Over-optimism in Software Development Projects: "The winner's curse"

Magne Jørgensen[1], Stein Grimstad[1]
(1) Simula Research Laboratory, Norway
{magnej, steingr}@simula.no

Abstract

It is well known that software development projects tend to be based on over-optimistic cost estimates. Better knowledge of the sources of this over-optimism is necessary to improve realism in software development project bids and budgets. This paper analyses the effect of "the winner's curse". The winner's curse is a result of the selection of software providers among those with the lowest bid, i.e., those with a tendency towards the highest level of over-optimism. The winner's curse has not been extensively analyzed in software cost estimation studies, but is a well known phenomenon in domains such as auctioning. We exemplify the effect of the winner's curse with data from a real software development bidding round and simulate how increase in number of bidders and cost uncertainty impact the expected profit. We argue that the winners' curse is a problem for both clients and providers, and that it may lead to inefficient use of scarce resources. Possible remedies for reduction of negative effects of the winner's curse are discussed.

1. Introduction

A recent review of surveys on software cost estimation found that 60-80% of software projects have cost overruns and that the average cost overrun is about 30% [1]. This level of cost overrun seems to have been stable over, at least, the last 20 years, i.e., there is no substantial evidence indicating improvement. In other words, research on cost estimation methods, e.g., the COCOMO estimation model [2], have not have had the desired impact on software cost estimation accuracy.

The reasons for the cost overruns have been studied in several papers. A brief summary of a representative sample of these studies is given in Table 1.

Table 1: Reasons for Software Estimation Error

Study	Reasons for Estimation Error
Phan et al. [3]	Most important reasons were "unrealistic over-optimism" and "frequent changes".
Van Genuchten [4]	Most frequent reported reasons were "more time spent on other work than planned" and "complexity of application underestimated".
Lederer and Prasad [5]	Most important reasons were "frequent requests for changes by users", "users lack of understanding of their own requirements", and "overlooked tasks".
Subraman-ian and Breslawsk i [6]	Most important reasons were "requirement change, addition, or deletion", "programmer or team member experience, turnover", and, "design changes, scope, complexity".

The reasons provided in Table 1 share a focus on cost overrun reasons related to the clients and users, e.g., "frequent requests for changes by users". This, we believe, provides a biased picture and is mainly a result of the studies' predominance of project managers as respondents in these studies. To illustrate this, the study of construction projects reported in [7] report that the *clients* believed that "poor site management and supervision" and "inadequate managerial skill" was the main reasons for cost overrun, while the *contractors* believed that the overruns were mainly caused by "delays in design information" and "long waiting time for approval of drawings", i.e., there is probably an asymmetry in perceived reasons for cost overrun dependent on role. We, therefore, cannot assume that all the important reasons for cost overruns are identified and analyzed through the previous studies.

Absent from the studies on reasons for software development cost overruns are analyses of basic

economic and organizational structures leading to cost overruns. This paper looks at one potentially important structure-related reason, "the winner's curse". "The winner's curse" has been studied in other domains, e.g., auction theory [8], but seems to be neglected in analysis of reasons for software cost overruns. The goal of this paper is to investigate how properties of the bidding process impact the level of over-optimism in software project bids.

The remaining part of this paper is organized as follows: In Section 2 we describe what we mean by "the winners curse" and briefly describe a few previous studies on the effect of it. Section 3 reports from a study demonstrating the effect in a real-life software bidding round. In Section 4 we simulate the effect of number of bidders and uncertainty of cost estimate on the winner's curse through a simple Monte Carlo simulation model. We then discuss the relevance and importance of the findings in Section 5 and conclude in Section 6.

2. The Winner's Curse

The winner's curse is likely to emerge when:

- There is a competitive environment, e.g., more than one provider tries to win a software development contract or a too high price means that the software project will not be started.
- Software providers differ in optimism when estimating the most likely cost of developing software and/or the benefits of winning the contract. Some providers are over-optimistic, some realistic, and, some over-pessimistic.
- Software providers with over-optimistic estimates of most likely cost tend to have the lowest bids.
- Software development project clients require fixed-price contracts.
- Software development project clients tend to select providers among those with the lowest bids.

From this it follows that software projects tend to be won by providers that are among the most optimistic, i.e., the probability of over-optimism increases compared with a random selection or a competence-only based selection of software providers. The tendency to win bidding rounds when being over-optimistic results in winning bids that may produce very low or negative profits for the bidder. This is what we term the winner's curse.

The winner's curse is not a new phenomenon. Already in 1805 Adam Smith, in his famous *An Inquiry into the nature and causes of the wealth of nations*, discusses the effects related to the winner's curse. He claimed that selection of bidders (mainly in the context of accepting higher interest rates on loans) based on highest bid lead to inefficient allocation of capital. Over-optimistic entrepreneurs were, he believed, less able than realistic ones and lending more money to the over-optimistic entrepreneurs compared with the realistic ones is therefore inefficient. Although otherwise strongly in favor of market price ("the invisible hand" - mechanism), Adam Smith recommended regulations (!) to avoid the negative effect of the winner's curse. In Section 3 we describe a study which supports Adam Smith's observation in the context of software development.

The winner's curse has been extensively studied in auctioning, e.g., oil field bidding auctions [9]. These studies show that the profit is negative or very low in situations with many bidders and high uncertainty [10].

In situation where the product won is well-defined or non-changeable the winner's curse is mainly a problem for the bidder. In software project development situations, however, the product is typically neither well-defined nor non-changeable. We show in [11] how over-optimistic estimates may lead to low quality and project completion problems. This implies that the winner's curse in software development projects may not only be a problem for the software providers, but for the software clients, as well. This is further discussed in other sections of this paper.

3. A Study of a Software Bidding Process

The purpose of the study described in this section is to illustrate the winner's curse in a real-life bidding round.

3.1 The bidding process

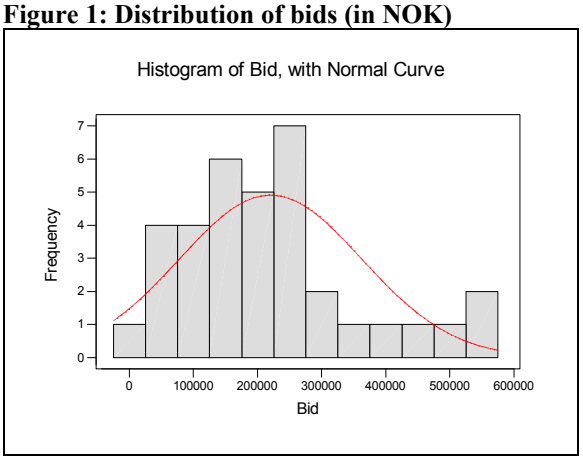
We examined software project bids made by 35 Norwegian and international software companies. The bidding companies consisted of large, medium, and small development companies operating in Norway. The high number of bidders (35 companies) was to some extent motivated by research needs and, for that reason, 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, or how many other, companies we had invited to join the bidding process.

The software companies were instructed to give firm-price bids based on a reasonably well-specified requirement specification. The bids were received three weeks after the companies were sent the final requirement specification. 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.

3.2 Results

Figure 1 displays the distribution of the bids provided by the companies. All bids are in Norwegian Kroner (1000 NOK is about $140 – October 2004). The mean value of the bids was 220 000 NOK, ranging from 21 000 to 560 000 NOK. As far as we have observed in other bidding rounds, this range of bids is not uncommon when the number of bidders is high.

Figure 1: Distribution of bids (in NOK)



While there were obvious differences in how the providers would implement the software and in their development efficiency, it is reasonable to assume that the most optimistic bidders are among the companies with the lowest bids. We selected four companies to develop the software, i.e., we got four independent software applications meeting our requirements. The decision to select more than one company was motivated by research needs. The four companies represented different sizes of bids. The three companies with the lowest bids (Company I, II and III) were among the cheapest given their rigor of development method and various properties of the suggested solution. The only company where we did not choose among those with lowest price was Company IV. To preserve anonymity we have not included information that enables a link from these data to the bidding data, but have instead provided an interval that includes the bid and indicates the size of the bid. The bids and the cost overrun are described in Table 2. The cost overrun is based on a comparison of the actual effort with what the companies believed was the most likely use of effort at time, i.e., the effort estimate on which they had based their bids. The solution from all four companies satisfied identical acceptance tests regarding functionality and quality, i.e., all solutions had similar quality and functionality.

Table 2: Cost Overruns

Company	Cost Overrun	Bid range (in NOK)
I (very low bid)	130%	[0; 100 000]
II (low bid)	174%	[100 000; 200 000]
III (median bid)	156%	[200 000; 400 000]
IV (high bid)	15%	[400 000; 600 000]

As can be seen from Table 2, the three companies selected among those with lowest price had very high cost overruns, and it is very likely that most of those companies lost money on the project (given normal salaries of the employees). This is what we would expect with respect to the "winner's curse". The only company with low cost overrun, and most likely an acceptable profit, was the company selected on other criteria than low price.

Our experience with the project with the lowest bid (Company I) showed that it was not only the provider that had to pay for over-optimism. The client (us) had to do very much of the work in this project, e.g., supervision, testing and installation. If we as clients had been unable to do this, the project would probably been a total failure. This exemplifies that the winner's curse is not only a problem for the provider, but for the client, too.

4. Simulation of the Winner's Curse

The purpose of the simulation described in this section is to demonstrate how the number of bidders and the level of uncertainty regarding use of cost impact the level of average cost overrun, i.e., how these variables impact the effect of the "winner's curse".

4.1 Design

Our simulation model is based on the following assumptions:

1) The distribution of the companies' estimates of most likely cost is a beta-distribution with the

following parameters: alpha = beta = 2. These values make the distribution symmetric.
2) The true cost of all projects, for all companies is $1,000,000. This value is unknown to the companies.
3) The expected profit level is 25% for all companies.
4) The bid of a company is calculated as: Bid = Estimated most likely effort * (1 + profit level).
5) The company with the lowest bid wins the contract.

Three scenarios are examined. The scenarios are determined by the A and B parameters (the minimum and the maximum cost) of the beta-distribution:

- Low uncertainty and unbiased estimates: A = 900,000, B = 1,100,000
- Medium uncertainty and weak bias towards over-optimism: A = 700,000, B = 1,200,000
- High uncertainty and strong bias towards over-optimism: A = 300,000, B = 1,300,00
- The number of bidders in a bidding round has three levels (n=2, n=5, n=10).
- Each simulation consists of 100 bidding rounds.

The bias towards over-optimism in two of the scenarios is based on findings that degree of over-optimism tends to increase with increasing uncertainty [12]. For each level of uncertainty and number of bidders we calculate the mean profit of the companies.

The assumptions are, we admit, somewhat arbitrarily and unrealistic. Real software companies would, for example, normally not be as "passive" as in the simulation. They would, for example, look at possibilities to simplify and lower quality when the bid is won with an over-optimistic estimate (this is bad for the clients). In addition, in reality there would not be the same true cost for all companies.

We believe, nevertheless, that the simulation illustrates an important relationship between profit, number of bidders and uncertainty.

4.2 Results

The results of the simulation are displayed in Table 3. The results in Table 3 show how strongly the number of bidders and level of cost estimation uncertainty impact the level of profit. Even if we remove the bias towards over-optimism the effect can be shown to be strong. Winning a bid clearly is not always a blessing in situations with a high number of bidders and high uncertainty. Such situations are not unusual in software development contexts.

Table 3: Mean Actual Profit (Expected Profit 25%)

	Low uncertainty (unbiased estimates)	**Medium uncertainty (weak over-optimism bias)**	**High uncertainty (strong over-optimism bias)**
Two bidders	22% profit	10% profit	-15% profit
Five bidders	18% profit	2% profit	-33% profit
Ten bidders	17% profit	-2% profit	-41% profit

6. Discussion

The existence of the winner's curse is undisputed, although not discussed much, maybe not at all, in the software engineering literature.

6.1 Awareness

There are reasons to believe that many software development organizations, software clients, and software researchers are not sufficiently aware of the winner's curse:

- In the bidding study described in Section 3 none of the companies asked for information about the numbers of competing companies. If the companies were aware of the strong impact of the number of bidders on the expected profit in high-uncertainty situations, this type of information would have been essential to collect. Winning a bidding round with many bidders means that the winner's curse is highly likely, i.e., it is harder to win a bidding round with realistic bids when there are many competitors.
- The reasons for cost estimation errors described by software project managers, see Section 1, do not include the winner's curse.
- Software researchers typically do not discuss how the winner's curse impacts the interpretation of estimation surveys. The sample of cost estimates that is evaluated in surveys does not represent the population of all estimates. This means, for example, that surveys of estimation cost overruns should *not* be interpreted as estimation ability of software providers. Surveys are only able to calculate the average cost overrun of the sample of mainly over-optimistic cost estimates, i.e., those selected by a non-random client selection strategy. This may, in fact, be an important reason for the strong tendency to cost overruns reported in several surveys.

- We have experienced that software clients, especially public sector clients, tend to select providers as if the winner's curse does not exist. A too low price may, however, strongly increase the risk of low quality and delays. US Air Force (see *Aviation Week & Space Technology*, September 2004, p 23) informed their bidders that "… *if their price was much lower than the service's estimate* [The US Air Force own estimate of the cost]*, it would be seen as a risk to the program, not a benefit.*" This strategy is the US Air Force's reaction to the US Air Force's problems with low-cost bid that turn into delays, overruns and quality problems, i.e., the effects of the winner's curse. The provider selection strategy now tested by US Air Force is unusual and we have heard about no other clients that include such drastic measures to avoid the winner's curse.

6.2 Recommendations

It is not obvious how software providers, clients and researchers should deal with the winner's curse. Below are some recommendations, most of them without much supporting evidence and in strong need of further research.

Clients:

- Increase the awareness of the relation between low price and increased risk. Selecting bidders with average or relatively high price often reduce the risk of project failure. There are cases, however, were a low price does not necessarily lead to higher risks. This may be the case when, for example, an experienced provider applies a low price to get a satisfied reference customer and profit-giving work as a consequence of this.
- Consider acquisition models that lower the emphasis on the price and increases the emphasis on the provider's capability. One way to achieve this is by pre-qualifying providers prior to bidding.
- Realize that a low, fixed price without fixed delivery, which is the typical situation in software development projects, is not really a low, fixed price as it makes the providers look for shortcuts and be less flexible. Getting the lowest price rarely is a wise strategy when buying software.
- If a provider with a low bid has been selected, expect to put in much effort to support and control the development work, and have a budget/schedule reserve. As found in the bidding study, the providers with the lowest bids had less relevant experience than those with medium or high bids. Even worse, providers with appropriate experience and good skills may perform worse due to the winner's curse. For example, we have observed that too low estimates may lead to too little work on design and user interaction as a result of a desperate attempt to stick to the initial too optimistic cost estimates [11]. This again, may lead to chaos, delays and poor quality.
- Recognize that most of the responsibility for the winner's curse is on the client. Fixed price, invitation of many bidders and selection of providers among those with lowest price are the conditions that most likely lead to the winner's curse and subsequent problems for the provider and the client.

Providers:

- Assess the uncertainty and the number of bidders. Use this information in the decision on whether to participate in a bidding round or not. If a provider has no obvious competitive advantage and win a bidding round with a high number of bidders and high uncertainty, the bidder has probably been over-optimistic (even if the bidder does not believe this themselves) and will experience a loss or low profit.
- A strategic low price is acceptable, e.g., as an investment for future contracts. It should, however, not be acceptable that a project meant to make profit is experiencing loss as a consequence of the winner's curse. If a bidder decides to make a bid in situations where the winners' curse is likely to occur, e.g., many bidders and high uncertainty, they should consider adding an extra risk buffer to the estimates to compensate for the winner's curse.
- When analyzing reasons for estimation error, a stronger focus should be put on the effect of structural issues, such as the winner's curse, leading to over-optimism.

Researchers:

- Measurement of average estimation accuracy of all completed projects, e.g. surveys including estimation performance of companies within a country, should *not* be interpreted as a measure of average *estimation ability*, i.e., the estimates are selected from a sample of estimates that have a strong tendency to over-optimism. In fact, it is theoretically possible that a different provider selection strategy, with a much stronger focus on ability instead of low price, would remove the strong tendency towards over-optimism.

- Analyses of reasons for estimation errors have tended to be narrow-minded, only focusing on direct reasons and from the providers' perspective. We need more studies on impact of structural issues, e.g., provider selection strategies, on cost overruns and efficient use of scarce software development resources.

7. Conclusions and Further Work

Frequently, the responsibility for improvement of software cost estimates and software quality is assigned to the software providers. This is natural, i.e., the cost estimates and the software are developed by the software providers and not the software clients. Our study on the winner's curse suggests, however, that an important reason for software cost overruns and low software quality is nevertheless the selection strategy adopted by software clients. When there is a variance in level of optimism among software providers, a high number of bidders, and high uncertainty in use of resources, then a provider selection strategy focusing on price instead of competence will most likely lead to over-optimistic cost estimates, delays, low quality and low profit for the providers.

There is a strong need for further research on this topic. In particular, there is a need for studies on alternative bidding processes. An example of an alternative bidding process is where a realistic price is estimated by the client, e.g., through use of independent consultants, and where the bidders are informed that a much lower price would require a very good argumentation. This type of bidding process, now implemented by US Air Force, may contribute to a change of selection focus from lowest cost to highest delivery capability.

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