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RISK MITIGATION IN FAST TRACKING PROJECTS

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Abstract

In an expanding market for polyolefin's, a business opportunity developed for a Netherlands based owner/operating company when an existing site in Germany could be taken over. On this site a polyethylene plant and a polypropylene plant had to be constructed in a very short time. This meant that the phased approach (feasibility study, conceptual engineering, basic engineering, EPC-phase) would have taken too much time. As a consequence, the appropriation of the project had to be done before the start of the basic engineering. Because there was no formal appropriation estimate with the required accuracy, the funding was based on a Monte Carlo risk analysis. The risk analysis was performed by the contractor as well as by the owner. The contractor used inputs to the risk analysis that were derived from the project execution plan. The owner used inputs to the risk analysis based on historical cost data of executed projects. Both ways of risk analysis are presented in more detail in this article. The appropriation estimate was chosen as the point on the probability distribution of the total expected cost with a probability of cost overrun of 30%. The contract with the contractors was a design-build contract with a lump sum part for contractor services and a reimbursable part for material and labor. To further mitigate the risks attached to this non-phased approach the contract contained an incentive on cost underrun. This way of "gain and pain-sharing" is also described in more detail in this paper. The plants were constructed well within the fast track schedule. A very important lesson learned was to spend more time on scope quantities review, as a large part of the cost under run was caused by quantity under runs on materials and work hours.

Introduction

The phased approach to project realization is a thorough, but time consuming process. Not only the sequential phases conceptual engineering, basic engineering and (Detailed) Engineering, Procurement en Construction (EPC-phase) take their time, but also the decision steps in between these phases. Sometimes there is a business opportunity if the time to market can be short enough. In this paper a project is described where the necessary short schedule was enhanced by reducing the number of decision steps and by a continuous change-over from basic engineering to the EPC-phase. Within the owner organization appropriation of major capital projects is normally based on completed basic engineering with a +/- 10% estimate. In this case the +/- 10% estimate was replaced by a Monte Carlo risk analysis, which gave the range of possible capital cost outcomes for the projects. The intent of this paper is to describe the two approaches taken to construct a model of the estimate as input for the risk analysis. Special attention is given to the importance of correlations between inputs to the risk model. If these dependencies are not recognized, the variance of the total project cost (output of the model) will be too small (the range of the possible capital cost outcomes will be too narrow) and wrong conclusions may be drawn from the risk analysis. To further mitigate the project cost risks a design-build contract was developed that contained an incentive for the contractor to underrun the direct (Material & Labor) part of the project budget. This contract will also be described in more detail.

Basics of Monte Carlo risk analysis

In applying Monte Carlo risk analysis to an estimate, parts of the estimate are treated as stochastic variables, i.e. variables with a probability distribution. In many cases simple triangular distributions with a "minimum", a most probable (likeliest) and a "maximum" value for the possible costs for that part of the estimate are sufficient:

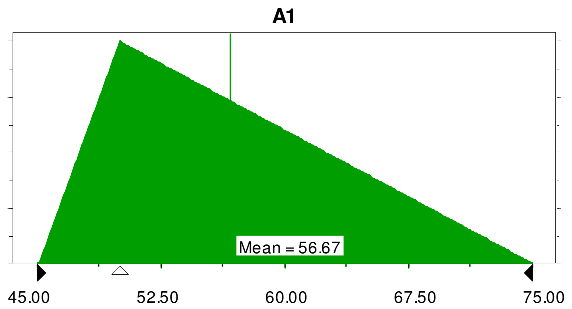

figure 1, triangular distribution

In this example the distribution chosen is skewed, showing the expectancy that cost overruns on this part of the estimate are more likely than cost underruns. These probabilities are the inputs to the risk model. The total project cost, being the sum of the stochastic estimate parts, is the output of the model. The risk analysis itself is done in off-the-shelve PC-software. This software calculates a few hundred or even a few thousand times the total project costs, taking at each calculation (iteration) another value from the probability distributions of the estimate parts. This is accomplished by a random number generator within the software; the random numbers are then transformed to simulate a probability distribution. In this way the values from each estimate part are taken according to the form of this distribution, e.g. in the case of the triangular distribution, only few values near the minimum and near the maximum are taken, and most values are taken at the likeliest point of the distribution). In practice 1,000 iterations are sufficient to get enough convergence in the output. The possible outcomes for the total estimate are divided in classes, for instance 2 counts in class 147 - 148 mln, 6 counts in class 148 - 149 mln, 10 counts in class 149 - 150 mln, etc. This in itself is another probability distribution:

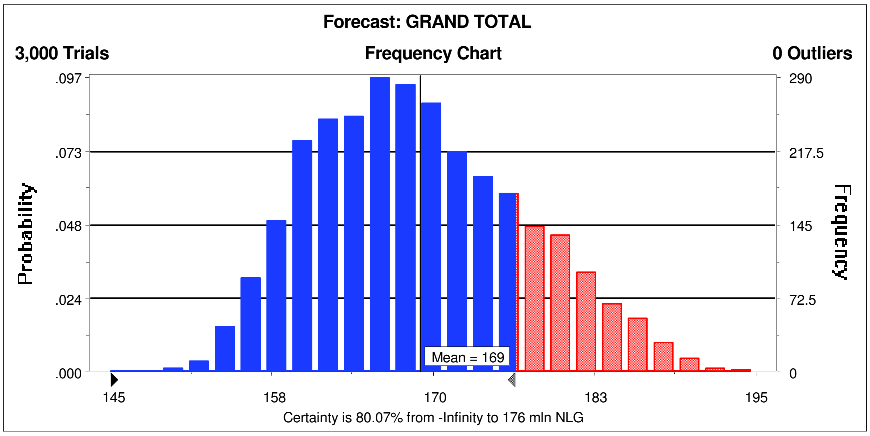

figure 2 distribution of forecast

This figure shows the total range of the project cost but also shows the mean value (50% possibility of overrun and underrun) and for instance the value with a probability of overrun of 20%. It makes management aware of the maximum project cost and it enables to decide on how much extra money in the project budget is needed to reduce the risk of overrunning that project budget.

The influence of correlations

When performing a risk analysis on an estimate special attention should be given to possible dependencies between estimate parts. For instance, if the possible cost for process equipment is increasing, this could be due to an increase of the number of equipment items or to applying more expensive materials of construction. In either case the cost of piping will also increase. In other words: There is a dependency between the costs of process equipment and the cost of piping. The effects of these dependencies can best be demonstrated using the normal distribution:

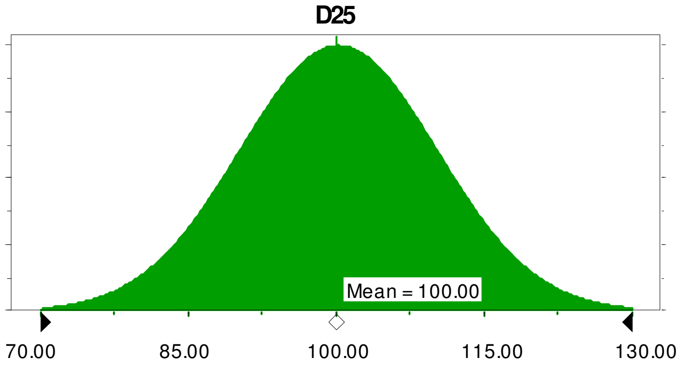

figure 3 normal distribution as input

The above normal distribution has a mean value μ (also called the expected value) of 100. It represents the "center of gravity" of the distribution, the number 100 has probabilities of over- and underrun of 50% each. The standard deviation σ is a measure for the spread of the distribution around the mean, a low σ giving a high peak and a high σ giving a low and broad distribution. One could say that the standard deviation is the mean of the differences of the various values in a distribution from their own mean. For the above (normal) distribution the standard deviation is 10. Fig. 3 shows the normal distribution when used as input in the software package. When simulated, the forecast will be shown as figure 4:

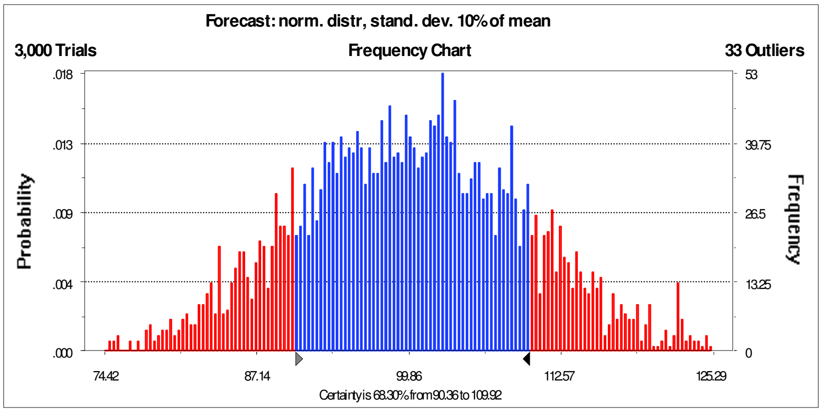

figure 4 normal distribution as forecast

From all possible outcomes approx. 68% are contained within the range μ - σ to μ + σ, which is characteristic for a normal distribution.

The square of the standard deviation, σ^2, is the variance.

If we have stochastic variables $\underline{x}$, $\underline{y}$ and $\underline{z}$, and $\underline{z} = \underline{x} + \underline{y}$, then the following relations are valid:

$$\mu\ (\underline{z}) = \mu\ (\underline{x}) + \mu\ (\underline{y}) \tag{1}$$

Translated to estimates: the mean value of the sum of two (or more) estimate parts is equal to the sum of their means. This relation holds both for independent variables x and $\underline{y}$ as well for dependent variables $\underline{x}$ and $\underline{y}$.

$$\sigma^2\ (\underline{z}) = \sigma^2\ (\underline{x}) + \sigma^2\ (\underline{y}) \tag{2}$$

For estimates this means that the variance of the sum of two (or more) estimate parts is equal to the variance of the sum of their standard deviations. It also means that the standard deviation of the sum of two (or more) estimate parts equals the square root of the sum of the variances of the estimate parts:

$$\sigma\ (\underline{z}) = \sqrt{}\ (\sigma^2\ (\underline{x}) + \sigma^2\ (\underline{y})) \tag{3}$$

Relations (2) and (3) are valid only if variables $\underline{x}$ and $\underline{y}$ are independent. So, if we have e.g. ten estimate line items each having a mean value $\mu = 100$ and a standard deviation $\sigma = 10$ (which is 10% of the mean), then the sum has a mean value $\mu = 1000$ and a standard deviation $\sigma = \sqrt{}\ (10 \times 10^2) \approx 32$ (which is approx. 3% from mean). This narrowing of the total range is caused by the fact, that the plusses and minuses of the ten estimate line items (if presumed to be independent of each other) tend to compensate each other.

In real life however parts of an estimate, representing parts of the scope of work, will not be independent. If for instance process equipment increases, piping and process control will also increase. If these dependencies are not recognized, the variance of the total project cost (output of the model) will be too small (the range of the possible capital cost outcomes will be too narrow) and wrong conclusions may be drawn. Figures 5 and 6 show the impact of the theory above: In figure 5 all 10 estimate parts are dependent, in figure 6 all 10 estimate parts are independent.

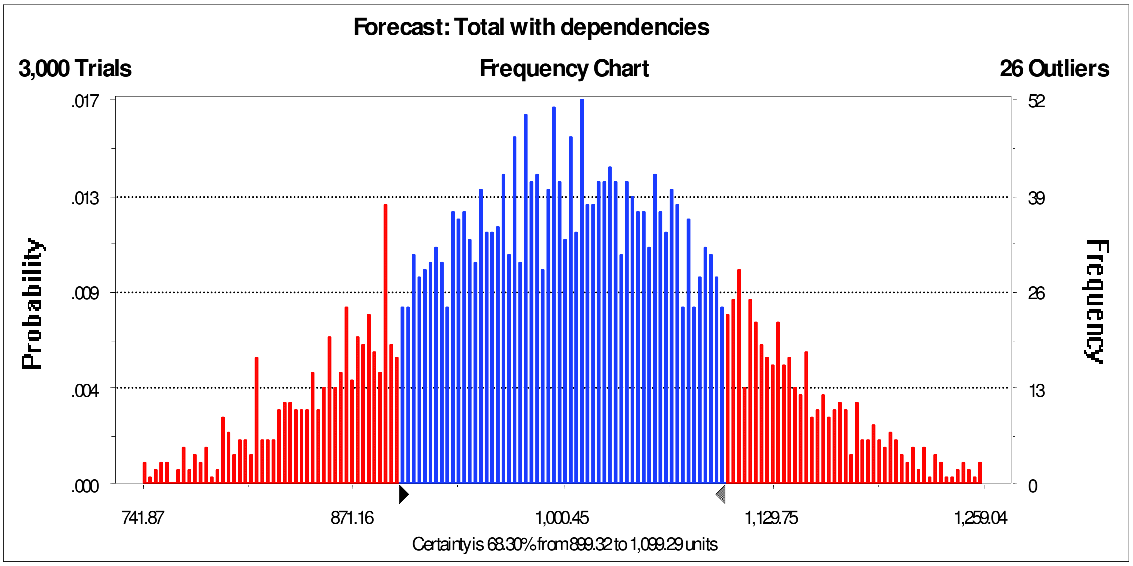

figure 5 forecast with dependencies

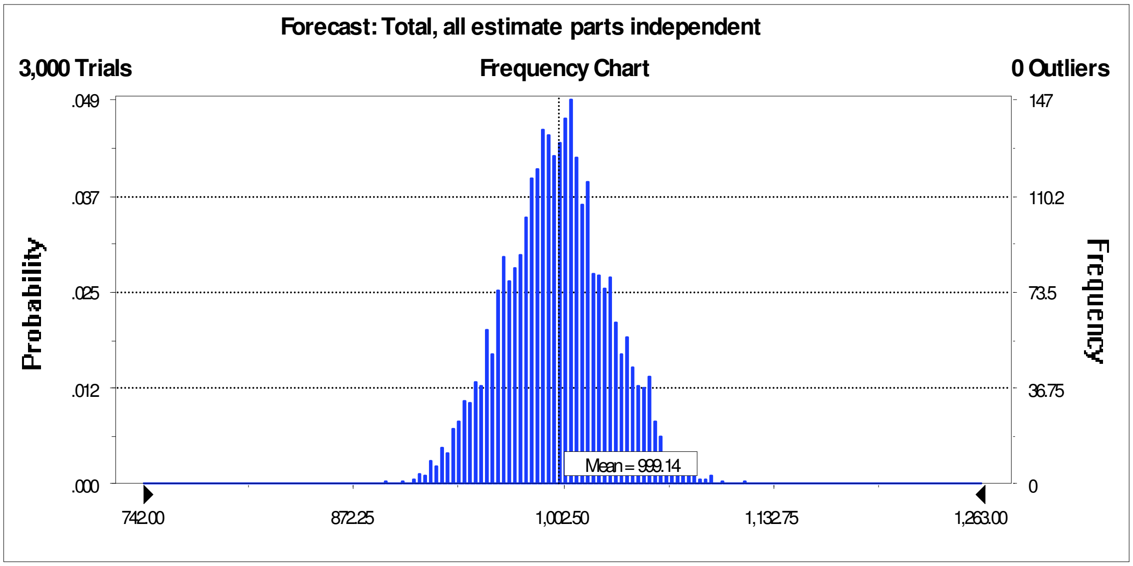

Figure 6 forecast for total range with independent parts

In figure 6 the total range is the same as the range in figure 5, in order to clearly demonstrate the narrowing of the range when assuming that all estimate parts are independent.

If figure 6 is expanded, the percentage certainty within the range μ - σ to μ + σ can be made visible again:

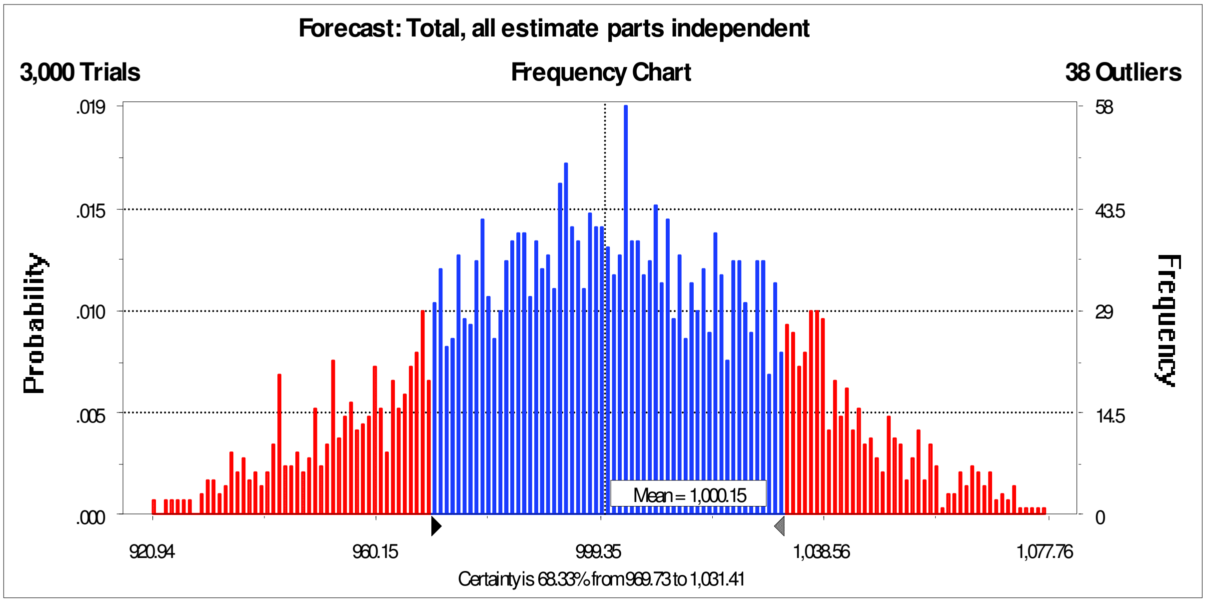

figure 7 forecast with independent parts

As can be seen, the mean value again is 1,000, but the standard variation is indeed approx. 32.

The project

In an expanding market for polyolefin's, a business opportunity for a Netherlands based owner/operating company developed when an existing site in Germany could be taken over. On this site a polyethylene plant and a polypropylene plant had to be constructed. Because the plants had to be completed in a very short time the formal, phased approach (after conceptual engineering perform basic engineering, develop a funding estimate, get appropriation and finally start the EPC-phase) with time-consuming decisions in between had to be abandoned because that would have taken too much time. Instead the appropriation was done after conceptual engineering and basic engineering gradually changed over to the EPC-phase without having another decision step.

This approach was chosen because the polymer-processes were well known licensor-processes, and there was a relative good mutual understanding and trust between owner and contractor-organizations.

Risk analyses were performed by the contractor as well as by the owner. The contractor, having engineered and constructed comparable plants, loaded the risk analysis with practical, real life possibilities. The owner used historical in-house data to produce the input for the risk analysis. When the two ways of looking at the project risks produced comparable results, confidence grew and the 'go' was given for the project.

During basic and detailed engineering (which were not two separate phases in this case) the target estimate for the project was developed. This estimate was checked and challenged by the owner. Any underrun of this target estimate was shared by the contractor.

The contractors' approach to risk analysis

The estimate for the project was a semi-quantitive estimate based on provisional quotes for process equipment and quantities and unit rates per trade derived from historical data and metrics. The contractor, from his experience with earlier projects and by making the conceptual estimate and drafting a project execution plan, gained insight in the real risks for the project cost. To these risks probability distributions were assigned. For instance productivity at the project location has a probability of 10 % of being less than 70%, a probability of 50% of being less than 90% and a probability of 90% of being less than 110%. (These numbers refer to cumulative triangular distributions). The determined risks in the form of correction factors and their distributions were tabulated as follows:

Risk #	Description	cumulative probability less than than:		
		10%	**50%**	**90%**
1	Productivity	0.7	0.9	1.1
2	Market situation equipment	0.95	1.0	1.2
3	Quality of Material Take Off	0.8	1.1	1.4
4	etc.			

table 1 project risks

Next, the influence of the various risks on the identified estimate parts was tabulated:

Code of account	Estimate	Influenced by risk(s) #
Process equipment	60	2, ...
Piping labor	30	1, 3, ...
etc.		
Grand total	250	(output)

table 2 relation between code of accounts and risks

Since the standard risk simulation applications are add-ons to spreadsheets, the risk profiles can be easily incorporated in the spreadsheet used to build the estimate. This means that the contents of a cell being for instance the estimate for process equipment can be multiplied with the contents of a cell, being the risk profile for the market situation on process equipment. These products are the inputs to the Monte Carlo risk application, the output being the cell containing the total estimate figure.

The possible risks identified by the contractor were independent from each other, so no correlations were needed.

The owners' approach to risk analysis

First of all the owner organization checked and challenged the contractors' estimate. Then the major line items from the estimate were taken as a basis for the inputs to the risk model. From historical data of previous projects the actual cost per trade e.g. piping, process control etc. was known. These data were normalized by dividing actual cost for a certain trade by the conceptual base estimate (estimate without contingency) for that trade. Because the database contained approx. 300 projects these data could be shown as probability distributions. These distributions were approximated to triangular distributions and applied to the corresponding numbers for the current estimate as follows:

Code of account	Base estimate	cumulative probability less than:		
		10%	50%	90%
Process equipment	60	60	63	66
Piping	50	45	60	75
Process control	30	24	40	56
etc.				
Grand total	250	(output)		

table 3 historical distributions

After establishing the distributions for the estimate parts, correlations between the estimate parts were applied. Process equipment was defined as the independent variable, all other trades were defined as variables depending on process equipment with correlations varying from 1 for piping to 0.5 to civil, buildings and structural steel. The output of the risk analysis is shown in figure 6:

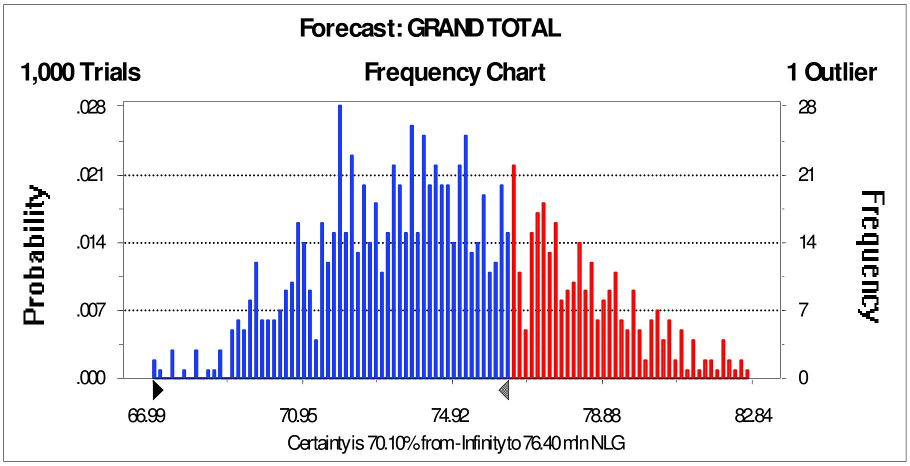

figure 8 project forecast

This risk profile established by the owner was quite similar to the risk profile established by the contractor. The estimate figure with a probability of overrun of 30% was chosen as the appropriation estimate.

Target estimate and incentives

Because of the fast tracking approach the scope was not very well defined when the contractor became involved. Hence the contract chosen was reimbursable for material and labor. This kind of contract has a relative large probability of cost overrun on material and labor which of course is the larger part of the project cost.
To further minimize this risk the contract contained an incentive for the contractor to minimize actual cost. During the basic engineering a target estimate was developed. Again this estimate was checked and challenged by the owner. The target estimate proved to be somewhat lower than the appropriation figure, which was not surprising since the appropriation figure was chosen such that only 30% probability of overrun was foreseen. This also meant that some management reserve was available.
The incentive for the contractor to achieve a low capital cost project was that a possible underrun was shared between owner and contractor. Underrun is defined as the target estimate minus the actual cost. On the other hand also the sharing of the possible overrun was included in the contract, providing a penalty to the contractor. However, as the power of an incentive is thought to be greater than the power of a penalty, the contractors' share in the overrun was substantially smaller than his share in the underrun. This way of "gain and pain sharing" is shown in figure 9.

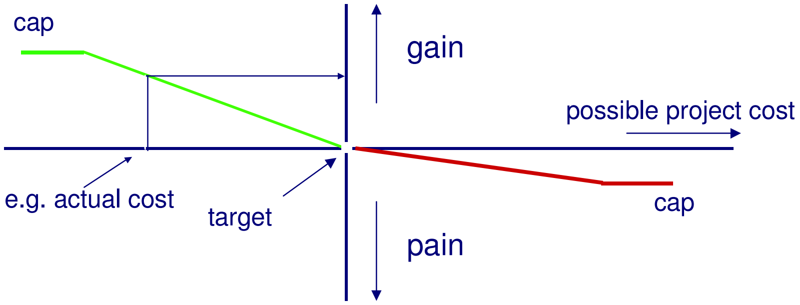

figure 9 incentive scheme

In case of underrunning the target (Note that in this incentive scheme underrun is anticipated and it should not be seen in the usual negative context) the actual cost is lower than the target and the contractor gains his share of this underrun. The contractor's share in the underrun as well as his share in the overrun are capped to a maximum.

Project execution and lessons learned

Project execution ran smooth and the project was mechanical complete well within the schedule and with good safety records during construction. There were no major start-up problems. The actual cost was approx.10% lower than the target estimate.

The purpose of realizing a project within schedule and budget was achieved. The risks that have been taken by skipping a formal appropriation estimate were successfully mitigated by the Monte Carlo risk analysis and by the selected contracting strategy.

The underrun being as high as approx. 10% is due to the following reasons, which can be split in two groups:

1. There was a fierce competition for major process equipment, resulting in low bids
Also the project experienced favorable market conditions at the time of placing the orders for materials and subcontracts

These conditions are more or less exogenous, some projects are lucky to experience these conditions, others do not.

2.The location factor for Germany versus Netherlands was thought to be greater than 1, but proved to be slightly less than 1.
The underrun on cost was not only due to favorable market conditions, but also caused by a large underrun on scope quantities.
Since these processes were licensed processes, it means many plants of the same type were built "on a row". This leads to learning effects and hence to lower cost, which was not anticipated in the estimate.

These findings led to the following lessons learned:

- have a thorough check on scope quantities supplied by the contractor by the owners' discipline engineers
- have a contract clause that stipulates that quantity underrun not caused by design optimizations can lead to lower (quantity adjusted) target-estimates

Conclusion

If the phased approach does not fit with the scheduled start-up date of the plant, the funding decision may be taken earlier in the project development. This decision was enhanced by performing a risk analysis. This analysis provided management with a graphical representation of the risks with regard to project capital cost. It showed the maximum exposure and the trade-off between extra budget versus less probability of overrunning the project budget. It was shown that in a Monte Carlo risk analysis it is very important to be aware of the various dependencies between parts of the estimate. Also shown is the importance of having appropriate contracts to further mitigate the risks of overrunning the project budget.

In this particular project the chosen approach worked well, having proven licensor processes and a good working relationship with the contractor. One of the lessons learned is that it is imperative for the owner to check and challenge scope quantities, or to have a target estimate that may be adjusted for quantity variations.

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