An Empirical Study of Software Project Bidding

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***Abstract**: The study described in this paper reports from a real-life bidding process in which 35 companies were bidding for the same contract. The bidding process consisted of two separate phases: A pre-study phase and a bidding phase. In the pre-study phase 17 of the 35 bidding companies provided rough non-binding price indications based on a brief, incomplete description of user requirements. In the bidding phase, all 35 companies provided bids based on a more complete requirement specification that described a software system with substantially more functionality than the system indicated in the pre-study phase. The main result of the study is that the 17 companies involved in the pre-study phase presented bids that were on average about 70% higher than the bids of the other companies. We propose a preliminary theory that has the potential to explain this difference. This preliminary theory is based, amongst other things, on the "precautionary bidding effect" found in auctioning studies. Two important implications of our preliminary theory are that: 1) Software clients tend to achieve better price/uncertainty relationships, i.e., better prices, when the requirement uncertainty perceived by the bidders is low. 2) Software clients should not request early price indications based on limited and uncertain information when the final bids can be based on more complete and reliable information.*

1 Introduction

Bidding for contracts is a crucial part of today's software development business. For a company to survive it has to provide bids that are low enough to get contracts, while high enough to make profit. This bidding process is complex, as can be illustrated by the process suggested by (Kerzner 2003, p 513):

1) *Develop a cost model and estimating guidelines; design proposed project/program baseline for minimum cost, to minimum client requirements.*
2) *Estimate cost realistically for minimum requirements.*
3) *Scrub the baseline. Squeeze out unnecessary costs.*
4) *Determine realistic minimum costs. Obtain commitment from performing organizations.*
5) *Adjust cost estimate for risks.*
6) *Add desired margins. Determine the price.*
7) *Compare price to client budget and competitive cost information.*
8) *Bid only if the price is within competitive range.*

Even the rather comprehensive and complex process described by Kerzner does not give much support in important bidding issues, e.g.:

- *Issues not related to price*: The clients do not just evaluate price, but base their evaluations on their belief in the software providers' skill, their perceptions of the quality of the proposed solutions, their perceptions of the risk involved, and time schedule issues. This means, for example, that smaller companies may have to provide lower bids than larger companies to win a contract in situations where the clients believe that there is a higher risk connected with the selection of a small company.

- *Long-term benefits*: The long-term benefits of establishing a relationship with a client and gaining experience with a product may in many cases be more important than a short-term profit. Examples of long-term benefits are maintenance and enhancements of existing projects, use of a client as a reference client, increased probability of winning future contracts, and learning effects.
- *Alternative use of resources*: The alternative use of resources is important. Sometimes the alternative to getting a contract based on a loss-generating price may be a high probability that costly resources will not be used, resulting in even larger losses.
- *Client flexibility*: A frequent cause of cost overruns is requirement changes during the project that cannot be billed to the client (Jørgensen and Moløkken 2004). Some clients are tough negotiators regarding requirement changes, others are more flexible. This type of information may be important when deciding on a bid.
- *Compensatory actions*: Companies may offer additional functionality or services, e.g., a shorter delivery time than requested by the client. This may compensate for a higher price or other disadvantages of a software development company.
- *The price defines the project*: A bid based on a vague requirement specification may be considered to define the project just as much as reflecting the needs (Jørgensen and Sjøberg 2001). If the client accepts a high bid, it affects how the specification is implemented. An implication of this is that the important issue for clients and bidders is to find the "best price", not the "lowest price".

There are, as far as we know, no empirical studies on how software companies actually perform the bidding. However, there are studies in similar domains which suggest that the complexity of the bidding process implies an extensive use of managerial experience and judgment, e.g., the study of bidding in versatile manufacturing companies in (Kingsman and Souza 1997). In other words, it may be difficult to replace judgment-based bidding with formal bidding models. Formal bidding models may nevertheless play an important role, e.g., as a simulation tool when examining different bidding strategies (Kitchenham, Pickard et al. 2003).

The inherent complexity in bidding, combined with the need for human judgment, suggest that bidding processes may easily get impacted by irrelevant information. One potential effect is so-called "anchoring"[1]. Anchoring in software cost estimation contexts is examined in (Jørgensen and Sjøberg 2001; Jørgensen and Sjøberg 2004). An implication of anchoring in software estimation contexts is that irrelevant information, e.g., early, too low, estimates based on limited information, may have large and unwanted impacts on the cost estimates. The anchoring effect on cost estimates seems to be largely

[1] In Armstrong, J. S., Ed. (2001). Principles of forecasting: A handbook for researchers and practitioners. International series in operations research & management science. Boston, Kluwer Academic Publishers, anchoring is defined on page 764 as: "*The tendency of judges' estimates to be influenced when they start with a 'convenient' estimate in making their forecasts. The initial estimate (or anchor) can be based on tradition, previous history, or available data.*"

unconscious, e.g., the estimators may not notice the extent to which their estimates are affected by irrelevant anchoring information.

The study described in this paper aimed at following up the results of those two previous studies on anchoring effects in estimation contexts (Jørgensen and Sjøberg 2001; Jørgensen and Sjøberg 2004) and was initiated by our desire to answer the following research question:

What is the impact of an early price indication, based on a sub-set of the final requirement specifications, on the final bid?

Based on the previous studies we expected an early price indication to act as an anchor in bidding situations similarly to the previously studied estimation situations. When the initial price indication was based on a requirement specification that described a smaller system than the final requirement specification, we would consequently expect the early price indication to lead to lower bids.

The remaining part of the paper is organized as follows: Section 2 describes the design of the bidding study. Section 3 describes the results from the study. Section 4 discusses the findings and proposes a preliminary theory. Section 5 concludes the paper.

2 Design of Study

2.1 Bidding Process

The study examines project bids made by 35 Norwegian and international software companies. We selected the companies so as to ensure that the studied sample of companies included large, medium, and small development companies operating in Norway. In respects other than company size, the selection was based on random draws from the population of software development companies operating in Norway.

None of the companies had previous relations to the client that could affect the bids. The high number of bidders (35 companies) was to some extent motivated by research needs and we, for that reason, we decided to pay the bidding companies for their bidding work. The bidding companies were informed that we would select *at least* one of them as provider, perhaps more than one. The bids were related to the development of a database of research studies at Simula Research Laboratory (where both authors work). We did not inform the bidders about which other companies we had invited to join the bidding process.

The software companies were randomly divided into two groups, with 17 companies in Group A and 18 companies in Group B. The bidding process was conducted as follows:

1. *Pre-study phase*: The software companies in Group A were instructed to sketch a solution, suggest ideas, and provide rough (non-binding) prices for a software application, based on a brief one-page description of user needs. Group B companies did not participate in this phase. The responses from the Group A companies were received three weeks after they were sent the pre-study documentation. We required

that all discussion about requirement and solution during this three-week period should be based on e-mail discussions. Each company was paid NKR 5000 (approx. 600 Euro) for their participation in the pre-study. Appendix 1 includes an excerpt of the instructions and the description of user needs applied in the pre-study phase.

2. *Development of the final requirement specification*: Based on the suggestions from the pre-study output and our own judgment, we (the client) wrote the final, eleven-pages long, requirement specification[2]. This requirement specification described an application with substantially more functionality and more complexity than the application suggested by the pre-study description of needs, e.g., we now wanted the database to be integrated with the company's existing intranet as opposed to the stand-alone application indicated in the pre-study description. This increase in functionality and complexity enabled us to study the effect on the final bid of an initial price indication on a smaller system on the final bids.
3. *Bidding round phase*: The software companies in Groups A and B were instructed to give firm-price bids based on the final requirement specification. This was our first contact with software companies in Group B. The Group B companies did not know that some companies, i.e., the Group A companies, had participated in a pre-study phase. The bids were received three weeks after the companies were sent the final requirement specification. The companies were paid NKR 5000 (approx. 600 Euro) for their participation in the bidding round, as in the pre-study phase. The instructions in the bidding rounds were the same as those in the pre-study (see Appendix 1), except that the brief description of user needs was replaced with the final requirement specification, and that we requested bids instead of price indications.

Subsequently, we selected four of the companies to implement the system. The reason for selecting more than one company was related to research goals different from those in our study, e.g., studies of effects of different design methods. We report the deviation between the estimated work-hours (as indicated in the bidding documents) and the actual work-hours of those four companies in Section 3.3. Other results from the study of the four implementations of the system will not be discussed in this paper.

Finally, we de-briefed the companies about how we had selected the four companies. As part of the de-briefing we included a few questions related to better understanding of the results of the study.

2.2 Participating Companies

Table 1 describes the size, the application-related experience, the technology-related experience, and, the proposed development method of the participating companies. This information was based on the pre-study phase and bidding documents. The categories we applied are as follows:

- Company Size (CompSize): Small = 5 or fewer developers, Medium = 6-49 developers, Large = 50 or more developers. (*These categories are somewhat arbitrarily set, and mainly reflect the situation in Norway, as perceived by the authors of this paper.*)

[2] The final requirement specification will be sent to interested readers upon request to one of the authors.

- Experience with Relevant Applications (ExpApp): Yes = There were references to similar projects described, No = No reference to similar projects were described.
- Experience with Technology (ExpTech): Good = Company claims to have employees with experience with all parts of the technology, Some = Company claims to have employees with experience with some parts of the technology.
- Proposed Development Method (DevMeth): Waterfall = Any sequential, non-iterative and non-incremental method, IncIt = Any incremental or iterative method (e.g., RUP).

Some fields are marked with "NP" (not provided), which means that we were not able to extract information about the variable from the documents provided by the companies.

Table 1: Companies

Group	CompId	CompSize	ExpApp	ExpTech	DevMeth
A	1	Large	Yes	Good	IncIt
A	2	Large	Yes	Good	Waterfall
A	3	Small	No	Some	IncIt
A	4	Small	Yes	NP	NP
A	5	Small	Yes	NP	Waterfall
A	6	Large	No	NP	IncIt
A	7	Medium	Yes	NP	IncIt
A	8	Large	Yes	NP	IncIt
A	9	Medium	Yes	Some	IncIt
A	10	Small	Yes	Some	IncIt
A	11	Medium	Yes	Good	Waterfall
A	12	Medium	Yes	NP	Waterfall
A	13	Small	Yes	Some	Waterfall
A	14	Medium	Yes	Good	Waterfall
A	15	Large	Yes	Good	IncIt
A	16	Medium	Yes	Some	Waterfall
A	17	Medium	Yes	Some	Waterfall
B	18	Medium	Yes	NP	Waterfall
B	19	Medium	Yes	Good	Waterfall
B	20	Small	Yes	Some	Waterfall
B	21	Small	No	Some	NP
B	22	Medium	No	Some	IncIt
B	23	Small	Yes	Good	Waterfall
B	24	Medium	No	NP	Waterfall
B	25	Medium	No	Good	Waterfall
B	26	Large	No	Unknown	IncIt
B	27	Large	No	Unknown	IncIt
B	28	Medium	Yes	Good	IncIt
B	29	Medium	Yes	NP	NP
B	30	Large	Yes	Some	Waterfall
B	31	Medium	Yes	Good	Waterfall
B	32	Large	Yes	Good	IncIt

B	33	Small	Yes	Some	Waterfall
B	34	Small	No	NP	NP
B	35	Small	Yes	Some	Waterfall

Table 2 summarizes the characteristics of the companies of Group A and B.

Table 2: Comparison of Group A and B Companies

Group	**CompSize**	**ExpApp**	**ExpTech**	**DevMeth**
A	Large: 29% Medium: 47% Small: 24%	Yes: 88% No: 12%	Good: 29% Some: 35% NP: 35%	Waterfall: 47% IncIt: 47% NP: 6%
B	Large: 22% Medium: 44% Small: 33%	Yes: 61% No: 39%	Good: 33% Some: 33% NP: 33%	Waterfall: 56% IncIt: 28% NP: 17%

Table 2 shows that there were no large differences in company size (CompSize), experience with technology (ExpTech) or proposed development method (DevMeth) between the two groups. There is, however, a difference in the documented experience with development of similar applications (ExpApp). We should therefore not exclude the possibility that the Group A companies are slightly more experienced and include this possibility in the analysis of the resulting bids. This difference in ExpApp is a result of the random allocation of companies to the Groups A and B. Although random allocation is a proper and simple allocation method, randomness provides no guarantee that the groups will be similar regarding all potentially relevant aspects.

3 The Results

3.1 Pre-study Phase

As described earlier, only the 17 Group A companies participated in the pre-study phase. Based on the brief information about the user needs (see Appendix 1) the companies outlined solutions and provided price indications. All companies seemed to base their price indications on expert judgment, i.e., there was no indication of use of formal estimation or pricing models. Table 3 shows the non-binding price indication (PriceInd) of the Group A companies.

Table 3: Pre-study Information

CompId	**PriceInd (NOK[3])**
1	352 800
2	289 000
3	140 400
4	145 000
5	55 650

[3] 100 Norwegian Kroner (NOK) is (Jan. 11, 2004) about 11.6 Euro. This means, for example, that the mean price indication (PriceInd) was about 21 300 Euro.

6	155 362
7	225 000
8	218 700
9	76 900
10	286 000
11	128 000
12	76 500
13	79 000
14	112 000
15	104 800
16	120 000
17	546 750
Mean	**183 051**
Median	**140 400**
Std	**126 943**
Min	**76 500**
Max	**546 750**

The proposed solutions showed that there was a high variance in how the different companies would have implemented the system, e.g., some of the companies wished to apply pre-made components or tailor commercial publishing systems to fit the requirements. These differences in proposed implementation, together with differences in productivity and other matters, led to price indications ranging from NOK 55 650 to NOK 546 750, i.e., the highest price indication was about ten times higher than the lowest.

3.2 Bidding Phase

Table 4 shows data collected in the bidding phase where:

- *Delay* categorizes the companies' delivery behavior in the bidding process: No = Company delivered the bid and other information on time, Yes = Company did not deliver the bid and other information on time.
- *Completeness* is based on an evaluation of whether or not the proposed solution met the requirements. The evaluation was completed by two software professionals with experience in evaluating similar solutions. These professionals were different from the researcher who designed the study and analyzed the data.
- *Bid* is the companies' bid (price) in Norwegian Kroner (NOK).
- *Increase* is the percentage increase from the pre-study price indication (Group A companies only) to the bid.

Table 4: Bidding Data

Group	CompId	Delay	Completeness	Bid (NOK)	Increase
A	1	No	OK	455 200	29%
A	2	No	OK	552 500	91%
A	3	No	Not OK	148 050	5%

A	4	Yes	Not OK	145 000	0%
A	5	No	Not OK	79 500	43%
A	6	No	OK	271 160	75%
A	7	No	OK	276 000	23%
A	8	No	OK	306 900	40%
A	9	No	OK	207 500	170%
A	10	No	OK	418 500	46%
A	11	No	OK	202 500	58%
A	12	No	OK	215 000	181%
A	13	Yes	OK	95 000	20%
A	14	No	Not OK	270 000	141%
A	15	No	OK	229 600	119%
A	16	No	OK	363 000	203%
A	17	No	OK	486 000	-11%
B	18	No	Not OK	97 500	
B	19	No	OK	559 500	
B	20	Yes	Not OK	168 750	
B	21	No	Not OK	21 000	
B	22	No	OK	232 000	
B	23	No	Not OK	206 510	
B	24	No	OK	39 780	
B	25	No	Not OK	231 600	
B	26	Yes	Not OK	133 000	
B	27	No	Not OK	268 200	
B	28	No	OK	70 000	
B	29	No	Not OK	39 000	
B	30	Yes	Not OK	266 000	
B	31	No	OK	207 872	
B	32	No	OK	160 000	
B	33	No	OK	94 500	
B	34	No	OK	35 000	
B	35	No	OK	160 140	

The mean increase from the pre-study price indications to the bidding round bids was 73%. This suggests that the final requirement specification was perceived as describing a substantially larger system than the description in the pre-study phase. It is, however, interesting to notice the large variation in increase from -11% (perceived decrease) to 203%.

Table 5 summarizes the bidding characteristics of the two companies in the two groups.

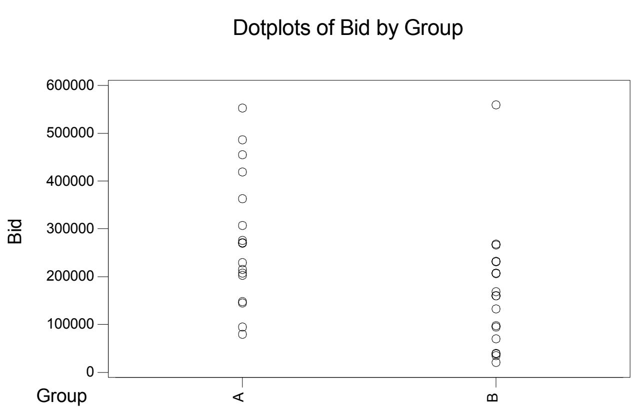
Table 5: Comparison of Group A and B Companies

Group	Delay	Completeness	Bid (NOK)
A	No: 89% Yes: 11%	OK: 76% Not OK: 24%	mean: 277 730 median: 270 000 std: 137 472 min: 79 500 max: 552 500
B	No: 83% Yes: 17%	OK: 50% Not OK: 50%	mean: 166 131 median: 160 700 std: 127 827 min: 21 000 max: 559 500

Table 5 suggests that there are important differences between Group A and B companies:

- Group A bids are systematically higher than Group B bids (see Figure 1). The effect size[4] (Cohen 1992) of this difference is 0.8, i.e., the difference is large even when adjusting for the high variance in bids. This observation is the principal result of this study. The difference in bids is the opposite of what we expected based on our earlier studies on "anchoring", i.e., while we had expected Group A companies to have the lowest bids they turned out to have the highest bids.
- The proportion of acceptable proposals (Completeness = OK) is larger in Group A (76%) than in Group B (50%), which indicates that it is not unlikely that an early involvement (pre-study involvement) increases the probability that a proposal will be acceptable. However, this difference does not explain the difference in bids. In fact, when considering only the companies with complete proposals the difference in bids get even larger! The mean bid of Group A companies with Completeness = OK is NOK 313 758, while the mean bid of Group B companies with Completeness = OK is NOK 173 199.

Figure 1: Bids of Group A and Group B companies

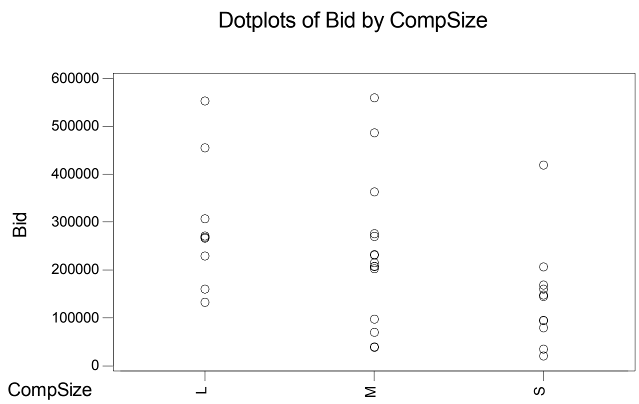


[4] Effect size (d) is defined as: $(mean_A - mean_B)/\sigma$

We conducted several exploratory analyses of company-related factors that potentially could explain the difference in bids or reveal interesting bidding relationships.

Analysis of impact of size category of company: There was a strong relationship between the size of the company and the bid, see Figure 2, where L = Companies with 50 or more developers, M = Companies with 6-49 developers, and, S = Companies with 5 or fewer developers. As can be seen in Figure 2, the larger companies tended to make higher bids. The mean bid of "large" companies was NOK 293 618, "medium" companies NOK 233 150, and, "small" companies NOK 142 905. However, the similarity in distribution of large, medium and small companies in the Groups A and B (see Table 2) means that difference in size cannot explain the difference in bid.

Figure 2: Bid of Companies of Different Size (CompSize)



Analysis of impact of development method: There was no difference in mean bid related to the use of development methods. The mean bid of companies applying the waterfall method was NOK 244 316, while the mean bid of companies applying an incremental or iterative method was NOK 238 647. Development method therefore cannot explain the difference in bids between Group A and Group B companies.

Analysis of impact of experience with relevant technology: Less experience with relevant technology (ExpTech) was connected with lower bids, i.e., NOK 221 703 vs NOK 285 935. However, this difference seems to be explained by the smaller size of the companies with "Some" compared with those with "Good" technological experience, i.e., comparing bids and ExpTech for companies of similar size removes the difference. ExpTech cannot explain the difference in bids between Group A and B companies.

Analysis of impact of experience with development of similar applications: Less documented experience from similar applications (ExpApp) was also connected with *lower* bids, i.e., mean values of NOK 153 310 vs NOK 243 537. In contrast to the ExpTech relationship, this relationship cannot fully be explained by company size. The companies with ExpApp = "No" had the lowest bids even when comparing companies of similar size only, i.e., lack of experience seems to be an indicator of low bids! This, in some respects surprising, effect due to lack of experience, may be have been caused by a strong desire to win the contract to achieve such experience. Alternatively, it may have been caused by a lack of ability to understand the complexity of the application. An examination of the data shows that the difference in ExpApp cannot explain the difference in bids between Group A and B companies. Considering, for example, the companies with previous application experience (ExpApp = “Yes”), the difference between Group A and Group B companies remains almost as large as before (mean values of NOK 286 813 vs NOK 184 525).

In short, none of the examined company-related variables were able to explain the difference in bids between the Group A and Group B companies. Section 4 examines possible effects brought about by the bidding *process*.

3.3 Implementation Phase

As described in Section 2.1, we selected four companies to implement the system. These companies were partly selected on the basis of price and partly on the basis of other properties, such as quality of proposed solution and appropriateness of development process, i.e., the companies were *not* selected to represent two typical Group A and two typical Group B bids. Hence, we should be careful when interpreting the results. Table 6 provides information about the deviation between estimated effort, as presented in the bidding document, and the actual effort. To preserve anonymity we have not included information that enables a link from these data to the bidding data.

Table 6: Deviation Between Estimated and Actual Effort

Company	Group	Effort Overrun[5]
I	A	15%
II	A	156%
III	B	130%
IV	B	174%

All solutions satisfied the acceptance tests regarding functionality and quality. Results from the parallel implementation of the system other than those presented in Table 6 will not be presented in this paper.

As can be seen in Table 6, one Group A company and two Group B companies under-estimated the work strongly and probably made losses on the contract. The average deviation of the two Group A companies is 85%, while the average deviation of the two Group B companies is 152%, i.e., the average deviation is much lower among the two Group A companies. This is, however, nothing more than a very weak indication of a difference, since the number of data points is low, and the four companies were not necessarily representative of their group.

[5] Effort Overrun = (Actual Effort – Estimated Effort) / Estimated Effort)

4 Impact of the Bidding Process

In Section 3 we reported that the companies participating in the pre-study and then the final bidding round (Group A companies) tended to have higher bids than the companies only involved in the final bidding round (Group B companies). This section discusses potential process-related reasons for that difference. We begin with a report of the reasons for the difference provided by the bidders themselves (Section 4.1). Then, we present an experiment that repeats elements the bidding study with an experimental design similar to that applied in two previous studies on anchoring effects (Jørgensen and Sjøberg 2001; Jørgensen and Sjøberg 2004) (Section 4.2). The purpose of the experiment is to examine whether the lack of anchoring effect in our bidding study was due to the difference between a real life *bidding* context, and an experimental *estimation* context, or to the particular project chosen in our bidding study. Finally, we suggest a simple and preliminary theory of how the requirement uncertainty affects the bids (Section 4.3).

4.1 Reasons for Difference in Bids As Perceived By the Bidders

As part of our de-briefing with the bidders, we had brief telephone-based meetings with all persons responsible for the bidding. The de-briefing included a report of the observed difference in bids between Group A and B and a request to provide reasons for the difference. Nineteen of the 35 companies were able to provide meaningful reasons for the difference between Group A and Group B company bids. The other companies mainly provided reasons for the size of their bid only, or, could not see any reason for the difference.

The provided reasons, translated from Norwegian, are described in Table 6. We have categorized the reasons into four categories:

- MORE ESTIMATION WORK: Participation in the pre-study means that more time and effort is spent on understanding the user needs and analyzing different designs and architectures. The increase in insight due to more estimation work may lead to higher estimates of cost and consequently to higher bids. This reason was given by four Group A companies and five Group B companies.
- PERCEPTION OF (NOT) BEING SELECTED: When a company is invited to a pre-study it may feel selected, i.e., that the likelihood of being selected is higher than otherwise. A perception of being selected may lead to higher bids. By contrast, when a company believes that it has no advantage compared with other companies, this may decrease the bid. This reason was given by one Group A company and five Group B companies.
- EXPECTING REQUIREMENT CHANGES: The companies participating in the pre-study experienced that the client changed the requirements for the bidding round. These companies may conclude that there is a high likelihood that the client will change the requirements again, i.e., they experience a higher requirement uncertainty than the companies that participate only in the bidding round. A higher uncertainty means a higher contingency budget and possibly a higher bid. This reason was given by one Group A company and two Group B companies.
- "BALLOON EFFECT": The price indication based on the pre-study phase information was high because the requirement specification was vague, i.e., the

high uncertainty led to high price indications. When, subsequently, the bidding round requirement specification described a larger system the bid had to be higher than the initially indicated price. This effect is a type of anchoring effect, but with the opposite effect, i.e., a "balloon effect" that lead to final values too far from the initial estimates. The "balloon effect" was mentioned by one Group B company, only.

Table 6: Reasons for Difference in Bids As Perceived by the Bidders

Group	CompId	Category	Reason Provided
A	1	MORE ESTIMATION WORK	*"The only explanation I can think of is that companies in Group A had more time to think about the solution between the two phases and possibly saw more opportunities and got higher ambitions."*
A	3	EXPECTING REQUIREMENT CHANGES	*"I can guess why the Group B companies' bids were lower. The requirement specification in the bidding round was of good quality, which gave the Group B companies high confidence in the estimation work. These companies may have perceived the client as more professional and consequently perceived the project as less risky. Companies participating in the pre-study phase experienced a client without clearly defined requirements and, consequently, a more uncertain project."*
A	4	MORE ESTIMATION WORK	*"I suspect that the companies examined the requirement specification more thoroughly when participating in two rounds. Maybe they saw issues that they had not seen otherwise, e.g., more functionality and more potential problems."*
A	10	MORE ESTIMATION WORK	*"Maybe, the reason is that the more a company works with the analysis of a requirement specification, the higher the price."*
A	13	PERCEPTION OF BEING SELECTED	*"Companies selected to participate in the pre-study believed that they had an advantage compared with other companies. Consequently, it is safer to increase the price."*
A	15	MORE ESTIMATION WORK	*"We read the requirement specification more thoroughly when reading it twice (i.e., in the pre-study and the bidding round). For this reason, we saw more issues and increased the price."*
B	19	MORE ESTIMATION WORK + PERCEPTION OF BEING SELECTED	*"The companies involved from the beginning may have understood the complexity better. Also, they felt more 'selected'. In our group (Group B) there may have been companies that tried to compensate for late involvement with a very low price."*
B	20	EXPECTING REQUIREMENT CHANGES	*"When the companies in Group A received the final requirement specification they encountered a system that was larger and more complex than initially expected. This experience may create the expectation that there will be more changes in the future. They increase the price to cover for future surprises, because they have already been surprised once."*
B	21	MORE ESTIMATION WORK	*"The price was based on a quick estimate from one of the programmers. I believed it was too low, but used it anyway. If we had been involved in the pre-study phase we would probably have seen the project as more complex and more*

			serious and offered a much higher price."
B	22	PERCEPTION OF BEING SELECTED	*"It is possible that group B companies lowered their price because they were involved later in the process."*
B	23	PERCEPTION OF BEING SELECTED	*"The only reason I can think of is that the companies involved in the early phase believed that they had an advantage compared to us involved later."*
B	24	BALLOON EFFECT	*"The poorer requirement specification, the higher the price, i.e., those starting with a vague specification may have had to indicate a high cost to cover the uncertainty. When the final specification arrived, with more functionality, it would be unnatural to go down in price. There was only one way to go, up."*
B	25	PERCEPTION OF BEING SELECTED	*"The only explanation I have is that those in Group A felt more secure than companies in our group (Group B)."*
B	27	MORE ESTIMATION WORK	*"It is possible that there is a relation between time spent on thinking about how to solve a project and how large the project is estimated to be."*
B	29	MORE ESTIMATION WORK	*"The companies involved from the beginning had more time to understand the requirements, work on the proposals and maybe to increase the price."*
B	30	MORE ESTIMATION WORK	*"It is possible that those involved earlier got a better understanding of the complexity of the project."*
B	31	PERCEPTION OF BEING SELECTED	*"When a company is involved later in the process and has no relation to the client, they know that their chances are low. The price may be lowered for this reason."*
B	34	PERCEPTION OF BEING SELECTED	*"Since the Group A companies were involved from the beginning they may have believed that it was safe to increase the price."*
B	35	EXPECTING REQUIREMENT CHANGES	*"The companies participating in the pre-study phase may have perceived the final requirements as more uncertain, since they were involved when the client had only vague ideas about the requirements. We (Group B companies) got only the final specification and perceived the requirement to as being based on a solid analysis and the client as more professional. Lower uncertainty always means a lower price."*

We see no reason to exclude any of the provided reasons as potential reasons. Possibly, all reasons contributed to a difference in bids related to involvement in a pre-study phase. Interestingly, the companies provided both estimation-related reasons, e.g., more estimation work leads to higher estimates, and bidding-related reasons, e.g., perception of being selected leads to higher bids. Consequently, the observed difference may be important in pure estimation contexts, as well.

4.2 Experiment on Difference Between Bidding and Cost Estimation Contexts

Based on earlier experiments on anchoring in effort estimation contexts (Jørgensen and Sjøberg 2001; Jørgensen and Sjøberg 2004), we expected the Group A bids to be *lower* than the Group B bids. As reported in Section 3, the results pointed in the opposite direction, i.e., the Group A bids were much higher. The experiment described in this section tests whether the difference in results is due to the difference in study designs, or has something to do with the particular application chosen in our bidding study. The experiment therefore applies the same requirement specifications as in the bidding study, but focuses on estimation instead of bidding, and is based on an experiment instead of a real-life observation.

Participants: Nineteen estimation teams from a Norwegian software development company participated in the study. The company manager in charge of all projects in that company composed the estimation teams so as to be, as far as practically possible, meaningful for the estimation work to be performed. The participants knew they were part of an experiment, but were instructed to behave as similarly as possible to the way in which they would normally behave real estimation work. An important incentive for serious estimation work was that all the teams should present their estimation work in the presence of the other teams and the company's management.

The estimation task: The estimation teams were instructed to estimate the effort of the same project as in the bidding study, i.e., to estimate the effort needed to implement a web-based system for storing and retrieving research studies at our research laboratory (Simula Research Laboratory).

Estimation process: The nineteen estimation teams were separated at random into two groups. The Group ExpA teams received estimation instructions similar to the Group A companies in the bidding study, i.e.,:

a) *Provide an early estimate*: Estimate the most likely effort of the project based on the one-page specification of user needs (see Appendix 1).
b) *Provide a final estimate*: Estimate the most likely effort of the project based on the final requirement specification.

The Group ExpB teams received estimation instructions similar to the Group B companies in the bidding study, i.e., they completed only step b). All teams were instructed to base their effort estimates on the normal productivity level of their company.

The teams spent between 1 and 1.5 hours on the estimation work, i.e., less than in a normal estimation situation. This limitation in time spent on estimation work, and the closeness in time between steps a) and b), entails that the degree of realism in this study is similar to the earlier experiment anchoring effects, but somewhat different from the real-life context in our bidding study. The estimates provided by the estimation teams are displayed in Table 7.

Table 7: Results From the Experiment

TeamId	**Group**	**Early Estimate (work-hours)**	**Final Estimate (work-hours)**	**Increase from early to final estimate**
1	ExpA	160	800	500 %
2	ExpA	126	413	328 %
3	ExpA	400	750	188 %
4	ExpA	700	5200	743 %
5	ExpA	40	136	340 %

6	ExpA	570	1543	271 %
7	ExpA	60	192	320 %
8	ExpA	37	149	403 %
9	ExpA	56	310	554 %
10	ExpA	80	152	190 %
11	ExpB		484	
12	ExpB		2280	
13	ExpB		2080	
14	ExpB		752	
15	ExpB		456	
16	ExpB		2640	
17	ExpB		800	
18	ExpB		88	
19	ExpB		820	

The mean estimate of the Group ExpA teams is 966 work-hours, while the mean estimate of Group ExpB teams is 1156 work-hours, i.e., a small difference in the opposite direction to the bidding study. This direction of the difference is, however, as expected based on the earlier results on the anchoring effect in estimation contexts.

It is not unreasonable to consider Team 4 as an outlier, based on information from the project manager. A removal of Team 4 would make the anchoring effect in the experiment even clearer. A summary of the results (including Team 4) is provided in Table 8.

Table 8: Summary of Experiment

Group	**Mean** (work-hours)	**Median** (work-hours)	**Std**	**Min** (work-hours)	**Max** (work-hours)
ExpA	966	362	1552	136	5200
ExpB	1156	800	922	88	2640

The difference found in this experiment is, as stated earlier, in accordance with the anchoring effect, but in the opposite direction from the bidding study results. This suggests that the reason for not observing the anchoring effect in the bidding study is not related to the requirement specification, but perhaps to the bidding context and the increased realism in the bidding study. There is, consequently, a need for greater insight into when the anchoring effect can be expected to occur. Perhaps anchoring is principally an experimental phenomenon that disappears in most important real-life contexts?

4.3 A Preliminary Theory on Some Bidding-Relationships

The preliminary theory presented in this section aims at describing important bidding relationships in software project contexts. It is based on the following sources:

- Earlier research on bidding and related activities.
- Relationships suggested by the bidders themselves.
- The data from the bidding study.

Our preliminary theory is in some respects speculative and far from complete. It needs validation, refinement, and extension. However, we believe that it is based on the best available information and that our preliminary theory is better than no bidding theory at all. For example, it has clear predictive consequences that can be tested. It may therefore be a good starting point for an increasingly sophisticated and valid theory of software project bidding. Together with the theory we describe its scope, important implications, its evidence, and how to test the it.

To support our theory-building attempt we surveyed many studies and text-books on project bidding, e.g., (Gilley, Karels et al. 1986; Tweedley 1995; Kingsman and Souza 1997; Chapman and Ward 2002; Kerzner 2003; Kitchenham, Pickard et al. 2003). Unfortunately, we found little information about the relation between project bidding process format and bids. The literature on project bidding tends, in our opinion, to treat bidding as a rational, unbiased process, and so operates with assumptions that are not necessarily supported by the results from our bidding study.

One domain where we found papers on the importance on the design of the bidding process was "bidding in auctions". A particularly relevant study on bidding in auctions is described by Esö and White (Esö and White 2003). They examine the importance of the perceived uncertainty regarding the value of a product ("*ex post* risk") and its effect on bidding behaviour in auctions. Essentiallly, they show that certain types of bidders "*reduce their bids by more than the corresponding increase in risk premium when pure risk is added to their values*". They call this effect the "precautionary bidding effect". The authors predict that this effect would lead to better (from the buyer's viewpoint) prices in high uncertainty auctions, e.g., in internet auctions where one cannot examine the product. As we understand it, better prices in high uncertainty auctions is a necessary consequence of the "precautionary bidding effect" only if the *perceived* and the *actual* uncertainty corresponds. We discuss the relevance of separating perceived and actual uncertainty later in this section. The authors do not provide empirical data to support their predictions, but we find it reasonable to believe that their predictions are correct in many situations. For example, people may not want to invest in high-uncertainty stocks unless the *expected* return is substantially higher than the expected return of lower uncertainty alternatives. The "precautionary bidding effect" also seems to be consistent with the "prospect theory" (Kahneman and Tversky 1979) found in human judgment studies. The "prospect theory" is based on the observation that negative outcomes, e.g., the possibility of losing money, tend to be attributed higher importance than positive outcomes, e.g., the possibility of winning money. The "prospect theory" would predict that the risk of losing money in a high uncertainty situation is attributed higher importance than the possibility of winning money, and that the companies consequently will over-compensate for increased level of uncertainty.

Both the "precautionary bidding effect" and the "prospect theory" predict that the bidders, when the perceived uncertainty increases, increase their bids more than the corresponding increase in perceived uncertainty, i.e., they base their bids on a higher "expected win". An observation that supports the correctness of the "precautionary bidding effect" is that the pre-study prices of the Group A companies (mean value NOK

183 051) were *higher* than the final bids of the Group B companies (mean value NOK 166 131) in spite of the substantially larger and more complex requirements in the bidding round.

Comparing the data from the bidding study with those from the estimation experiment we find evidence to suggest that the "precautionary bidding effect" is mainly related to situations where there is "something to lose". In situations were there is no need to be cautious, as in our experiment is Section 4.3, there will be no "precautionary effect". This is supported by the data in our experiment. While the mean pre-study estimate of the Group ExpA estimation teams was 229 work-hours, the final-round estimates of the Group ExpB estimation teams was as high as 1156 work-hours, which suggests that there were no precautionary effect in the experiment. This is clearly different from the bidding study where the early price indications of Group A companies and the bids of Group B companies were almost the same.

Combining the "precautionary bidding effect" and the "balloon effect" (see Section 4.1) we may now be able to explain the resulting higher bids of the Group A companies. In the bidding study, the Group A companies went from a high-uncertainty situation (in the pre-study phase) to a situation with lower uncertainty (in the bidding round). According to the "precautionary bidding effect" the Group A companies tended to add a risk premium that over-compensated for the perceived uncertainty. This explains the high Group A pre-study prices, relative to the final bids of the Group B companies. In the bidding round the uncertainty decreased, due to the more complete and stable requirement specification, while the functionality and complexity increased. An increase in functionality and complexity should obviously lead to a higher price, see "the balloon bidding effect" described in Section 4.1. The Group A companies may, however, not have been able to adjust sufficiently for the reduction in requirement uncertainty from the pre-study to the bidding round. Alternatively, they might not have performed a new, independent uncertainty analysis at all, but based the bid mainly on the increase in functionality and complexity alone.

We now try to formulate a preliminary theory about how the perceived level of uncertainty affects software project bids. We have chosen to limit the theory to what we believe are the two most important relationships between uncertainty and bids, so we do not include all findings of our bidding study and all reasons provided by the bidders themselves in this theory. The theory is stated using the following format:

1. Relationship (R1 and R2)
2. Scope of relationship (S1 and S2)
3. Example of important implications (I1 and I2)
4. Supporting evidence (E1 and E2)
5. Example of how to test the relationship (T1 and T2)

R1: Software companies in bidding situations tend to over-compensate for perceived uncertainty, i.e., they tend to base their bids on higher expected returns on investments in situations with high perceived uncertainty. Factors discussed that may lead to high levels of perceived uncertainty are, for example:

- The vagueness of the requirement specification.
- The level of effort spent on understanding the complexity of the project. (More insight may both lead to increased and decreased level of perceived uncertainty. In our study the bidders believed that more estimation work led to higher levels of perceived uncertainty.)
- The frequency in change of requirements as experienced by the bidders.

S1: The similarity of findings in different domains as different as software projects, auctioning, and, general human judgment makes us believe that R1 is fairly general, i.e., that it is a general relationship that applies to situations including most software bidders, projects and contexts. It is, however, important to be aware that there may be competing effects in bidding processes. For example, we cannot exclude the possibility that high uncertainty in political situations, e.g., in situations where it is essential to convince other people that the price will be low, also enables a bidder to be more optimistic. Consequently, there is consequently a need to refine the scope of R1 to context.

I1: Software companies may achieve better price/uncertainty relationships when reducing the uncertainty of a project, as it will be perceived by the bidders, before inviting companies to participate in a bidding round. Whether or not a client will actually benefit from a reduction in uncertainty depends, amongst other things, on how the uncertainty is reduced. For example, clients obviously do not benefit from reducing the uncertainty, if this reduction is based on a too early, and hence non-optimal, choice of technology.

E1: Supporting evidence comprises the relatively high pre-study price indications in this study, and the previous studies on the "precautionary bidding effect" and the "prospect theory". In addition, the difference in deviation between estimated and actual effort of two Group A and two Group B companies implementing the system (see Section 3.3) is in accordance with what we should expect if R1 is valid. As stated earlier, the limited number of observations combined with the non-random selection of companies entails that the estimation deviation results from those four companies provide only a weak support for R1.

T1: An experiment testing R1 could be designed as follows: Separate the bidders into two groups (G1 and G2). The bidders are supposed to bid for the same project, but with one difference in instructions. G1 bidders get the additional information that: "*There is a 50% probability that there will be a 25% increase in functionality that cannot be billed to the client, and, a 50% probability that there will be a 25% decrease in functionality that does not lead to any reduction in price.*" If G1 bidders, on average, have higher bids than G2 bidders, this will support R1, otherwise it will contradict R1.

R2: Early price indications in high requirement uncertainty situations followed by bids in lower requirement uncertainty situations tend to lead to higher bids, compared with bidding in situations with no early price indications in high uncertainty situations. The underlying reason for R2 is that *decreases* in uncertainty are not sufficiently compensated for.

S2: We have not been able to find studies other than ours that support (or contradict) R2, and R2 may therefore be a relationship that is valid only in contexts similar to the one in our bidding study. There is a clear need for studies to assess R2 in other project bidding contexts.

I2: A client will on average receive lower bids from bidders that have not been involved in pricing the project when the uncertainty was higher, e.g., in a pre-study. Early involvement may, on the other hand, lead to better solutions, i.e., there may be a trade-off here.

E2: Supporting evidence is based mainly on the bidding study described in this paper. The underlying reason described as "the decrease in uncertainty is not sufficiently compensated for" is somewhat speculative and only indirectly derived from our study. It is, nevertheless, consistent with the bidding data and a powerful explanation of the difference between Group A and Group B. Clearly, this hypothesis should be tested before being accepted as more than a qualified judgment consistent with available data. Similarly to the E1 discussion, the estimation deviation results reported in Section 3.3 is in accordance with R2, i.e., the average level of over-optimism was lower among the two Group A companies compared with the two Group B companies implementing the system.

T2: A possible experiment testing R2 is as follows: Separate the bidders into two groups (G1 and G2). The bidders are supposed to bid for the same project, but with different instructions. The G1 bidders are first (Phase 1) instructed to base their bid on the information that: "*There is a 50% probability that there will be a 25% increase in functionality that cannot be billed to the client, and, a 50% probability that there will be a 25% decrease in functionality that does not lead to any reduction in price.*". Then (Phase 2), the G1 bidders are informed that there will be no increase or decrease in functionality, and, asked to change their bids in accordance with that information. The G2 bidders are requested to base their bids on the assumption that there will be no increase or decrease in functionality. If the G1 bidders in Phase 2, on average, have higher bids than the G2 bidders this will support R2, otherwise it will contradict R2.

Comments on R1 and R2:

- Neither R1 nor R2 imply that we will typically observe pessimistic bids in high-uncertainty bidding situations. R1, for example, states that the risk premium added to a bid in high-uncertainty situations *on average* over-compensates for the *perceived* uncertainty. Software clients tend to choose among the providers with the *lowest bids*, i.e., among the companies that more likely have under-compensated for the *actual* (as opposed to the perceived) uncertainty. The actual uncertainty is higher than the perceived uncertainty in many situations, see (Jørgensen, Teigen et al. 2004). In addition, the *average* pessimism/optimism of bidders can obviously not be studied in situations where there is a clear bias leading to evaluation of only the most optimistic bids. Finally, there are other effects that compete with the over-compensation effect, e.g., bids that are based on little or no analysis of the work involved, but instead on the elements "How much is the client willing to pay?" and "Our employees need something to do". Therefore, R1 makes only claim related to the *average* impact and the *perceived* uncertainty, not about the relation between the perceived and the actual uncertainty of a non-random, e.g., lowest price-based, selection of software bidders. A similar argument applies for the effects of R2.
- As stated in the previous bullet, software companies typically perceive the uncertainty to be lower than it actually is. If the difference between the perceived and actual uncertainty is higher in high uncertainty situations, i.e., there is an under-

compensation for increase in *actual* uncertainty, there will be an effect that competes with R1 (but not R2). We believe, however, that this is not the case, and that the "precautionary bidding effect" will dominate. The reason for this belief is based on a simple analysis of the project uncertainty data presented in the appendix of (Jørgensen 2004). We divided the 47 projects applying 90% confidence minimum-maximum effort intervals into two groups according to the relative width of their intervals (relative width = (maximum effort – minimum effort)/estimated effort). The relative interval width is a substitute for the perceived uncertainty of a project (Jørgensen 2004). The projects with the narrowest intervals, i.e., relative width lower than the median, were allocated to the Low Uncertainty group and the other projects were allocated to the High Uncertainty group. Then we compared the hit rate (the proportion of projects with actual effort inside the minimum-maximum effort interval) for the two groups. If the "precautionary bidding effect" were to dominate, the hit rate of the High Uncertainty Group would be higher than that of the Low Uncertainty Group. If there were an under-compensation for increase in actual uncertainty we would observe that the High Uncertainty Group hit rate was lowest. Our analysis of the data in (Jørgensen 2004) supports the "precautionary bidding effect". The hit rate of the High Uncertainty group was 80% while the hit rate of the Low Uncertainty group was 64%.

5 Conclusion

This paper reports from a study of 35 software companies bidding for the same contract. Of these 35 companies, 17 were involved in a pre-study in which early price indications were provided based on a vague one-page description of user needs. All 35 companies participated in the final bidding round. The final bidding round was based on a more complete requirement specification, which included more functionality and complexity than the initial description of user needs. The main result of our study is that the bidding process had a large impact on the bids, and that the companies involved in the pre-study tended to provide much higher bids. A preliminary theory connecting uncertainty and size of bids is proposed. An important implication of this theory, consistent with the results of our study and the "precautionary bidding effect", is that clients, on average, will benefit from reducing the uncertainty as perceived by the software companies. The main reason for this benefit is that bidders tend to over-compensate for uncertainty. We intend to conduct several follow-up studies to test and refine our preliminary bidding theory.

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APPENDIX 1: Excerpt of Pre-study Instructions and User Needs Description

The Simula Database of Empirical Studies

Introduction

Currently, the Software Engineering (SE) Department at Simula Research Laboratory (SRL) (www.simula.no/se) maintains an HTML table with information about their own scientific studies <*link to web-page*>. The SE Department now wants a more user friendly database containing study information. The database system of scientific studies is labeled "The Simula Database of Empirical Studies" (DES) in this document. This document includes an outline of the requirements to be met by the DES. The requirement outline is not meant to be complete, but is intended to be used as a basis for suppliers to outline "Phase 1" proposals for DES. We expect to suppliers to provide suggestions on cost efficient and **simple** solutions that meet our overall goal of user-friendly management of our information about scientific studies.

Based on the Phase 1 proposals on DES-design, functionality and estimated costs, the SE-group will make requirement and design decisions and develop a more complete requirement specification for the Phase 2 proposals. In other words, the Phase 1 proposals mainly constitute input to our requirement specification and design work. The decisions on choice of supplier(s) will be based on the Phase 2-proposal. Details on the proposal process are given in the covering letter sent with this specification.

Brief Description of User Needs

The DES should enable access to (search, read) and management (insert, change, delete) of the following (see Table 1) information about each study.

Table 1: Study Information

Information	**Description**
Study Name	Text
Study Responsible	One or more names of researchers at SRL
Type of Study	Text
Study Description	Text
Duration of Study	Integer
Start of Study	Day/Month/Year
End of Study	Day/Month/Year
Publication	Zero, one or more references to publications
Publication Notes	Text
Keywords	Text
No of Student Participants	Integer
No of Professional Participants	Integer
Study Material	Zero, one or more hyperlinks to files
Study Material Description	Text. One description for each file.

The DES should run on Simula Research Laboratory's existing web and database server: Our web server hosting *www.simula.no* and *www.simula.no/intranet* runs on a Dual Pentium III, 1 GHz with a Asus CUR-DLS U160 motherboard. Our database server storing the dynamic web data has the same hardware specification as the web server. Our web server runs Debian Linux unstable, Apache v. 1.3.36 (with PHP v. 4.2.*). The database server is running Debian Linux unstable and MySQL v. 3.23 Our internet web pages are using CSS. DES should support the following browsers: MS Internet Explorer v. 5 and 6 for Windows.

Structure of Proposal:

The proposal should include the following information:

1) A brief description of the proposed solution including
    a. A description of the understanding of user needs
    b. The suggested overall design of the DES, including assumptions
    c. A description of the development model to be used
    d. A description of the company's experience with relevant technology and applications.
2) A rough (non-binding) estimate of the cost, inclusive of an assessment of the uncertainty of the estimate.