PROBABILISTIC ANALYSES OF TENDER UNCERTAINTIES

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Abstract: At a tender in the Netherlands the contract is in general awarded to the contractor with the lowest bid. For the owner an engineering firm's cost estimate should be a good forecast of the bids in the tender. The amount of spread needed around the mean of the cost estimate and its position with respect to the average bid determine the performance of an estimator. An owner would select a well performing engineering firm based on past performances. However, these performances are not available because these have never been investigated on a large scale yet. First, this paper determines and compares the performances of three engineering firms. Hereby it makes a distinction between those periods, in which forbidden preliminary discussions did and those in which they did not take place. Second, it investigates the effect of preliminary discussions on the bids. Third, it determines if a second opinion can contribute to the accuracy of the cost estimate. Finally, calculations for the determination of the optimal number of contractors to be invited for a tender will be shown. The approach followed in this paper will be of interest to practitioners as well as academics.

CE Database keywords: probabilistic methods, tenders, bids and cost estimates

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INTRODUCTION

Traditionally, the owner employs engineering firms to design their new structures. Among other things, the firms make a cost estimate for the design, which is a forecast of the construction costs. Different demands are imposed on such cost estimates. On the one hand a cost estimate needs to be competitive, as an owner does not want to overpay for the project, on the other the cost estimate may not be too low, for this can lead to problems if the tender results show that the contractors, who bid for the work, bid much higher. In the Netherlands the owner or the engineering firm awards the work to the contractor with the lowest bid in most of the cases.

The reason for this study was the observation of a Dutch engineering firm that its cost estimates were relatively often lower than the lowest bid. However, this is not to be expected when the starting-point is that the quality of the estimators and the bidders is equal. Therefore, the question arose what the reasons were for that situation and if that situation was the same at other Dutch engineering firms. Nevertheless, the problem is that engineering firms do not know the strength of their performance (relative bias and accuracy of the cost estimates), not to mention that they do not know their performances compared to other engineering firms or contractors. For these reasons a model with which the relative bias and accuracy of the cost estimates of engineering firms and bids of contractors can be determined needs to be developed. As a result, the answer can be given on the question which party can best calculate the cost: an engineering firm that has carried out the design or the contractors who have a lot of construction experience?

The fact that the tender situation in the Netherlands has changed since 9 November 2001 has to be taken into account. On this date a former contractor disclosed the tender procedure, common among contractors, up to that day. He confessed that forbidden preliminary discussions took place in which contractors made appointments on the price of their bids at the following tender. All bids were lowered toward the lowest bid, but the sequence of the bids remained the same, which led to relatively little spread in the bids of the tenders before November 2001. Thereupon, the bids were heightened with such an amount that the lowest bid came near the known or estimated cost estimate of the engineering firm. However, the preliminary discussions probably have stopped since these disclosures.

Because the cost estimate forecasts the bids in the tender, it is of interest for the cost estimate to be as accurate as possible. In other words: the margin that is needed to catch the average bid in the tender with the cost estimate with a reliability of 70 % needs to be as small as possible. Possibly a second opinion by another engineering firm could contribute to the accuracy of the cost estimate.

Contractors' bidding behaviors are affected by numerous factors related both to the specific features of the project and dynamically changing situations. Therefore, bidding decision problems are highly unstructured. Decisions are commonly made based upon intuition and past experience. To remedy this, Chua et al. (2001) propose to use artificial intelligence case-based reasoning (AI/CBR). Shash (1998) was able to identify, through a questionnaire survey, many factors characterizing the bid decision-making process. His results indicated that the contractor's credit history, his habit in the issuance of periodical payments, and his leadership and capability in planning and managing the project are identified as the top factors that affect a subcontractor's decision to bid for a project. The subcontractor's previous relationship with the contractor, the contractor's capabilities, financial capacity, current work load, and special skills, and the prospect of future business relationships are the highest ranked factors affecting quotation decision, as also noted by Alsugair (1999). McKim (1997) discusses traditional bidding strategies in which the bidder can optimize the bid based on a probabilistic approach using the expected value of the bid. McKim (1997) puts forward a bidding methodology that includes social costs in the award process and allows the contractor to use the expected-value approach to bidding under the assumption that the low-bid method is used.

The past has shown that the number of contractors invited for tenders varies. Owners tend to think that the lowest bid will be lower if more contractors are invited. This is true for the probability of the lowest bid (of n independent bids with n number of invited contractors). On the other hand, when contractors do not get direct compensation for their estimation costs in the sense of a compensation paid by the owner then the effect will be that the overall project price will increase because these contractors have to be paid for these costs one way or another. This leads to the question of the optimal number of invited contractors.

The following section builds up a model with which the performance (relative bias and accuracy of estimates) of different engineering firms can be determined. The performances of three different firms will be calculated with this model. Second, a model is developed with which it is possible to estimate to which extent the assumption of independent bids was violated. Because before November 2001, contractors lowered their bids towards the lowest bid, and subsequently heightened all bids in such way that the lowest bid came close to the cost estimate of the firm. Third, the value of a second opinion at the determination of a cost estimate is investigated with respect to the accuracy of the cost estimate. Finally, another model calculates the optimal number of contractors that should be invited for a tender.

RELATIVE BIAS AND ACCURACY

MATHEMATICAL MODEL

Skitmore et al. (2001) and Connolly (2002) show that, in a "lowest wins" auction, analysis of the difference between the lowest and second lowest bids, or bid-spread, is of possible value in strategic bidding, providing an indication of mistakes in bids, determining a justifiable amount of bid security, and a means of providing some insight into the consequences of nontraditional auction arrangements.

In this section the ratios of the average bid and the lowest bid with the cost estimate will be studied to determine the performance of engineering firms. A model that describes how the mean and the variation coefficient of these ratios should depend on the number of bidding contractors will be built up. In the first instance, it is assumed that the quality of the estimators is equal to the quality of the contractors. This means that on average the price level of the cost estimates is the same as the price level of the average bids and that the variation coefficient of the cost estimate is equal to the variation coefficient of the bids. To be able to determine the relative bias of the average bid in a tender this average is compared with the cost estimate. Therefore, the relative bias of the average bid is defined the following:

$$R_1 = \frac{\textit{average bid}}{\textit{cost estimate}}$$

The further the ratio deviates from 1, the larger the overestimation or underestimation.

To be able to determine the relative bias of the lowest bid this lowest bid will now be compared with the cost estimate. The relative bias of the lowest bid is therefore defined the following:

$$R_2 = \frac{lowest\ \ bid}{cost\ estimate}$$

When n contractors bid independently then the cost estimate and the average bid are both normally distributed, but the lowest bid is not. All realizations are supposed to be drawn from one normal distribution N(1,σ). The firm's cost estimate is one realization from this distribution. The contractors' bids are n realizations from the same normal distribution. The average of the n bids is μ_{bids}, the standard deviation of this average is $\sigma_{\text{bid}}/\sqrt{n}$. Table 1 shows the mean and standard deviation of the cost estimate, the average bid and the lowest bid.

Table 1. Mean and standard deviation

	Mean	Standard deviation
Cost estimate	$\mu_{estimate}$	$\sigma_{estimate}$
Average bid	μ_{bids}	$\sigma_{\text{bid}}/\sqrt{n}$
Lowest bid	E(min(X_1,…,X_n))	$\sqrt{\text{var}(\min(X_1,\ldots,X_n))}$

From this follows for R_1 that:

$$\mu(R_1) = \mu_{bids} / \mu_{estimate} = 1$$

$$\sigma(R_1) = \sqrt{\sigma^2_{average\,bid} + \sigma^2_{estimate}} = \sqrt{\sigma^2_{bid} / n + \sigma^2_{estimate}}$$

$$= (1 + 1/n)^{1/2} \cdot \sigma$$

$$V(R_1) = (1 + 1/n)^{1/2} \cdot V$$

With the following assumptions:

$$\mu = \mu_{bids} = \mu_{estimate}$$

$$\sigma = \sigma_{bid} = \sigma_{estimate}$$

In the first instance 5.1 % is taken for the variation coefficient, for this is the average measured variation coefficient of all 261 available tender results of the three engineering firms in the period from 1993 until the end of 2002. Fig. 1 shows the corresponding theoretical bandwidth around the average of R_1, plotted against the number of contractors if the variation coefficient of the cost estimate and the bid both are 5.1 %.

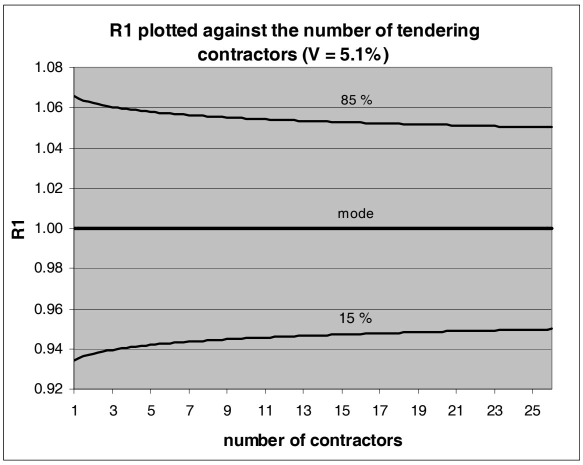

Fig. 1. R_1 plotted against n (with V = 5.1 %)

To determine the relative bias of the cost estimates of a firm with respect to the average bid, the average of R_1 is calculated over all available tenders of that firm. If this value is larger than 1, this means that the firm's estimate is more competitive than the average bid, a value smaller than 1 means the contrary.

The mean and variation coefficient of R_2 are calculated as follows:

The cumulative density function of a bid or cost estimate from a normal distribution is:

$$F(x) = \int_{-\infty}^{x} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{t-\mu}{\sigma}\right)^2} dt$$

The probability density function of a bid or cost estimate from a normal distribution is:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

The cumulative density function of the lowest bid is:

$$F_{\min(X_1,\ldots,X_n)}(x)$$

$$= P(\min(X_1,\ldots,X_n) \le x) = 1 - P(\min > x)$$

$$= 1 - P(X_1 > x) \cdot P(X_2 > x) \cdot \ldots \cdot P(X_n > x)$$

$$= 1 - (1 - P(X_1 \le x))^n = 1 - (1 - F_{X_1}(x))^n$$

The probability density function of the lowest bid is:

$$f_{\min(X_1,\ldots,X_n)}(x) = n \cdot (1 - F_{X_1}(x))^{n-1} \cdot f_{X_1}(x)$$

The expected value of the lowest bid is:

$$E(\min(X_1,\ldots,X_n)) = n \int_{-\infty}^{\infty} (1 - F_{X_1}(x))^{n-1} \cdot f_{X_1}(x) \cdot x \cdot dx$$

The variance of the lowest bid is:

$$\operatorname{var}(\min(X_1,\ldots,X_n)) = E(\min^2) - E^2(\min)$$

$$= n\int_{-\infty}^{\infty}(1-F_{X_1}(x))^{n-1} \cdot f_{X_1}(x) \cdot x^2 \cdot dx - \left(n\int_{-\infty}^{\infty}(1-F_{X_1}(x))^{n-1} \cdot f_{X_1}(x) \cdot x \cdot dx\right)^2$$

The mean and variation coefficient of R_2:

$\mu(R_2) = \dfrac{E(\min(X_1,\ldots,X_n))}{\mu_{estimate}}$ = dependent on n

V(R_2) = $\sqrt{V^2_{lowest\ bid} + V^2_{estimate}}$ = dependent on n

Again the assumption is that: $V_{bid} = V_{estimate}$

Fig. 2 shows the bandwidth around the average of R_2 plotted against the number of contractors if the value for the variation coefficient is 5.1 % again.

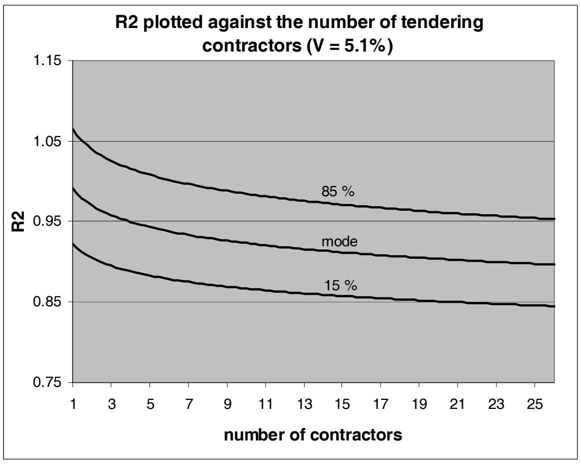

Fig. 2. R_2 plotted against n (with V = 5.1 %)

PERFORMANCES PRIOR TO THE CONFESSION

Now, the values of R_1 of the three engineering firms from before November 2001 will be plotted into fig. 1. This results in a new figure. When the average R_1 value equals one, and the accuracy of the estimators and the contractors are the same, then approximately 70 % of the R_1 values is expected to lie between the 15 % and 85 % lower limits, which were determined by the theoretical model. When clearly less than 70 % of these values lie between these lines then either the average R_1 value is not one or the accuracy of the bids and the cost estimate is not the same. The R_1 values of the different firms will be plotted separately, because the relative bias and accuracy can vary per firm.

Fig. 3, 4 and 5 show the R_1 values of the three different firms. Also the lower limits that followed from the model if $V_{bid} = V_{estimate} = 5.1$ % have been shown.

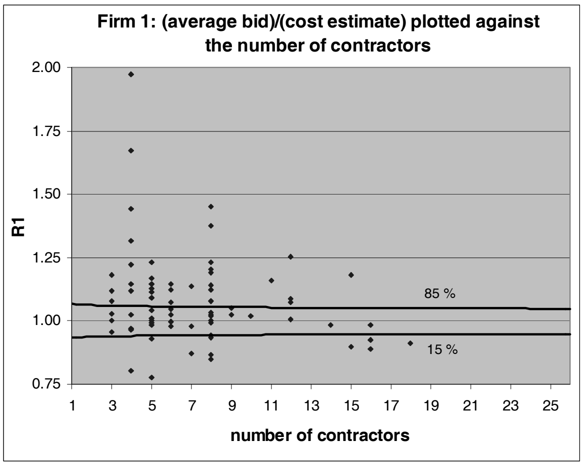

Fig. 3. R_1 values of firm 1 (before)

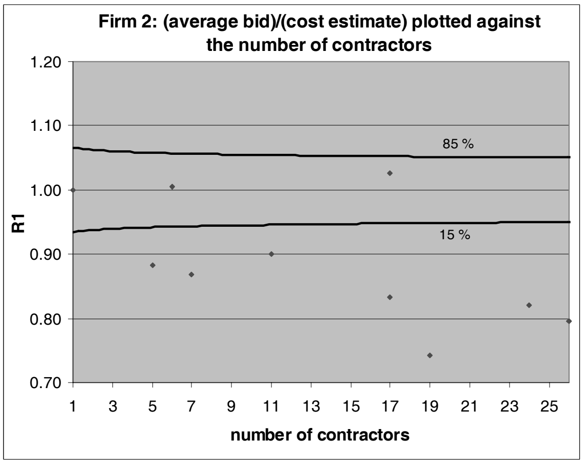

Fig. 4. R_1 values of firm 2 (before)

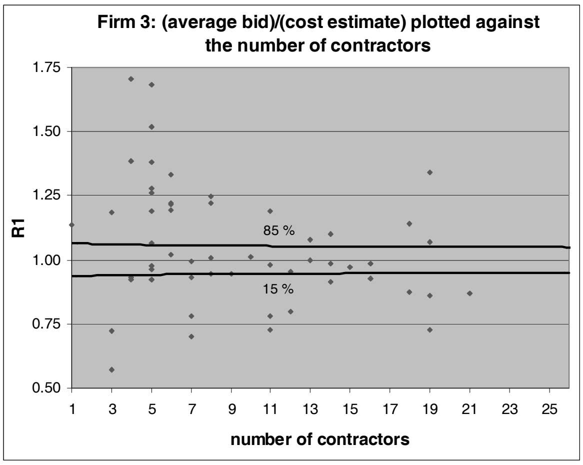

Fig. 5. R_1 values of firm 3 (before)

None of the three firms gets 70 % of the R_1 values between both lower limits. Firm 1 only gets 36 % between these lines, firm 2 only 30 % and firm 3 just 24 %. Only two possible reasons exist why less than 70 % of the R_1 values fit between both boundaries. Either the price level of the cost estimate differs from the price level of the bids, or the accuracy differs, or both.

Table 2 shows the mean of the R_1 value per firm and the margin that is needed around that mean to get 70 % of these values between both lower limits.

Table 2. Mean and margin per firm

	$\mu(R_1)$	margin(R_1)
Firm 1	1.08	11 %
Firm 2	0.89	10 %
Firm 3	1.06	21 %

The margin around R_1 can be seen as the variation coefficient of R_1: $V(R_1)$. Now that $V(R_1)$ and V_{bid} are known $V_{estimate}$ can be estimated per engineering firm if we take for n the average amount of tendering contractors at their tenders. This calculation goes as follows:

$V(R_1) = \sqrt{V_{estimate}^2 + V_{bid}^2/n}$

Firm 1:

$\mu(R_1) = 1.08$; $V(R_1) = 11$ %; $V_{bid} = 5$ %; $n = 7$;

$\rightarrow V_{estimate(1)} = 11$ %

Firm 2:

$\mu(R_1) = 0.89$; $V(R_1) = 10$ %; $V_{bid} = 5$ %; $n = 13$;

$\rightarrow V_{estimate(2)} = 10$ %

Firm 3:

$\mu(R_1) = 1.06$; $V(R_1) = 21$ %; $V_{bid} = 5$ %; $n = 10$;

$\rightarrow V_{estimate(3)} = 21$ %

In the above way the variation coefficient of the cost estimate of the three firms has been deduced from the variation coefficient of the relative bias of the average bid $V(R_1)$, the variation coefficient of a bid V_{bid} and the number of contractors n. The difference in variation coefficient between the cost estimates of the engineering firms and the bids of the contractors is rather large. Therefore, it seems improbable that these prices are derived from the same distribution. However, the relatively low variation coefficient of the bids is possibly the result of the appointments made in the preliminary discussions. The effects of the preliminary discussions will be investigated in the next section.

It is also striking that the variation coefficient of the cost estimates of firm 3 is much larger than the variation coefficients of the firms 1 and 2. An explanation for this coud be that firm 3 does never take the market situation into account, while the times that firm 1 and 2 take this into account varies.

Fig. 6, 7 and 8 show that now indeed 70 % of the R_1 values lie between both lower limits.

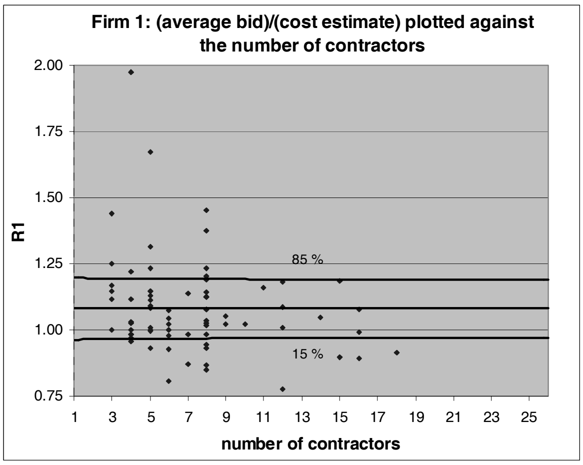

Fig. 6. R_1 of firm 1, $\mu(R_1) = 1.08$; $V(R_1) = 11$ %;

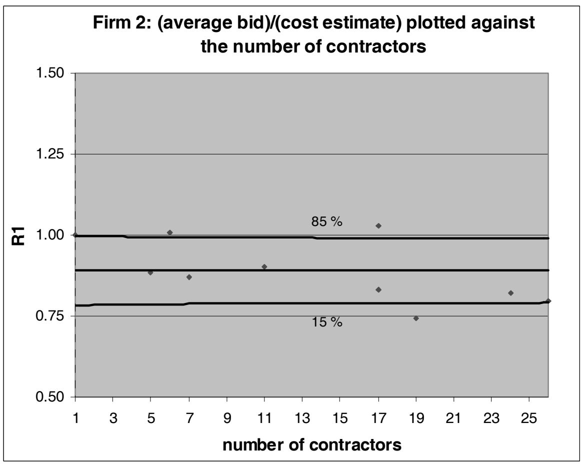

Fig. 7. R_1 of firm 2, $\mu(R_1) = 0.89$; $V(R_1) = 10\%$;

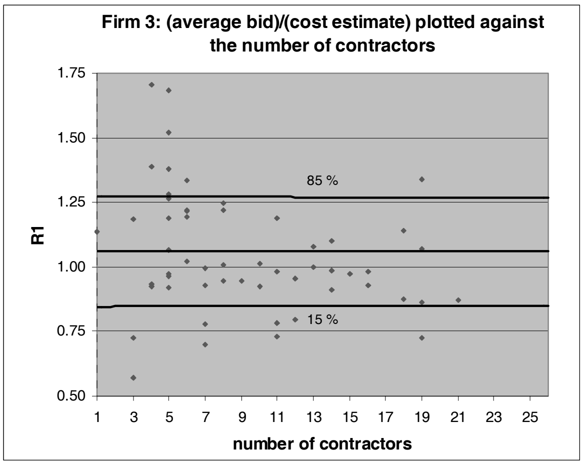

Fig. 8. R_1 of firm 3, $\mu(R_1) = 1.06$; $V(R_1) = 21\%$;

Now that we know the relative bias and accuracy of the cost estimates per engineering firm by means of $\mu(R_1)$ and the variation coefficient, these performances can be visualized. Fig. 9, 10 and 11 show this. To be able to compare the relative bias of the engineering firms mutually the average price level of the bids is set at 1.

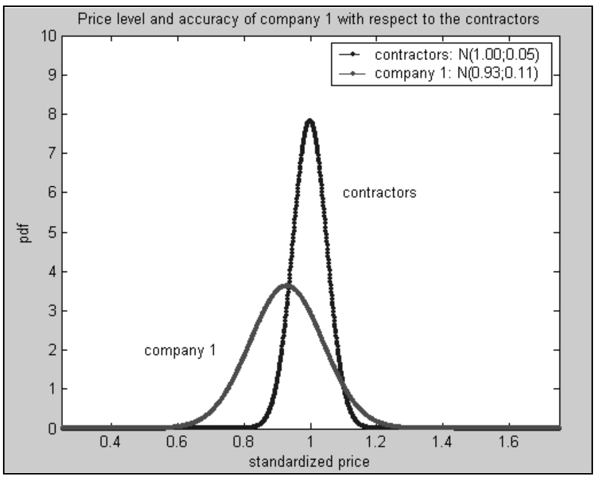

Fig. 9. Performance of firm 1

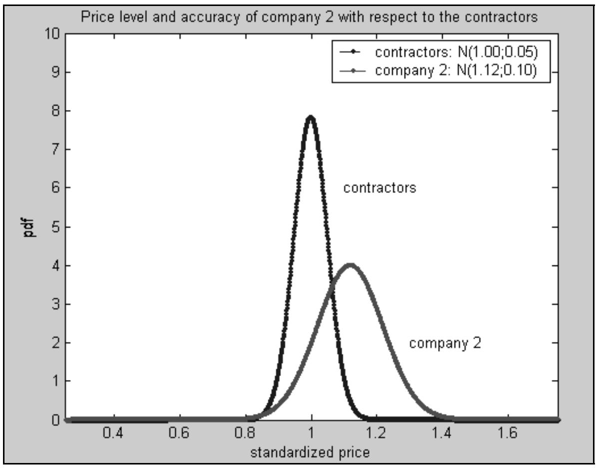

Fig. 10. Performance of firm 2

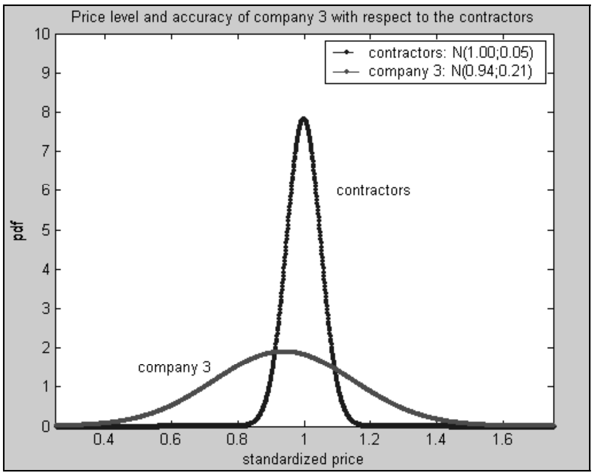

Fig. 11. Performance of firm 3

PERFORMANCES AFTER THE CONFESSION

Calculations showed that the variation coefficient of the bids has increased considerably from 5 % to 9 % since November 2001. Unfortunately, following this date only a proper tender data set of firm 1 was available. Nevertheless, the relative bias and variation coefficient of the estimates of this firm following this date can be calculated in the same way.

$V(R_1) = \sqrt{V_{bid}^2/n + V_{estimate}^2}$

Firm 1 (before):

$\mu(R_1) = 1.08$; $V(R_1) = 11$ %; $V_{bid} = 5$ %; $n = 7$;

→ $V_{estimate(1)} = 11$ %

Firm 1 (after):

$\mu(R_1) = 0.95$; $V(R_1) = 9$ %; $V_{bid} = 9$ %; $n = 10$;

→ $V_{estimate(1)} = 9$ %

While the variation coefficient of the bids has since increased from 5 % to 9 %, the variation coefficient of the cost estimate of firm 1 has decreased from 11 % to 9 %. Consequently, the variation coefficient of the cost estimate of firm 1 and the bids of the contractors are currently equal, as would be expected if the quality of both the estimate and the bids is the same. Another remarkable fact is that the $\mu(R_1)$ of this firm has decreased from 1.08 to 0.95. This signifies that the average bid has decreased with 13 % in comparison with firm 1's cost estimate since the illegal preliminary discussions have stopped and because the variation coefficient of the bids has increased this only means that the lowest bid has decreased even more than 13 %. Fig. 12 shows the difference between both periods.

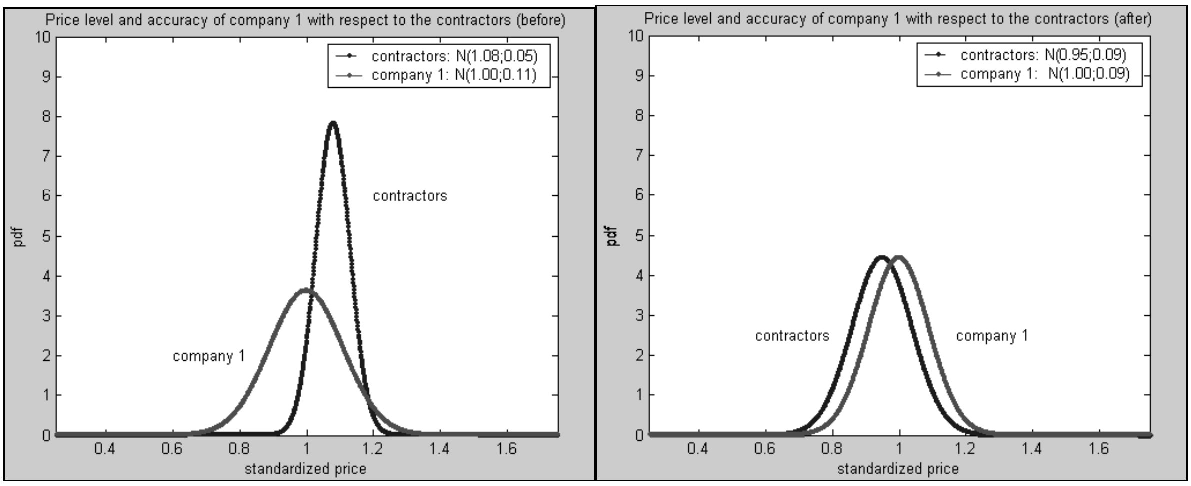

Fig. 12. Performance of firm 1 before and after.

EFFECT OF PRELIMINARY DISCUSSIONS

LOWERING OF THE BIDS TOWARDS THE LOWEST BID

To be able to understand the model that will be built up to determine the effect of the preliminary discussions on the bids it is essential to understand the following. Before November 2001 contractors held preliminary discussions in which they decided by means of a pre-tender which contractor was allowed to have the lowest bid in the tender. After this decision they often reduced the spread of the bids by lowering the bids towards the lowest bid while they kept the order of the bidders the same. This resulted in an artificially low variation coefficient of the bids and therefore it seemed that the bids of the contractors were very accurate.

The model is based on the following assumption: if contractors do not hold preliminary discussions then the bids are derived independently from a normal distribution with a variation coefficient of 9 %. This 9 % is the average of the variation coefficient of all held tenders (which were available) after November 2001. And, as probably no preliminary discussions have been held since, it is assumed that this is the real value of the variation coefficient of the bids if the contractors bid independently without preliminary discussions.

The corresponding lower limits of the variation coefficient have been calculated and the results are shown in Fig. 13 shows the results.

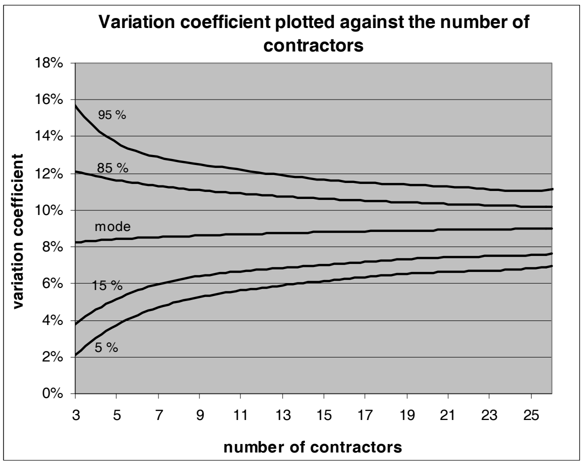

Fig. 13. Lower limits according to the model.

If the calculated variation coefficients of the tenders from before November 2001 are plotted into this figure we can test if the data complies to the model by determining if indeed 15 % of the data points lies under the 15 % lower limit.

A distinction has been made between two types of tradional tenders: private and public tenders. Therefore the variation coefficients of these tenders have been plotted separately. Figure 14 shows the variation coefficients of the private tenders, while figure 15 shows the variation coefficients of public tenders.

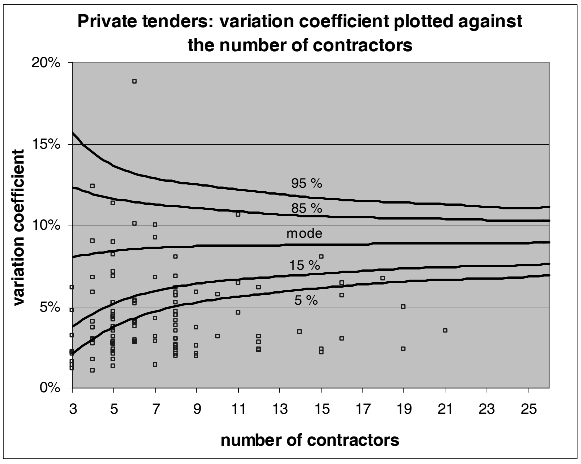

Fig. 14. Variation coefficient of private tenders.

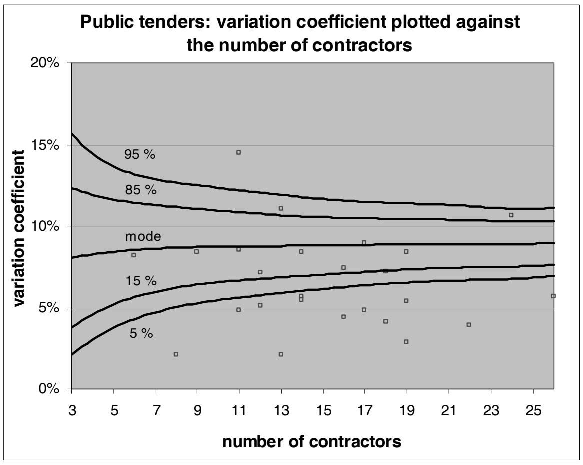

Fig. 15. Variation coefficient of public tenders.

Both figures show that relatively much data points lie under the 15 % lower limit, which follows from the model. In 81 % of the private tenders the calculated variation coefficient was lower than the 15 % lower limit value from the model. At the public tenders this percentage is 56 %. The following ratio can estimate the percentage of tenders in which the contractors have lowered the bids towards the lowest bid:

Percentage = $\frac{x\% - 15\%}{100\% - 15\%} * 100\%$

x = percentage of tenders of which the variation coefficient is lower than the 15 % lower limit.

Table 3 shows these percentages of the private and public tenders.

Table 3. Percentages

	Percentage
Private	78 %
Public	48 %

HEIGHTENING OF THE BIDS TOWARDS THE COST ESTIMATE

Contractors not only lowered the non-lowest bids towards the lowest bid in the preliminary discussions. They also heightened all the bids in such a way that the lowest bid was near the known or estimated cost estimate of the engineering firm. Subsequently, this heightening was divided over the non-winning contractors. Again, the model that determines the amount in which this took place is based on the assumption that the cost estimate and the bids are derived independently from a normal distribution with a variation coefficient of 9 %.

The cost estimate of the percentage of tenders in which heightening took place can be made with the help of R_2 ($lowest\,bid/estimate$). The lower limits of R_2 are determined for a variation coefficient of 9 % and for the assumption that the average R_1 value amounts 1. If the bids are realized without preliminary discussions then the expectation is that approximately 50 % of the R_2 values lie beneath the mode line.

Fig. 16 shows the lower limit values of R_2 per number of tendering contractors if V = 9 %.

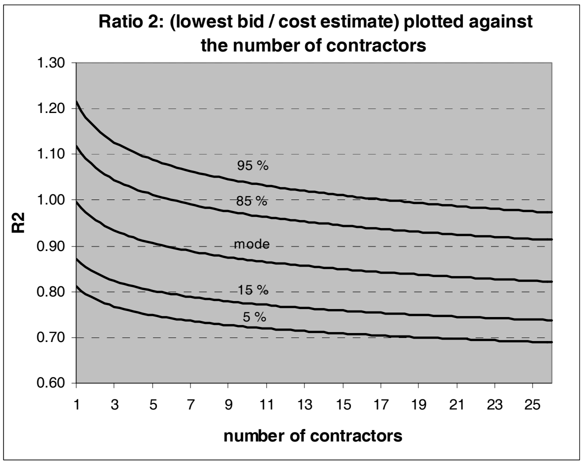

Fig. 16. Lower limits of R_2 (V = 9 %)

The following ratio can estimate the percentage of tenders in which the contractors possibly have heightened their bids in preliminary discussions:

Percentage = $\frac{y\% - 50\%}{100\% - 50\%} * 100\%$

y = percentage of tenders of which the R_2 value is lower than the mode.

The R_2 values of the engineering firms are treated separately, because of the differences in the performance of these firms. In brief, not only a distinction is made between the type of tender (public or private) but also between the firms.

The real measured R_2 values of the private tenders of firm 1 are shown in fig. 17a. The lower limit lines following from the model with V = 9 % are also plotted in the figure. The assumption is that on average firm 1 estimates 5 % lower than the average bid, as the average R_1 value of firm 1 was 0.95 after November 2001, when the preliminary discussion did not take place anymore. Fig. 17b shows the same of firm 3. It is assumed that the average price level of their estimate is the same as the price level of the average bid. This assumption is made, because no tender data of this firm from after November 2001 were available. Firm 2 is kept out of consideration because insufficient data were available.

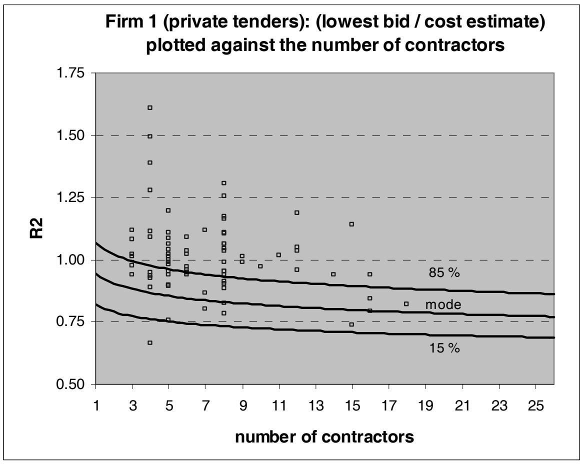

Fig. 17a. R_2 values of firm 1 (private tenders)

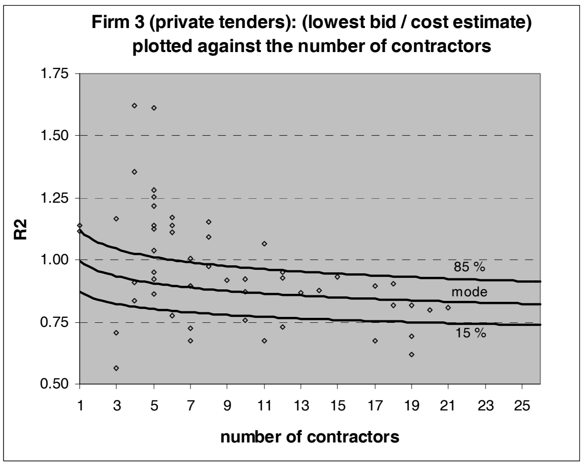

Fig. 17b. R_2 values of firm 3 (private tenders)

The R_2 values of the private tenders of firm 1 were in 92 % (y = 92 %) of the tenders higher than the mode following from the model. Firm 3's R_2 values were higher in 66 % (y = 66 %) of the tenders. Table 4 shows the calculated percentages of tenders at which the contractors probably heightened their bids.

Table 4. Percentage of private tenders with heightened bids

	Percentage
Firm 1	84 %
Firm 3	32 %

The difference in percentage of bid heightening is rather large. The fact that firm 3 does never take the market situation into account could be an explanation for this. For example, when, due to a declining economy, the bids in the pre-tender are low, the average bid in the tender can still -- even after heightening of the bids in the preliminary discussion -- be lower than the neutral estimate of firm 3. Nevertheless, the assumption that the average R_1 value of firm 3 is equal to 1 in the period after November 2001 could also have influence on this percentage. Because, when the real average R_1 value appears to be lower than 1 (like the R_1 value of firm 1) the percentage of heightened bids increases. For example, when the average R_1 value is set at 0.95 the percentage increases to 73 %.

Subsequently, the percentage of public tenders with heightened bids can be calculated. Firm 1 has not held this type of tenders and firm 2 only has a small amount of public tender data available. This is the reason why the percentage of heightened bids at public tenders has only been determined with the public tender data of firm 3. Fig. 18 shows the results.

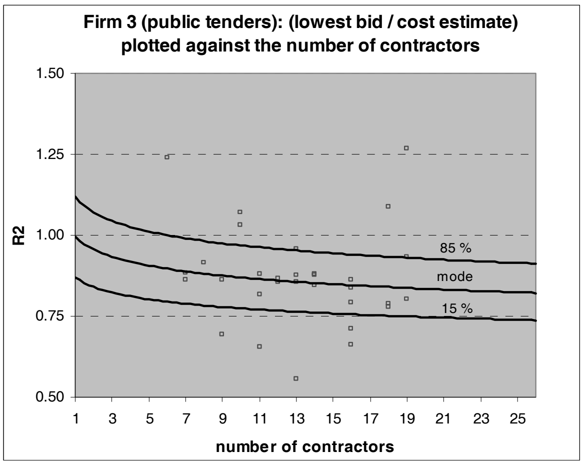

Fig. 18. **R_2 values of firm 3 (public tenders)**

At these tenders, it even appeared that there was negative heightening of the bids in 6 % of the cases. This percentage has been calculated with the assumption that the price level of the cost estimate of firm 3 is equal to the price level of the average bid. Actually, this needs to be checked with tender data from after November 2001, when preliminary discussions did not take place anymore. However, these data were not yet available. Nevertheless, when 0.95 is again taken for the average value of R_1 of firm 3 the percentage would increase to 60 %. This shows that the determination of this percentage is very sensitive to small deviations.

The question is if, in the future, the bids will stay this low in comparison with the cost estimates. At this moment, it seems impossible for contractors to still make a profit, because in the past, when preliminary discussions were being held, they only realized a yearly profit of 2 % or 3 %. It could be expected that the price level of the bids would increase to the former level or go beyond this level, because the preliminary discussions secured the continuity of orders for the contractors. This continuity is less certain nowadays, which means that the risks for the contractors have increased and this might be accounted for in the bids.

It is also in question if the owners are made to lose by this heightening. On the one side the bids were heightened in forbidden discussions, on the other side the contractors only realized a profit of 2 % or 3 % on the annual turnover. Probably the bids in the pre-tender were at relatively low levels, because a contractor knew that if he was the lowest bidder he would then probably be able to raise his bid.

BENEFIT OF A SECOND OPINION

The height of the variation coefficient of R_1, $V(R_1)$, is not only determined by the variation coefficient of the cost estimate, but also by the variation coefficient of the bids.

$$V(R_1) = \sqrt{V_{estimate}^2 + V_{bid}^2 / n}$$

The accuracy of R_1 not only depends on the accuracy of the cost estimate, but also on the accuracy of the bids and the number of tendering contractors. The variation coefficient of the cost estimate could possibly be reduced by the use of a second opinion for the determination of the estimate. A model will be build up to determine if this is possible. The starting-point is that the average of the bids and the cost estimate are equal, that both have a variation coefficient of 9 % and that the bids and the cost estimate are derived from a normal distribution.

In fact, (n+2) drawings are done out of the normal distribution N(1;0.09). N times by the contractors, two times by engineering firms.

$\mu(R_1) = \mu_{bid}/\mu_{estimate} = 1$

$$V(R_1) = \sqrt{V^2_{average\ bid} + V^2_{average\ estimate}} = \sqrt{(V^2_{bid}/n) + (V^2_{estimate}/m)}$$

$$= (1/n + 1/2)^{1/2} * V$$

The assumptions are:

m = number of cost estimates = 2

V = V_{bid} = $V_{estimate}$ = 9 %

μ = μ_{bid} = $\mu_{estimate}$

Fig. 19 shows the under limit lines of R_1 with and without a second opinion on the condition that the mean and the variation coefficient of both estimators are equal.

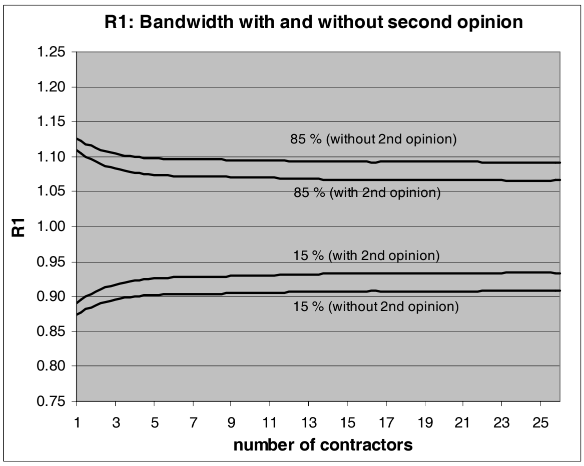

Fig. 19. Bandwidth of R_1 with and without 2^{nd} opinion

Fig. 20 shows that the bandwidth around R_2 also decreases with a second opinion.

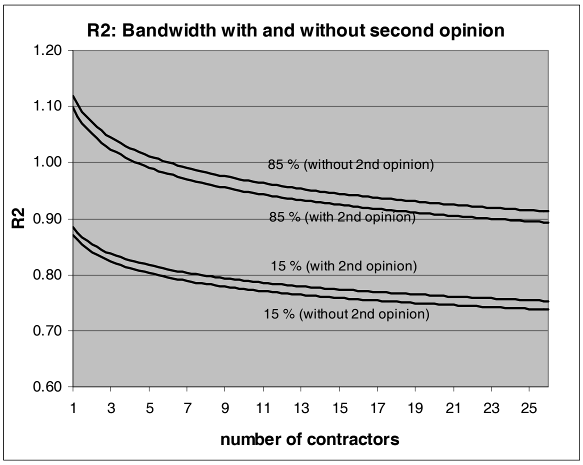

Fig. 20. Bandwidth of R_2 with and without 2^{nd} opinion

Nevertheless, in practice the price level of the cost estimates and the spread around these cost estimates are not equal (as we have seen) and the engineering firms do not even know their own price level. For this reason the benefit of a second opinion decreases.

However, a second opinion can still give an added value, in that a possible error in the first cost estimate can be noticed. If this error is seen prematurely the budget still can be adapted.

In this manner the probability can be decreased that an owner is not able to award a work because of budget problems due to a cost estimate error. However, when a second opinion only is asked in the specification phase, it will be too late to adapt the budget if necessary. On that account it is wiser to ask for a second opinion between the provisional and the definite design phase. If it then appears that the first cost estimate contains an error it is still possible to adapt the budget.

To know if the costs for making a second opinion counterbalance the decreased probability that a project is not tendered because of an error in the cost estimate, one should trace the percentage of tenders that had budget problems owing to an error in the cost estimate.

Subsequently, one should estimate the cost of not being able to award the work in question and the costs of a second opinion for that project.

With the help of the formula mentioned below it is possible to determine if it is financially attractive to ask for a second opinion. It is useful to ask for a second opinion if:

$$P * K \geq k$$

$$P \geq \frac{k}{K}$$

P = probability that a project can not be awarded because of budget problems due to an erroneous estimate.

K = costs of not being able to award the project.

k = costs of making a second opinion.

If the ratio k/K is smaller than P then it is advantageous to ask for a second opinion for that project. The P value varies per engineering firm because it depends on the price level and accuracy of the cost estimates. If the price level is low in comparison to the average bid and the accuracy is high then this value is relatively high. And therefore it is rather useful to ask for a second opinion then.

OPTIMAL NUMBER OF INVITED CONTRACTORS

At times quite a lot of contractors were invited to tender for a project. The owner's purpose was to receive a bid as low as possible.

Indeed, the expected value of the lowest bid decreases as the number of invited contractors increases. However, every tendering contractor incurs costs to come to its bid. And because owners in the Netherlands are not obliged to pay cost estimate compensation, they often neglect the cost of inviting an extra contractor. As a matter of fact this is not the case, because if an owner does not pay cost estimate compensation the contractor will have to recover these costs in another way, and these costs will show up in the price in some way. In this section will be determined what the optimal number of invited contractors is.

Kuiper (1997) has developed a model for the determination of the optimal number of invited contractors. This model depends on the transaction costs and the variation coefficient of the bids. It is generally assumed that for projects with traditional builder's specifications a self-financing calculation compensation is approximately 0.5 % of the sum contracted for. Before November 2001 the tenders appeared to have an average variation coefficient of 5 %, nowadays it has increased to 9 %. Another important difference is the fact that the bids were sometimes heightened before November 2001. For this reason the model of Kuiper (1997) did not hold in the past. Nevertheless, since this heightening has ended it can be useful to base the choice for the number of invited contractors on this model.

The optimal number of invited contractors has been defined as the number at which the social costs are minimal. Below follow the formulas that are needed to determine the optimal number.

Costs:

transaction costs = bid costs * n

cost price (lowest bid) = μ_{bids} - σ_{bids} * $\xi(n)$

total costs = transaction costs + cost price

Optimal number of contractors:

$$\frac{d\left(total\ costs\right)}{dn} = 0$$

$$\frac{d\left((bid\ costs \cdot n) + (\mu_{bids} - \sigma_{bids} \cdot \xi(n))\right)}{dn} = 0$$

$$bid\ costs - \sigma_{bids} \cdot \frac{d\xi(n)}{dn} = 0$$

$$bid\ costs - \sigma_{bids} \cdot \frac{\left(\frac{\mu_{bids} - E(\min(X_1,...,X_n)}{\sigma_{bids}}\right)}{dn} = 0$$

$$bid\ costs + \frac{d\left(E(\min(X_1,...,X_n)\right)}{dn} = 0$$

The above formula shows that the optimal number of contractors is where the sum of the changes in the expectation value of the lowest bid and the offer costs equal zero.

The general opinion is that for tenders with traditional specifications the offer costs per contractor are approximately 0.5 % of the cost price. For the variation coefficient of the bids 9 % is held, this is the average measured variation coefficient since November 2001.

Fig. 21 shows that the optimal number of contractors for tenders with traditional builder's specifications amounts approximately 9 or 10, because at that number lies the minimum of the total costs. Fig. 22 also displays that the total costs only increase slowly above the optimal number of contractors. The figure also makes clear that it would be unwise to invite a very limited number of contractors. When one or two contractors are invited, the total price is still higher than if for example 25 contractors were invited.

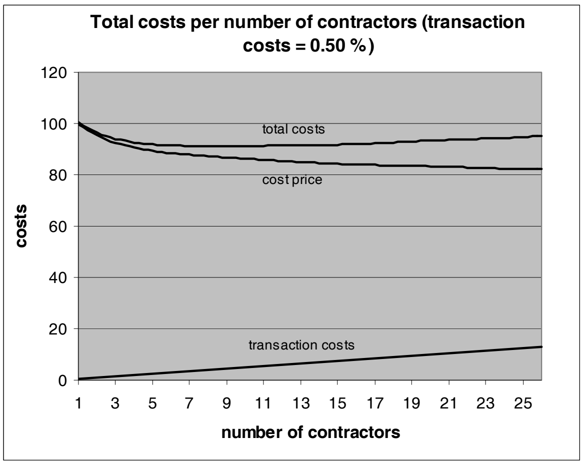

Fig. 21. Costs per number of contractors.

Not all invited contractors calculate a price for the project and therefore it is recommended to invite one or two additional contractors, on top of the number which is derived from the model. This causes no problem when all contractors do tender a price for the work. The total costs with two additional contractors are still less then the total costs with two contractors below the optimal number.

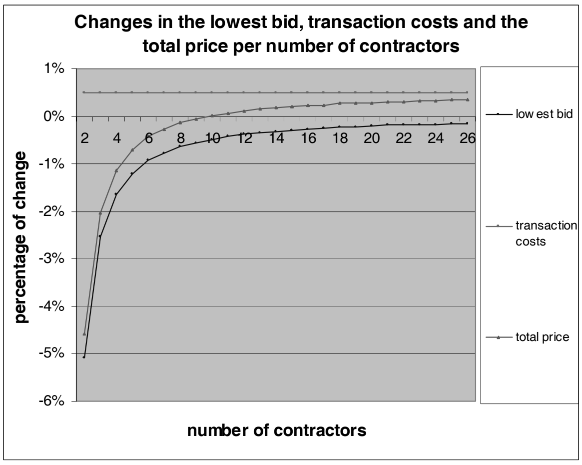

Fig. 22. Percentage of change of costs per number of contractors.

If one considers the offer costs to be different than the 0.5 % of the sum contracted for then fig. 23 shows the optimal number of contractors for other percentages of the bid costs. The undermost line displays the total costs if the bid costs amount 0.1 %, the line above it the total costs if the bid costs are 0.2 %, etceteras. The uppermost line shows the total costs if the offer costs amount 1.0 %.

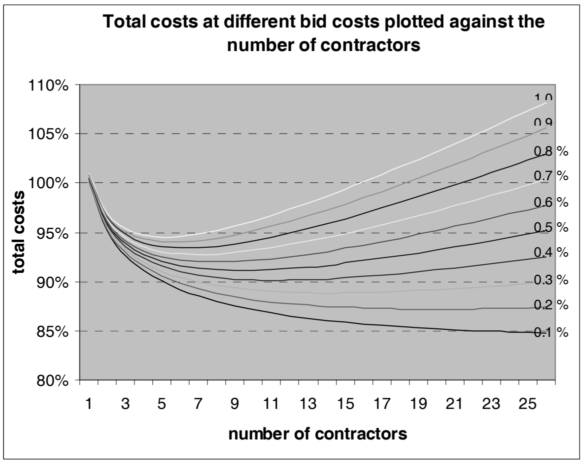

Fig. 23. Total costs per number of contractors at different bid costs (V_{bid} = 9 %).

The above-calculated optimal number of contractors of 9 or 10 only holds for tenders with traditional builder's specifications. The optimal number for design and construct projects can not be calculated in the same way. At these projects competition is not only on the price of a prescribed concept, but on the choice of the concept as well. At design and construct works the contractors provide for both the design and the construction of the project. The underlying idea of design and construct is that a contractor prepares a sound concept. At tenders with traditional specifications there is only one concept, most of the time designed by an engineering firm, which the contractors price. The benefit of design and construct is the possibility for the contractor to come with a better concept. However, the disadvantage is that competition of price within that particular concept does not take place.

If an owner were to ask different engineering firms (or contractors) to make different concepts then the best concept can be chosen. In addition, the best concept can be tendered to create price competition within that concept. Consequently, the owner not only gets the best concept but also the best price within that concept. Fig. 24 shows how such a system would work.

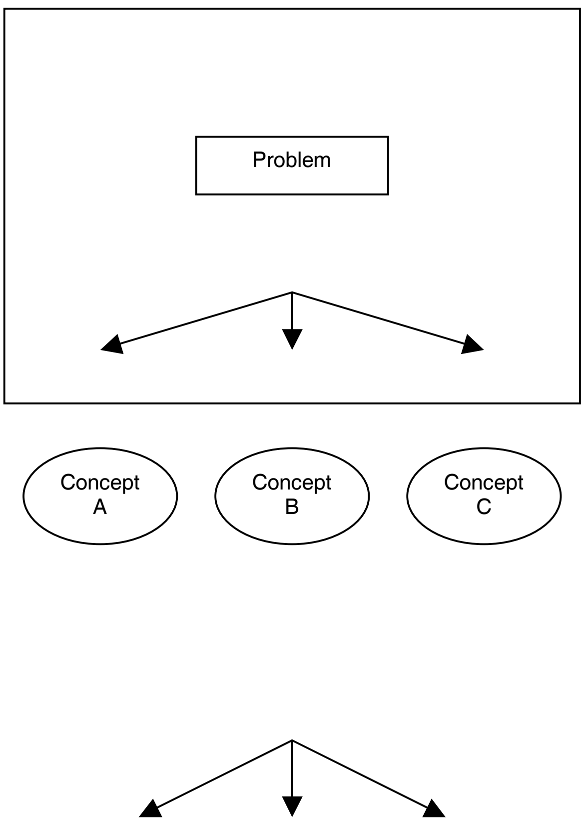

Fig. 24. New system for design and construct.

Once the choice is made for a concept this system is nothing else than the system of works with traditional specifications, because the competition on price can start then by means of a tender. As a result, the question is if it is worth to ask for different concepts and therefore to be able to chose the best concept. In other words, the costs for making extra concepts have to be weighed against the worth of the choice between more concepts.

SUMMARY AND CONCLUSIONS

This research has paid attention to the performance of contractor's bids in comparison to the performance of the cost estimate of engineering firms. The study concluded that the performance of different engineering firms varies rather much. The difference in the accuracy of the cost estimate might be caused by the different approach of the firms in taking account for the market situation while preparing their cost estimate. It also demonstrated that large difference exists between the price level and the accuracy of estimates and bids from before and after 9 November 2001, the date on which a former contractor gave disclosures of the tender procedure until that day. This caused changes in the tender procedure, and as a result the price level of the average bids in private tenders has decreased with 13 % since that date. The variation coefficient of the bids has changed from 5 % to 9 %. This means that the bids are currently less accurate than before and that because of this larger variation coefficient the lowest bid in private tenders has even increased more than 13 %. As a result, owners currently pay less for realizing a project. Probably the halting of preliminary discussions, which no longer take place, causes these changes.

Then, a mathematical model, developed to estimate the extent to which contractors manipulated the tender bids, showed that in the preliminary discussions the bids were probably lowered towards the lowest bid in approximately 78 % of the private tenders and in 48 % of the public tenders. The model also calculated that in probably 84 % of the private tenders the bids were heightened towards the cost estimate.

Subsequently a model showed that a second opinion could contribute to the accuracy of a cost estimate in theory. However, as the performances of different engineering firms are not the same, it would be a challenge to increase the accuracy. Nevertheless, a second opinion may be beneficial if it discovers errors in the first estimate, which could lead to budget problems, before the budget is determined.

Finally another model calculated the optimal number of contractors to be invited for a tender. This number depends on the variation coefficient of the bids and the contractors' costs to prepare their bid. It resulted in an optimal number of approximately 10 contractors for tenders with traditional builder's specifications

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