complex organizational context of estimation and investigates whether estimates may be distorted, i.e. intentionally changed for reasons beyond legitimate changes due to changing prerequisites such as requirements or scope. An exploratory study was conducted with 15 interviewees at six large companies that develop software-intensive products. The interviewees represent five stakeholder roles in estimation, with a majority being project or line managers. Document analysis was used to complement the interviews and provided additional context. The results show that both estimate increase and estimate decrease exist and that some of these changes can be explained as intentional distortions. The direction of the distortion depends on the context and the stakeholders involved. The paper underlines that it is critical to consider also human and organizational factors when addressing estimation problems and that intentional estimate distortions should be given more and direct attention.

Keywords:
Cost estimation, distortion, human factors, organizational factors, organizational politics, estimation inaccuracy, software engineering, empirical study

1. Introduction

The software industry is competitive and cost is in focus for most firms. Therefore, cost estimation of software projects is an important activity used for planning and follow-up of projects and costs. Cost estimation is thus used as a forecast for understanding whether or not a product will be profitable and subsequently for selection of new projects and features. However, estimation is often associated with difficulties (Lederer and Prasad, 1995) and there has been substantial effort to improve estimation practice in research as well as in practice. Yet there is ample evidence that it continues to be a source of problems and controversy in development organizations (Heemstra, 1992; Lederer and Prasad, 1993; Sauer and Cuthbertson, 2003; Moløkken-Østvold et al., 2004).

During the past 20 years the research on estimation has focused on developing and improving estimation tools and methods, for an overview see Jørgensen and Shepperd (2007). Jørgensen and Shepperd drew attention to the low number of studies that took organizational context into account (16%) (see Jørgensen and Shepperd, 2007, p38) and argued that the dominant focus on technical issues did not correspond to what were perceived as being the most prominent problems in estimation practice. Software practitioners seem to share this view according to the several studies conducted to explore perceived estimation inhibitors (Phan et al., 1988; Lederer and Prasad, 1995; Subramanian and Breslawski, 1995; Jørgensen and Moløkken-Østvold, 2004; Magazinovic and Pernstål, 2008). Many of the inhibiting issues reported in these studies are human-related, such as frustration about requirement uncertainty and change, developer experience and a focus on fast delivery time instead of costs, thus not relating to the main focus for the research community, namely methods and tools.

A central challenge for the practical use of cost and effort estimation is that requirements often - of course - change during project execution (Subramanian and Breslawski, 1995; Magazinovic and Pernstål, 2008) due to factors such as changing needs, improved understanding, changing technology and markets, etc, which makes it difficult to compare actual costs of a project (actuals) to the early estimates. In that respect, the estimate is a plan meaning that the estimates often do not reflect the projects that were carried out (Grimstad and Jørgensen, 2006) which was, to some extent, mentioned in nearly all of the studies that explore perceived reasons for inaccurate cost and effort estimates. These studies reported unclear and changing requirements

as top issues (Phan et al., 1988; Lederer and Prasad, 1995; Subramanian and Breslawski, 1995; Jørgensen and Moløkken-Østvold, 2004; Magazinovic and Pernstål, 2008). The very nature of development is change and changing prerequisites that directly (and logically) affects the accuracy of estimates and consequently implies a need for change in estimates. However, there are also other aspects of estimation and estimates that cause both changes and inaccuracy. For instance, cognitive biases in cost estimation have during the recent years gained more attention (Jørgensen et al., 2004; Grimstad and Jørgensen, 2007; Aranda and Easterbrook, 2005). These biases affect cost and effort estimation but since they are unconscious and unintentional they are difficult to both observe in ones' own behavior and to avoid.

There have also been reports on conscious and intentional changes and inaccuracy in estimation practice. Focusing on stakeholder objectives Lederer et al. (1990) interviewed 17 software information systems (IS) managers and other staff members and four user managers with interest in cost estimation of IS projects. They showed the importance of understanding the political aspects of the organization. In a follow-up survey of 116 IS project managers and analysts Lederer and Prasad (1991) connected different stakeholder groups' interests to shrinking (changes that decreased estimates) and padding (changes that increased estimates) behaviors. In a later paper (Lederer and Prasad, 1995), based on the same 116 survey responses, the authors ranked 24 different causes of inaccurate cost estimates and factored them into four groups where one in particular focused on intentional distortions, by the authors referred to as political factors. To our knowledge, these are the only studies that have directly addressed the subject of intentional estimate distortions.

In line with the work by (Lederer and Prasad, 1991) we define an effort estimate as:

> *'A forecast of most likely development effort produced using information available at the time of estimation.'*

This definition highlights that estimates are always a plan to which deviations are expected since changed and better information available after the time of estimation are legitimate reasons for changes. This kind of uncertainty that is built into the estimate and its subsequent necessary changes is not what we refer to as distortions. Distortions are changes (either increases or decreases) that lead to the creation and use of estimates that are

not the most likely forecast of development effort given the available information. Distortions can be unintentional, i.e. result from biases that are not under conscious control. Distortions can be intentional, i.e. result from changes that aim to fulfill objectives outside the estimation context, i.e. objectives other than producing the most likely forecast of development effort or cost. Since recent research has focused mainly on unintentional distortions there is a need to better understand intentional distortions. We aim to extend Lederer and Prasad's work (Lederer and Prasad, 1991, 1995) by directly investigating organizations that develop software-intensive products and answer the questions:

- RQ 1: Are there intentional distortions of estimates in the development of software-intensive products?
- RQ 2: What are the reasons for intentional estimate distortions?

These concepts are difficult both to observe and to openly and honestly acknowledge and discuss. Furthermore, the concept of an estimate itself can be used differently by individuals and companies, e.g. as a budget or as an early plan. It is thus critical to use a research method that allows for follow-up questions and clarifying feedback. Consequently, to answer the research questions, an interview study was designed and carried out in six large, mature companies. To complement the interviews descriptions of formal development and estimation processes, and organizational context were derived from internal documentation at the companies.

The remaining part of this paper is organized as follows: Section 2 describes related work followed by Section 3 where the research methodology used is addressed. A generic process for product development in the participating firms is briefly presented in Section 4. In Section 5, the results are reported and analyzed and in Section 6 we discuss the findings, our research questions and relate the findings to the literature. The paper ends with conclusions.

2. Related Work

Most of the research on software cost and effort estimation is focused on development and tuning of estimation tools and methods. The few studies that take organizational context into account include surveys on estimation

practice, impact of estimates on project work, estimation in general context of project management and reasons for estimate inaccuracy (Jørgensen and Shepperd, 2007). A summary of the highest ranked perceived reasons for estimation inaccuracy reported in these studies (Phan et al., 1988; van Genuchten, 1991; Lederer and Prasad, 1995; Subramanian and Breslawski, 1995; Jørgensen and Moløkken-Østvold, 2004; Magazinovic and Pernstål, 2008) is presented in Table 1. The table is restricted to a list of highest ranked issues as some of the studies reported extensive lists of issues. The reported inhibitors differ to some extent, however, unclear and changing requirements seem to be commonly reported together with user related problems and technical issues. Common for the perceived estimation inhibitors is that they often are external to the subjects, i.e. they are neither caused by nor can easily be improved by the subjects that have been investigated.

The notion of cognitive biases has also been reported to affect estimates. Anchoring is an example of a cognitive bias that describes adjustment of an answer towards an anchor, even if that anchor obviously is incorrect (Grimstad and Jørgensen, 2007; Aranda and Easterbrook, 2005). In an anchoring experiment (Jørgensen and Grimstad, 2008) the participants were given specifications for a system and customers expectations of completion time were mentioned. The expectations were clearly too high or too low (both cases were included), but the participants were asked to disregard the described expectations, and told that the client asked for the most likely effort needed to develop the required system. Still, the expectation of the client clearly affected the estimates. Also, Aranda and Easterbrook (2005) showed that anchoring affects the estimates independent of the estimation technique used.

Over-confidence is another example of a cognitive bias that affects software professionals. When asked about prediction intervals (stating an estimation interval they believe with x% certainty will include the actual result), practitioners showed a tendency to present too narrow intervals (Jørgensen et al., 2004). Interestingly enough, while too narrow estimate intervals (or point estimates) do not reflect the uncertainty of requirements correctly, they were still rewarded by project managers (Jørgensen and Moløkken-Østvold, 2004).

Few studies have directly investigated how organizational factors affect estimation processes. One of the exceptions is the case study of 17 IS managers, staff members and four user managers by Lederer et al. (1990) that focused organizational aspects of cost estimation. Lederer et al. (1990) pointed at the importance of understanding the political aspects in the organization. They

Study	Top perceived cost estimation inhibitors
Phan et al. (1988)	Optimism
	Frequent changes
	Duration
van Genuchten (1991)*	More time spent on other work than planned
	Complexity of application underestimated
Lederer and Prasad (1995)*	Frequent requests for changes by users
	Users' lack of understanding for their own requirements
	Overlooked tasks
Subramanian and Breslawski (1995)*	Requirement change/addition/definition
	Programmer/team member experience
	Staff turnover
Jørgensen and Moløkken-Østvold (2004)*	No systematic feedback
Interviews	Poor project planning and overlooked tasks
	Poor requirements specification
Jørgensen and Moløkken-Østvold (2004)*	Unexpected and overlooked tasks
Questionnaires (qual analysis)	Change requests from clients
	Simpler task/more experienced developer than expected
Jørgensen and Moløkken-Østvold (2004)*	Project estimated by developer
Questionnaires (stat analysis)	Project estimated by a person not participating in the project
	Client focus on time-to-delivery, not cost or quality
Morgenshtern et al. (2007)	High level of uncertainty
Magazinovic and Pernstål (2008)	Feedback problems
	Shared resources between projects
	Negotiations
	Requirement uncertainty and change

Table 1: Results from studies on perceived cost estimation inhibitors (the three highest ranked inhibitors were included for studies where the number of inhibitors was too hight for all to be included, marked with *)

found that cost estimates were used for many purposes in an organization and that stakeholders within the estimation processes wanted to contribute to the company success to further their careers. One way of contributing was to finish a higher amount of projects, in which case they preferred lower estimates in order to get the projects approved. Another way was to finish projects within their estimates, which created a preference for higher estimates. The relative importance of these objectives also differed between stakeholder groups.

In a follow-up study Lederer and Prasad (1991) specifically examined the padding or shrinking of estimates, such that they are both conscious and internal to the subject, what we collectively call intentional distortions. The study showed that stakeholders in the estimation process had differing objectives and that those objectives affected their estimates. Greater preference for project completion leads to intentional increase in estimates and estimator-developers (developers that also estimate costs for the system they

later developed) were most prone to this type of behavior. Greater preference for completion of higher number of projects was more likely to lead to intentional decrease of estimates, a behavior that was most common among estimators (planners with inside knowledge of the system and estimation process).

In a later study by Lederer and Prasad (1995), respondents were asked to identify the extent to which 24 possible causes, taken from literature, were responsible for inaccurate estimates. From a factor analysis of the responses four main factors emerged: Methodology; Politics; User communication; and Management control. Methodology includes causes that focus on the estimation method and feedback from earlier projects whereas User communication focus on the users' understanding and frequent changes in the requirements and Management control focus on performance and estimation review as well as comparison of estimates to actuals. Politics collected four causes dealing with pressure to manipulate the project to stay within the estimate: management pressure to increase or reduce estimates, scope reduction to stay within estimate, padding removal by management and red tape (Lederer and Prasad, 1995).

In a later paper based on the same empirical data Lederer and Prasad (1998) developed a model for cost estimation error prediction suggesting that the best strategy for accuracy improvement is using estimation accuracy when reviewing performance of those responsible for the estimates while letting them base their estimates on expertise. The results also point at the inability of complex statistical formulas, software tools and established standards to predict estimation accuracy indicating that human and organizational factors are more or at least as important.

Intentional distortions of estimates have by some researchers been referred to as lying. Glass et al. (2008) defined lying as "intentionally distorting the truth" (p. 90) and reported that lying about estimates was the most predominant form of perceived lying in software projects, where the reasons for estimate distortions were reported to be 'cave-in to people with more power', 'to win via low estimate' and 'padding with a high estimates to keep reserves'. Flyvebjerg et al. (2002) also used the term lying, or "intentional deception" (p. 280), in an investigation of reasons for cost underestimating in public works projects suggesting that deception was the most likely explanation of the underestimation (referred to as political explanation by the authors, p. 289), rejecting technical, economic and psychological explanations.

While research on intentional estimate distortions is still rare in literature

on software cost and effort estimation, some explanations for this types of behaviors may be found in other areas, e.g. within the project management literature or as Flyvebjerg et al. (2002) suggested, within organization politics (Pinto, 2000) (Buchanan, 2008). Pinto (Pinto, 2000) argues that many organizations invest thousands of hours in planning, scheduling and staffing of projects, costly activities dependent on cost estimates, only to end up with a project that is derailed by politics. Since project and line organizations often are separated and projects have to fight for the resources, negotiations and bargaining are common, and so-called political behaviors are often used to secure resources. Political behaviors are very common in organizations according to respondents in the Buchanan study (Buchanan, 2008). Practitioners also report that politics are used at all organizational levels and believe that political behaviors are necessary to succeed as a project manager. Further, respondents do not only report behaviors they observe in others, 75% of the respondents state that they themselves engage in organizational politics.

Intentional estimate distortions are highly human-centered. There seems to be a gap in software cost and effort estimation research as it mainly focuses on technical issues such as design and improvement of estimation methods and tools and not as much on social aspects of estimation in firms. This paper aims to contribute to filling that gap by adding knowledge about intentional acts that creates distortions in software estimation processes.

3. Research method

This study was designed to examine cost and effort estimation practices, focusing on intentional estimate distortions. Six large mature companies were examined (Table 3) that all have complex product development processes where estimates are used as a regular part of the organization practice. All interviewees take an active part in the estimation process and represent the project organization, the line organization, product planning, higher management or the developers. The number of interviewees per company varied, see Table 2. The asymmetry does however not pose a problem since the goal is to collect diverse perspectives on estimate distortions, not to compare cases.

3.1. Data collection

The data was collected in two rounds. The initial round of four interviews had as purpose to test the interview guide. As only few minor changes were made in the interview guide the data collected in three initial interviews was included in this study. One of the interviews was excluded, as it did not fit the focus of the study on the large, mature organizations.

The interviews were tape-recorded with an average length of 69 minutes with standard deviation of 17.3 minutes. The recordings were and fully transcribed and only speaking fillers were removed in order to increase readability of the texts.

3.1.1. Selection of interviewees

The 15 interviewees were selected based on their knowledge and experience of the estimation practice rather than to reflect the general population (theoretical sampling, e.g. Alvesson and Sköldberg (2000)). In order to make sure that all important stakeholder groups involved in the estimation of costs and effort in software projects were represented, industrial experts were consulted. This resulted in five stakeholder groups (Table 2), their involvement in the estimation process is described below:

- *Project management* (PM) is responsible for planning and execution of software development projects with focus on both technical and managerial activities, and for delivery of the specified functionality within time and budget.

- *Line management* (LM) is responsible for staffing of projects with personnel that has the right competence for the task. Many projects run in parallel, which makes this a difficult task for the line management.

- *Higher management* (HM) decides which projects are to be initiated. Project managers report costs and forecasts to higher management, and HM has the power to close projects that are not executed according to the plan, or prioritize among projects awarding more resources to some and removing resources from other.

- *Product planning* (PPL) organizations main task is to understand new trends and wishes of potential customers, specify a product that would be appealing to the targeted consumer group, and communicate those specifications to the development teams. The communication of specifications is done in the initial project phases and is often iterative where PPL and development teams meet to resolve uncertainties. Requirement specifications produced by PPL are then used as input to cost and effort estimation.

Interviewee	Company	Role
1	A	PM, LM
2	A	PM
3	B	PM, LM
4	C	PM
5	D	PPL
6	D	PM
7	D	PM
8	D	PM
9	D	PM
10	E	PM
11	F	D
12	F	LM
13	D	HM, PM, LM
14	D	PM
15	A	PM, LM

Table 2: Interviewee information

- *Developers* (D) are responsible for development and testing of functionality that is assigned to them. The development tasks assigned to developers are based on the specifications provided by PPL. The developers are also asked to produce a bottom-up estimate of time needed to finish their tasks.

Software is not always produced in isolation; the companies investigated in this study produce embedded systems where software and hardware components are integrated to produce the final product. Estimates for the embedded systems often include additional stakeholders e.g. after-market managers (dealing with spare parts), manufacturing managers, etc. However, as the focus of this study is on estimation of software development, the focus has been on sub-projects where software is developed and these stakeholders have not been excluded.

Most of the interviewees have a long work experience, which provides better understanding of estimation practice and possible distortions that arise during the estimation process. Several of them have also experienced more than one stakeholder role (Table 2), which should give them a broader perspective of estimation and estimate distortions.

All interviewees live and work in Sweden and are employed in a total of six large, mature companies. Four of the companies have globally distributed development sites; the remaining two are based in Sweden, but owned by international corporations. The included companies produce software as a part of mechanical or electronic products (Table 3).

Company	Product	Organization	Employees	Interviewees	Roles
A	Mechanical, SW embedded	Matrix	20 000	3	PM, LM
B	Mechanical, SW embedded	Matrix	13 000	1	PM, LM
C	Electronic components	Matrix	87 000	1	PM
D	Mechanical, SW embedded	Matrix	90 000	7	HM, PM, LM, PPL
E	Electronic device	Matrix	8 500	1	PM
F	Mechanical, SW embedded	Matrix	117 000	2	PM, D

Table 3: Company information

3.1.2. Interview design

The invitation that was sent out to the interviewees included a description of the study and the interview duration asked for was 1h. The interview guide was designed and iteratively revised by the authors prior to the study and also tested in four initial interviews. The results of the initial test-round were published in (Magazinius and Feldt, 2010) and used to improve the interview instrument resulting in only minor changes. As very few changes were made to the interview guide, it was decided to include three of the initial interviews in this study and exclude one. The excluded interview was conducted at a company that did not fit this studys focus on large, mature organizations.

The interviews consisted of three parts. First part of the interview was dedicated to clarifying the purpose of the study and providing information about anonymity procedures and data storage (Introduction in Table 4) . The interviewees were ensured that all personal, company and product specific information would be made generic (for example replacing the company name with Company in the transcripts).

Sensitive subjects, such as organizational politics, are difficult to approach directly in research interviews (Madison et al., 1980). Flyvebjerg et al. (2002) connected the concept of intentional estimate distortions to political behaviors, thus the interview guide designed for this study was designed to approach the subject with caution. Following the advice of Madison et al. (1980) the second part of the interview (Interview questions in Table 4) was designed in such way the term 'intentional distortion' was not directly mentioned. Instead, the interviewees were asked to recall a recent project and related estimation activities representative of those they usually participate in. They were then asked to describe development and use of estimates, as seen from their perspective, and to include a description of their stakeholder role and interests in the process. They were also asked to provide information about other stakeholders they interacted with and what they believe to

be the interests of those stakeholders. Further, the respondents were asked to describe how the interests of the involved stakeholders affected the estimates and how possible interest conflicts were handled (questions 3 - 5 in Table 4 were asked about each conflicting issue). During this part of the interview information about intentional estimate distortions was captured using follow-up questions where information on details and context of the distortion was collected. As mentioned earlier, practitioners likely perceive intentional estimate distortions to be a sensitive subject to discuss in direct dialogue with a researchers. Thus, only the last question addressed the issue directly in order to ensure that the respondents have shared all important information with us.

A side effect of this design of the interview study is that some respondents also reported on unintentional distortions and factors that lead to such distortions. This is inevitable since asking directly about intentional distortions might make some respondents less likely to share their experience. We have decided to keep the unintentional distortions in our result and analysis sections since it they both give a contrast to and context for understanding the intentional distortions, but also since they add further empirical support for describing estimation distortion in general in the development of software-intensive products.

During the third part of the interview additional background information about the interviewees was collected such as educational background, experience and stakeholder role (Interview closure in Table 4).

3.2. Data analysis

Two sources of data were used in the analysis: company specific development process documentation and the data collected in the interviews. The interview data analysis will be described in Section 3.2.1. and the documentation analysis will be described in Section 3.2.2.

3.2.1. Analysis of interview data

The data was analyzed using theoretical coding (Flick, 2006), a procedure used to develop grounded theory (Strauss and Corbin, 1998). In quantitative data analysis coding is fix and mostly a way to manage data. Using theoretical coding on the other hand, the data was coded continuously, and the analysis model was iteratively improved to fit the emerging categories. The coding was conducted in three steps (Flick, 2006):

Introduction
1. Purpose of the study.
2. Data handling information (anonymity, who has the access to the information, etc)
3. Permission to record the interview.
Interview questions
1. Could you tell me how a recent project was estimated?
2. What was your role in the estimation?
3. Which other stakeholders are present in the estimation process? What are their interests?
3. What are the different stakeholders' interests?
4. Do the stakeholders' interests collide in the estimation discussions?
5. How are these collisions handled?
6. Who has the power in the estimation discussions? What is that power based on?
7. Are there any other estimate changes or behaviors that affect the estimates we have not talked about?
Interview closure
1. Name.
2. Educational background.
3. Work experience.
4. Current role at the company.

Table 4: Interview protocol

Code	Citation	Role
Project managers are affected by their subsidiaries and brands	1.23	PM
If the resources are given to a project they are spent	2.33	LM
There is a deliberate lowering of estimates to try to sell upgrades	4.43	D

Table 5: llustrative example of open coding

1. The process started with *open coding*. The raw interview transcripts were divided into statements that were numbered in order to simplify back tracing of the analysis steps. Each statement was reviewed and statements that contained any information about estimate distortions (e.g. how and why the estimate was distorted, who distorted it, in what situation the distortion manifested, etc.) were extracted and given codes that summarized the larger extracted text. To ensure the traceability of the analysis each code was linked to the interviewee, his/her role, and statement number (Table 5). All information was stored in a database. Open coding was primarily carried out by one of the authors, the remaining two authors coded two interviews each that did not overlap. Based on the total of four doubly coded interviews differences were discussed and resolved among the authors and the analysis model was improved. This ensured agreement, and thus consistency, in how to code and extract data.

2. In the next step, *axial coding*, the codes extracted in open coding were reviewed and grouped in categories that responded to the research questions.

The work started with two categories, intentional and unintentional estimate distortions where the intentionality of a distortion was either clearly stated by the interviewee or implied by the context in which it was told. For example, the statement: "We increase the estimates as we know the higher management will try to decrease them" does not literally state the intention, but the context implies that the increase is intentional. Categorization based on intentionality was discussed and refined iteratively among the authors. Further, the two categories were divided in three categories each, describing the direction of the distortion as it was described by the interviewees: 'increase' (overestimation), 'decrease' (underestimation) or 'and/or' (a category where the direction of distortion differed depending on the source). The traceability of the analysis was secured by linking the categories to the codes, that in the previous step (open coding) were linked to interviewees, their roles and exact statement from which they were extracted. Also this work was primarily done by one of the authors, the remaining authors reviewed the results and validated the coding in discussion sessions. The results of the axial coding are presented in Section 5, Results and analysis.

3. The last step, *selective coding*, selection of one overall category that summarizes the rest of the categories is the core of this paper, which is: the estimates are distorted by both intentional and unintentional behaviors. This core category is described and discussed further in Section 6.

3.2.2. Documentation analysis

The companies' documentation of development and estimation processes describe the formal processes that should be used by the practitioners. In this study we have focused on the estimation practice and especially deviations from the formal estimation process. As the documentation does not provide information about estimation practice it could only be used to understand how that practice deviates from the estimation process.

As the interviewees were guaranteed anonymity with regard to personal, company, and product information we used the documentation analysis to describe a generic development process and estimation activities rather than provide company specific information. The generic development process and estimation activities are described in Section 4, Organizational context.

3.3. Validation of results

The results were presented in a seminar where representatives for two of the investigated companies were present (A and D in Table 3). Fifteen prac-

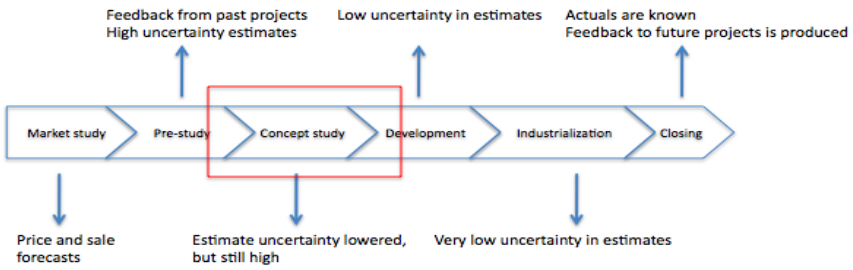

Figure 1: Generic product development process including expected estimate uncertainty (focus of this study marked in red)

titioners took part in the seminar representing three of the five stakeholder groups included in this study: project management, line management, and higher management. The participants questions lead to improvement in formulations of the issues, however, there was no disagreement on any of the reported distortions.

4. Estimation context

Software cost and effort estimation is an important part of a product development process, figure 1 presents a generic development process. Preparations for new development projects are when being external started by a *market study* often conducted by product planners. The demands of the target customers and/or users are explored together with the price the customers would be willing to pay for the product. Market study is followed by a *pre-study* where an investigation is started to explore the profitability of the product and ending with a decision of whether the project is to be initiated or not. At this point the first, highly uncertain estimates are produced, and there is still no investigation of possible implementation solutions. Then follows the *concept study* with the goal to examine the possible solutions that could be employed to develop the product.

In this study we have primarily focused on project start-up phases, where a decision has been made to initiate a project and early estimates are produced (marked in red in Figure 1).

At the end of the concept study a decision is made about the solutions to be implemented which reduces estimate uncertainty. The process continues

with a *development phase* where software is designed and developed. Estimate uncertainty is continuously lowered parallel to the ongoing implementation of functionality. If a company produces embedded systems, projects then face an *industrialization phase* where hardware is manufactured and software installed in the product. Usually, software is still tested and improved during this phase. Lastly, the project is closed (*closing*) and feedback produced, using known estimates and actual costs. The purpose of the feedback is improvement of future projects.

All six companies involved in this study are matrix organizations. The project organization is responsible for project delivery while the main responsibility of the line organization is staffing those projects with appropriate resources. The line organizations sections are functionally organized in departments and underlying groups focusing on development of hardware, software, etc. while project teams can be cross-functional. One section, department or group can provide team members to several (and often parallel) projects and one project can be staffed by employees from several sections, departments or groups. Project managers are responsible for project estimates while line managers estimate annual costs needed to staff the projects. The annual line estimates are affected by the project estimates, thus both parties are stakeholders in estimation of project costs. Other estimation stakeholders are higher management, responsible for selection and coordination of projects, product planners, responsible for understanding customers and deriving functional requirements, and developers, responsible for development of the first bottom-up estimates. We have chosen to include representatives for these five stakeholder roles in this study to gain broader understanding for the estimation practice.

5. Changes to estimates - Results and analysis

Below we first describe the main categories into which our reasons for changes to estimates can be divided. We then describe, in turn, the three categories of intentional changes while the last subsection describes the unintentional changes and other important estimation factors uncovered in our interviews.

5.1. Categories of estimate changes

Six categories of reasons that correspond to our two research questions emerged during the axial coding when analyzing the 15 interview transcripts.

The categories are based on the two dimensions of *intentionality* (intentional or unintentional) and *direction* (increase, and/or, or decrease) and the reasons that our respondents mentioned are shown in Table 6 below. In the following we are not strict in how we use the term distortion since the reason for the behavior that changes an estimate or the decisions it is used in are often a better descriptor than the actual behavior itself.

Even though the main focus of our paper is on intentional distortions we include also the unintentional since they help describe in more detail how the respondents discuss and judge intentionality and thereby puts the intentional reasons in context. Furthermore, since there is a general lack of research about distortions of the estimation processes of large software development organisations a fuller description has merits in itself. The table also reports the number of respondents that mentioned a particular distortion and the number of different organisations where they were mentioned. For example, four different respondents in three different organisations discussed how 'Avoiding overspending' lead to intentional increases in estimates.

Direction	**Intentional**	**Unintentional**
Increase (+)	Hiding activities (6 in 4) Avoiding overspending (4 in 3) Job securing (4 in 3) Excluding functionality (3 in 3) Myopic perspective (1 in 1)	*Not reported*
Decrease (-)	Management pressure (7 in 4) Selling ideas (6 in 3)	Missed risks/tasks (6 in 3) Optimism (2 in 2)
Varying (+/-)	Negotiations (6 in 6) Personal agendas (4 in 2) Organizational agendas (3 in 3) Budget determined (3 in 3) Disregarding uncertainty (3 in 3)	Misunderstanding reqs. (1 in 1) Inexperience (1 in 1)

Table 6: Categories of reasons for distortions based on intentionality and direction

While the direction (increase or decrease) of the distortion was evident from the interviews some of the reported distortions were by the interviewees regarded as unintentional lapses or cognitive problems, while others were described as intentional (deliberate) acts. The intentional distortions were in some cases clearly stated to be intentional, in other cases the intention was

not explicitly stated although clearly implied by the very description of the reported distortion or the context in which the distortion was described. The division into intentional or unintentional was later validated in our discussions with the respondents.

Thirteen (13) of the 15 respondents report some type of estimate distortion, most of them report both increase and decrease of estimates. Further, although the focus of this study was not on exploring how common estimate distortions were, the respondents indicated that they were not uncommon, which is in line with the findings of Glass et al. (2008).

In the two following sections we will discuss underlying reasons for intentional increase and decrease of estimates that constitute distortions, thus changes that are not explained by legitimate changes due to new prerequisites for the project, e.g. new knowledge.

5.2. Intentional increases of estimates

Increase of estimates was reported by 11 different respondents and all were described as intentional. In axial coding five unique reasons were identified for such distortions. Below we discuss them in turn.

The most commonly reported reason for estimate increase was *hiding other activities* in the estimated ones (called simply 'Hiding activities' in the table). Project managers were reported to add activities such as development of extra functionality or entire smaller projects in the estimates for larger projects. Or, as one of the interviewees stated: 'Small projects are sometimes hidden in the large ones'. The interviewees did however not consider hiding of entire projects in larger ones to be particularly common. An increase of the estimate that was indicated to be more common was reported from project teams that experienced that the estimated costs for the development of the functionality assigned to them were often too low. By increasing estimates they tried to 'buy' extra development time, to be used for example for testing or maintenance activities. But the actual tasks for which the estimates were increased and what it was made to hide differed among respondents, companies and even projects. For example, one of the respondents said: 'We increased the estimates for bug-fixing to buy time for development'.

Notable is that software is not the main product of several of the studied companies as the software is typically embedded in a mechanical product. The interviewees reported that the overall knowledge of software development processes in their firms was low outside the software development de-

partment. As an example the understanding of how uncertain software requirements are in the beginning of a project was reported to be low or even missing. Respondents described how this limited knowledge could make it easier to mask intentional increases, i.e. to distort. Often requirements are unclear or the requirements processes are immature which makes detection of estimate distortions more difficult. In this context, the hiding of other activities is made easier.

In a similar way, respondents reported that the limited knowledge about basic software development principles among project planners had been exploited by developers to increase estimates to *exclude functionality* considered superfluous. If developers thinks some functionality or product features are less urgent, less important or even unnecessary they would sometimes increase the estimates for these parts. The increased costs would make it more likely that project planners decide to remove the functionality or postpone it to later/future releases.

Another type of intentional increase reported in the interviews aimed at *avoiding overspending*. Some project managers were said to want to appear competent by ensuring that the estimate they provide was the worst case estimate and thereby would most likely be higher than the actual project outcome. Other project managers were said to intentionally add padding to their estimates in order to avoid re-estimation due to future changes in requirements. The re-estimation process or the post project analysis phase was by some respondents perceived as uncomfortable and one of the interviewees stated 'You don't want to make a fool of yourself' when explaining the reasons for estimate increase. Respondents stated that the skills of project managers can be questioned by the project planners or higher management in such situations even though it is well known that projects always change with regard to requirements and that some discrepancy should be expected. Because of this dynamic between higher management and project management the latter group intentionally increase estimates as a guarding mechanism to prevent themselves from being revealed as not being able to estimate. When the actual costs overrun the estimates it is more obvious, and more embarrassing, then when 'only' the estimates turn out to have been too high.

Another type of intentional increase of estimates was reported as line managers increasing estimates to increase the number of employees in their group or to save jobs of their staff, what we have collectively called 'job securing'. One of the respondents described this type of distortion further by saying: 'Line management's interests coincide with those of the co-located

development sites that wish to increase the number of employees at their site'. Another respondent explained reasons for job securing at different development sites as being more personally motivated: 'It is considered prestigious to have many employees in your group.' Yet another reason underlying this type of intentional increase was described by describing how the role of line managers is a difficult one where they sometimes have to lay off people in times of economic downturn or if the company loses and important customer. This can also lead to *job securing* behavior to avoid later frustration or difficult tasks.

Another respondent reported that project managers often do not have a holistic view of the company and resource distribution among projects, thus the interviewee perceived the project managers behavior as self-protective or even selfish: 'What they do as project mangers is most often quite selfish, (...) trying to get as much resources as possible.' We label this reason *myopic perspective* since they are considered to intentionally try to obtain as many resources as possible for their own project(s), disregarding what is best for the company at large.

A general remark about the intentional changes to estimates was that smaller project are more vulnerable to this since the estimates in large projects are scrutinized in much more detail before project execution. Some respondents even described how estimates in smaller project were not reviewed or discussed at all. This means that for smaller projects there is much more room for and thus opportunities for intentional distortions, whether increases or decreases, since fewer stakeholders will care about the relative size of changes as long as the total project duration is short.

5.3. Intentional decreases of estimates

Ten (10) of the interviewees reported that they have seen some evidence of *intentional decrease of estimates*. The overlap with respondents reporting increase in estimates was high but not complete.

The most frequently reported reason for this type of estimate change, and also one perceived as frequently occurring, was *management pressure* to lower the estimates. One of the interviewees stated: 'Estimates are often challenged by the upper management. We are told to deliver the same functionality cheaper.' Another respondent said: 'Upper management has better argumentation skills and they want development to be cheaper'. One of the tasks of development teams is to estimate changes in requirements such as removal of functionality. One respondent brought up this subject explaining

that: '(...) removal of functionality is always expected to lead to reduced costs. Certain functionality is a side-product of other and removing it does not decrease the costs'. Thus, it is difficult to decrease costs by removing functionality since there are so many interdependencies, yet, the request to decrease the total cost remains. As a consequence, the overall estimate must be decreased without being able, more or less, to actually remove any functionality. This in turn leads to an intentional decrease in estimate without obvious or rational reasons. The interviewee also said that developers in such situations feel the pressure to reduce the cost, which results in too low estimates for the rest of the functionality.

Another common reason for decrease in estimates was reported to be the intentional 'selling' of ideas for a project or for features/functionality (*selling ideas*). Respondents described lower costs as generally more preferable to higher management and project planners, see *management pressure* above. Accordingly, some project managers were reported to deliberately underestimate the costs in order to make their projects or ideas more 'cost attractive' and thereby more likely to be selected. This 'selling' of ideas to higher management and product planners is a deliberate activity. Some of the interviewees said that when the money runs out in the projects, more money is almost always possible to add and most often gets added. So, project managers know that an already started project will be finished anyhow, which opens up for this type of behavior since it is more important to get the project started than what the actual costs later will be.

5.4. Intentional changes with varying direction

Some intentional changes to estimates can be both increases or decreases, i.e. their direction varies with the context, stakeholders and individuals involved. An example of such a distortion is a situation where one of the stakeholders decreases the estimates prior to a negotiation, while the other one does the opposite. The increase and/or the decrease has its roots in the perception of a type of 'negotiation game' and thus is not related to the estimate or available information as such. This type of estimate change was reported by 12 respondents and perceived as common. 'There is a political game that everybody knows and plays', one of them stated, indicating that these changes are intentional actions that are taken independently of what is to produced and the relevant estimate for that. As an illustration, in preparations for *negotiations*, estimates are sometimes increased and sometimes decreased depending on the source of the estimate. One of the interviewees

said: 'You know your estimates will be lowered by the higher management'. Another respondent expressed this as: 'Since developers know product planners will try to lower the costs, they prepare by increasing them'. As can be seen this is related to the previously discussed *management pressure* distortion; however respondents here describe how the meetings and discussions creates an arena for discussing and questioning estimates which is different from the more one-sided distortion discussed above.

Another reported reason of changed estimates in this category was an underlying intent to promote oneself by for example impressing the higher management (personal agendas). One of the interviewees explained this: 'Project managers want to prove themselves in front of upper management'. A similar issue was brought up by another respondent that spoke of project managers wanting to improve their careers and build networks, e.g. with important individuals to be used in later potential political games. Whether such an intent, to impress on management or promote yourself, was fulfilled by an increase or a decrease of the intent varied with the specific situations. In some cases it was perceived as being impressive of running a large (and costly) project and in other the ability to run a project cost efficiently was what promoted the project manager.

The striving to follow different types of agendas, such as protecting interests of development sites, project teams, or customers, is another reported reason for estimate changes (organizational agendas). Product planners were reported to change the estimates as they were affected by the customers that e.g. need sooner delivery or by the product brands that needed to lower product costs.

Another issue perceived as common was *disregarding uncertainty* by the use of point estimates instead of an interval estimate. Respondents pointed out that interval estimates in addition to providing the most likely outcome also reflected the good (everything goes according to the plan) and bad (many of the foreseen risks affect the estimates) outcomes of the project. Two of the interviewees stated that it should be obvious to everyone that point estimates cannot be seen as promises since requirements are uncertain and often change during project execution. However, when later asked whether their estimates are questioned in the light of the results (projects are often more expensive than estimated) the two respondents stated that the first estimates are indeed often seen as promises.

Estimates were also reported to be derived directly from budgets (*budget determined*) bypassing the estimation process. One of the interviewees told

us that instead of spending time on estimation, some of the more experienced managers would ask for the budget and make that budget their estimate. This is clearly an intentional change.

Among the intentional distortions with varying direction the respondents also described an interplay between some of the distortions. The interviewees reported that individuals are, in their estimations, affected by their surroundings, e.g. development sites (*organizational agendas*) or own *personal agendas*, e.g. advancing in their careers. The organizational and personal agendas were, in themselves, reported to lead to estimate *negotiations* between organizational units and levels. One of the interviewees also reported a covert bidding between development sites where estimates were lowered in order to affect the decision of which site would get to develop certain functionality.

5.5. Unintentional distortions

Four different unintentional distortions in the estimation process was described in the interviews, two as leading to decreased estimates and two as leading to either an increased or a decreased estimate depending on the source of the estimate. However, for these distortions the distinction to the normal changes that need to happen during a project is less clear than for the intentional distortions described above. For example, the *misunderstanding requirements* distortion can in some situations be a normal legitimate change when we learn more about the product and its intended uses. However, since respondents described it as the information being available but someone making a mistake we have characterized it as an unintentional distortion.

Risks and tasks are sometimes overlooked and not included in the estimates (*missed risks/tasks*), leading to unintentional decreases in estimates. For instance, according to one of the interviewees, important risks can be rated as unlikely when the risk information is discussed and documented by project teams. When the risks as perceived by different development teams are summarized and forwarded to the higher management, it is the highest ranked risks that are summarized for each team excluding risks that are marked as less severe or less likely to occur. As described by the respondent, there was no intentional tampering with this process or actions taken that directly lead to risks being overlooked or information missed. However, it still lead to decreased estimates.

Two project managers recognized *optimism* as a bias that affects their subordinates which makes them produce too low estimates. Interviewees

only reported this bias as something that occurred in other people s behavior. They believed that optimism could not be avoided as it is unconscious and most people are not aware of how it affects their estimates. This is a type of unintentional distortion that clearly is more related to an individual stakeholder's general disposition or personality than to any intentional choices.

Misunderstanding of requirements and *Inexperience* are two factors that were reported to change estimates as well, neither of them was considered intentional and the direction of their effect varied. There are likely to be several other unintentional estimate distortions than those reported here; their absence in the results of this study depends on the study design where the focus was on exploring the estimate distortions of intentional type.

6. Discussion

Our results show that both intentional and unintentional distortions in the cost estimation practice exist that are related to other areas than the estimation as such. The underlying reasons for such estimate distortions are many and are found in increases or decreases in the estimates or both, depending on the particular situation and the stakeholders involved. Comparing our results to previous work by Lederer and Prasad (1991) (Lederer et al., 1990; Lederer and Prasad, 1995), we have added a richer description of the current state of the estimation practice including reasons for intentional estimate distortions, and conditions that make them possible. We have also linked the distortions with directions of the change they entail.

Estimation research has to a large extent focused on improvement of technical aspects (methods and tools). As has been extensively established by Jørgensen and others (Jørgensen et al., 2004) (Grimstad and Jørgensen, 2007) (Aranda and Easterbrook, 2005) the humans involved are essential as they are affected by many cognitive biases that affect the estimation processes. Our results complement this view by showing not only that such biases need to be taken into account; humans involved in software cost estimation can also intentionally distort estimates for reasons beyond the estimation as such. They can increase or decrease the estimate in order to gain benefits that are not directly related to the estimation process as such. This means that a technically improved model for estimation will not suffice in order to understand and potentially improve estimation inaccuracy. The inaccuracy also has deep roots in the deliberate changes of the estimates that results from the

personal and organisational agendas as well as concrete processes and incentives important within the organisation. Since these factors will remain it is likely that the inaccuracies will also remain despite excellent tools and models and a deeper understanding of the unintentional changes or unconscious biases. Rather, we need an even more detailed understanding of the overall estimation context and the opportunities that estimation opens up for. A recurring theme in our interviews was also the complex interdependence between the estimation task, the stakeholders involved, the overall process and the organization itself. Software cost estimation can thus not be viewed as an isolated event and studied out of context.

Below we discuss the factors behind the distortions that our interviews uncovered in more detail. We then elaborate on what our findings imply for an updated and more realistic view of software cost and effort estimation. Finally, we discuss threats to the validity of our results.

6.1. Distortional behaviors and underlying factors

We used the direction of the estimate as a dimension for categorizing the distortions that our respondents revealed: does the behavior lead to an increase, a decrease or can it lead to both depending on the situation and people involved? While Lederer and Prasad (1991) used the terms padding and shrinking to denote increase or decrease, respectively, we have opted to avoid these terms since it is not clear how they combine with the dimension of intentionality. The meaning of 'to pad' is clearly attached to an intention while the meaning of 'to shrink' may not be. Instead we have chosen to bring forward the notion of distortion and that such distortion may be intentional or unintentional.

In terms of intentionality, it is worth underlining that we make a distinction between what could be read (interpreted) out from the transcripts as to intentionality and what was actually stated by the respondents. Reading and interpreting the transcripts implies that there may be a larger extent of intentionality than was explicitly stated by the respondents. In this study we have chosen to keep to what was either directly stated or clearly implied by the interviewees, as explained in the methodology section. Since respondents seldom talked about a certain behavior as their own but rather talked in terms of other persons' behavior they, we argue, showed knowledge about deliberate intents to either increase or decrease the estimate due to factors other but the estimation process. Some of the reasons for intentional distortions described above can be argued to be of a personal nature (e.g. personal

agendas), others might be intended to benefit the company, project or the product, e.g. improving the product by adding functionality one perceives as important (selling ideas or excluding functionality). Thus, we note that the question about intentionality is not an easy one and will need to be expanded upon in future work. Here, we have chosen to use the respondents' own intentionality judgments for our classifications and we have chosen not to value the underlying reasons for the distortional behaviors we found.

We found a number of different underlying reasons for deliberate changes of the estimates, reasons that are found outside the estimation context and that mirror other areas of interest than estimation. The estimate is thus mainly used for other purposes, or in other words, used politically. These deliberate actions in the estimation process are though important for understanding the role estimation plays in the firm and subsequently for how to improve the estimation activity. The literature about organizational politics and effort estimation reports that managers or organizational members in general (consciously or unconsciously) employ tactics to improve their image and career possibilities. One such tactic is masking uncertainty with (overly) high confidence (Jørgensen et al., 2004) (Vardi and Weitz, 2003). Political skills are somewhat contradictory perceived; despite that political behavior in general is considered undesired, it is simultaneously perceived as a skillful manner by higher management (Jørgensen et al., 2004). Often it is thereby also needed in matrix organizations where project managers need to promote their ideas and compete for resources needed to finish their projects (Pinto, 2000). So, many of the reasons for intentional distortions presented in this paper are connected to resource negotiations and bargaining and to the relation to higher management and the pressure put on project teams by higher management, thus outside the estimation process. This type of 'political behavior' is both common and needed in project planning activity, and successful project managers are both aware of it and willing to use it (Buchanan, 2008). There is most likely no easy ways to avoid organizational politics implying there will always be political behaviors. Therefore, it is important that such behavior is explicitly considered and accounted for in both estimation research and practice.

6.2. The complexity of estimation and future work

In view of already existing perspectives, our results imply a need for an updated, more contextual, understanding of estimation in software development. Future work needs to consider several different aspects in how an

estimate is developed and how it emerges, i.e. both refined and distorted.

From a practical point of view, there is a strive for producing estimates that developers and managers act upon to be as accurate and relevant as is theoretically possible using the available information. Such an ideal estimate would still be uncertain, reflecting the uncertainty of the requirements etc, and initial estimates would thereby still change during the course of a project. Methods and tools are subject to deficiencies and not all information is available; an individual or group is unlikely to form an ideal estimate. But even if the best expertise and estimation methods and tools were applied, intentional distortions and biases would affect the outcome, and the reliability, of the estimation process. The results of this study further establish and detail that there are different types of intentional distortions that are driven by factors outside of the estimation process itself.

Much of the research on cost and effort estimation does not consider intentional estimate distortions. Rather, it is often assumed that firms and their employees have a goal of producing an honest forecast of effort needed to complete the task. In this paper we argue that this is seldom the case since estimates are often used for purposes outside the estimation context., e.g. safeguarding the number of employees, ensuring project proceeding or even impressing actions towards upper management. There are several different interests that lead to intentional distortions occur in the estimation process, making them an important factor to consider when both understanding and seeking to improve the estimation practice. Even though this has been investigated in previous research already twenty years ago by Lederer and Prasad (1991, 1995), our results show that this is still valid in modern organisation developing software-intensive products. Our result also point at the underlying reasons for the distortions; the context is the key in understanding what motivates the distortional behaviors and analysing the stakeholders, their agendas at different levels (personal, organisational) and their interplay. Unintentional, cognitive distortions such as e.g. *optimism* also hint at not only personal agendas being important but possibly also at the personalities of the people involved as has been investigated by for example by Feldt et al. (2010). In future research, deeper models both of the humans involved but also of software practitioners' motivation (Sharp et al., 2009) and group dynamics should be investigated. Future work should also strive to create models that unify the many elements and distortions discussed above.

6.3. Validity discussion

Although most of the steps in the empirical study were carried out by one of the authors, design, coding and analysis of the results were reviewed by and discussed and refined together with the two other authors in order to ensure credibility (Lincoln and Guba, 1985). If the interviews are not tape-recorded the answers need to be summarized by the interviewer parallel to the ongoing conversation. Summarization implies reduction of the information provided by the respondent, and thus importance of the information needs to be interpreted at an early stage. To avoid interpretation during the interviews the conversations were tape-recorded.

The subject described in this paper has not been well explored prior to this study, the study is of explorative nature and generalizability cannot be ensured. However, we have tried to overcome this by including multiple companies and roles when selecting interviewees. While the estimate distortions reported here appear to be common and likely transferable (transferability, see Lincoln and Guba (1985)), a quantitative investigation would provide more insight in how common they are in a more general setting.

To ensure dependability (Lincoln and Guba, 1985) complete records of the material were kept, including interview recordings, transcripts and the results of the two coding steps. The interview transcripts and coding are in Swedish.

The early results of this study were presented in a seminar were the respondents at two of the participating companies together with their colleagues were invited for discussion. Based on the questions asked by the audience during the seminar and the discussion that followed the presented issues were confirmed (confirmability, see Lincoln and Guba (1985)) by the participants.

Although we employed several countermeasures to account for validity threats (Feldt and Magazinius, 2010) that could be foreseen in this study, some of them could not be mitigated. As the topic of intentional estimate tampering is sensitive, respondent bias was to be expected and the respondents were likely to apply mechanisms that would help them control their image. The interviewer was on one occasion also asked to turn off the tape-recorder, but the information provided during the "off the record" conversation was mainly company specific. Most of the respondents have long experience of estimation practice and we believe that they are familiar with the investigated concepts and willing to discuss them. This is partly supported by the fact that one of the interviewees that reported no distortions

was also the youngest and least experienced among the interviewees. The terminology used by the interviewees when describing development and estimation processes is often company specific and can be difficult to adapt to quickly for the interviewer, which can lead to misunderstandings. However, we tried to overcome this threat by studying company-specific documentation on processes before conducting the interviews.

7. Conclusions

Cost estimation is an indisputably important activity for planning, follow-up and control of projects, especially in large organisations and when developing complex, software-intensive systems. However, cost and effort estimation is also used for other purposes such as protecting the head count in projects or organisational units or to ensure the continuation of a project.

In this paper we have specifically investigated behaviors in software cost estimation processes that have purposes other than the accurate and effective estimation itself, i.e. behaviors that rather distort the process that aims to create accurate estimates. Through an exploratory interview study with 15 practitioners in six large organisations developing software-intensive systems we have found that intentional distortion of estimates is both common, has multiple different reasons and leads to either or sometimes both, increased or decreased estimates.

The paper contributes in several ways: Firstly, compared to previous work by Lederer and Prasad (1991, 1995), we add a richer, empirically based description of the present-day organisational reality of cost estimation. We also describe reasons to why intentional distortions occur and conditions that make them possible. Secondly, we highlight the need for contextualizing the estimation process so that also purposes beyond estimation are considered when aiming at understanding the barriers and challenges in improving estimation in software development.

We argue that estimates produced by experts or estimation methods/tools are seldom used as a direct input to estimate and budget discussions. Instead, political behaviors that distort estimates, such as resource negotiations and image management, are perceived as common and often even necessary for stakeholders in the estimation process. This makes an estimate not only a planning tool but also a tool in the game of organizational politics. Future estimation research and development of new estimation practices should

therefore encompass this richer view, context and set of factors or they risk leading to only partial or unsustainable improvements.

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