The Dilemma of Pricing Against the Backdrop of the Chance/Risk Ratio

Christian Hofstadler
(Professor, Graz University of Technology, Graz, Styria, Austria)

Markus Kummer
(Project Assistant, Graz University of Technology, Graz, Styria, Austria)

Abstract

Calculating construction costs and times is one of the most important and demanding tasks in construction management and economics. Valid data and information is constantly being sought for labor consumption rates, output values, productivity levels, material consumption, quantities in stock, number of transport cycles, and cost and time parameters that must be estimated and/or calculated *ex ante*. Ultimately, final cost and time parameters are determined on the basis of such considerations and calculations. *Ex post* and/or *inter actio* analyses are performed to check if actual values achieved in the construction phase are identical to the target values. In an ideal scenario, the productivity level would be higher and/or material consumption or equipment utilization lower than originally planned. However, the chances that calculated assumptions are exceeded in a positive sense are also associated with risks of non-compliance in a negative sense.
Accurate figures must be stated or submitted at the end of any analysis. These depend on the complexity of the building or structure and on the conditions prevailing at the actual work stages and rely on more or less uncertain input data. One possible solution to this issue is to consider ranges that can deliver final conclusions on determined values. Applying probabilistic calculation methods appears to be useful to systematically consider ranges in input parameters. Key outcomes of probabilistic calculations include histograms derived from (numerical) simulations. These histograms are used to directly capture the chance/risk ratio relative to a specific (selected) value.
This paper outlines the dilemma of pricing and deals with the issue of viable bid prices in relation to the chance/risk ratio.

Keywords

management of chances and risks; chance; risk; Monte Carlo simulation; chance/risk ratio; costing; histogram

1. From Costing to Price

Irrespective of the method chosen to determine costs and prices, any bid submission will require a final and binding bid price. Steps to achieve this goal include estimates and/or (even better) calculations (see Fig. 1). Estimates and calculations can be either qualified or unqualified depending on the thoroughness of investigating boundary conditions and of the documentation provided, as well as the experience of the people to whom relevant works were contracted. Time is also a crucial factor when it comes to the quality standard of determining values. Irrespective of the chosen path, values must ultimately be stated for costs, prices, quantities, times etc. In so doing, working with ranges enables easier decision-making. Furthermore, it is highly beneficial to know the chance/risk ratio associated with the selected value.

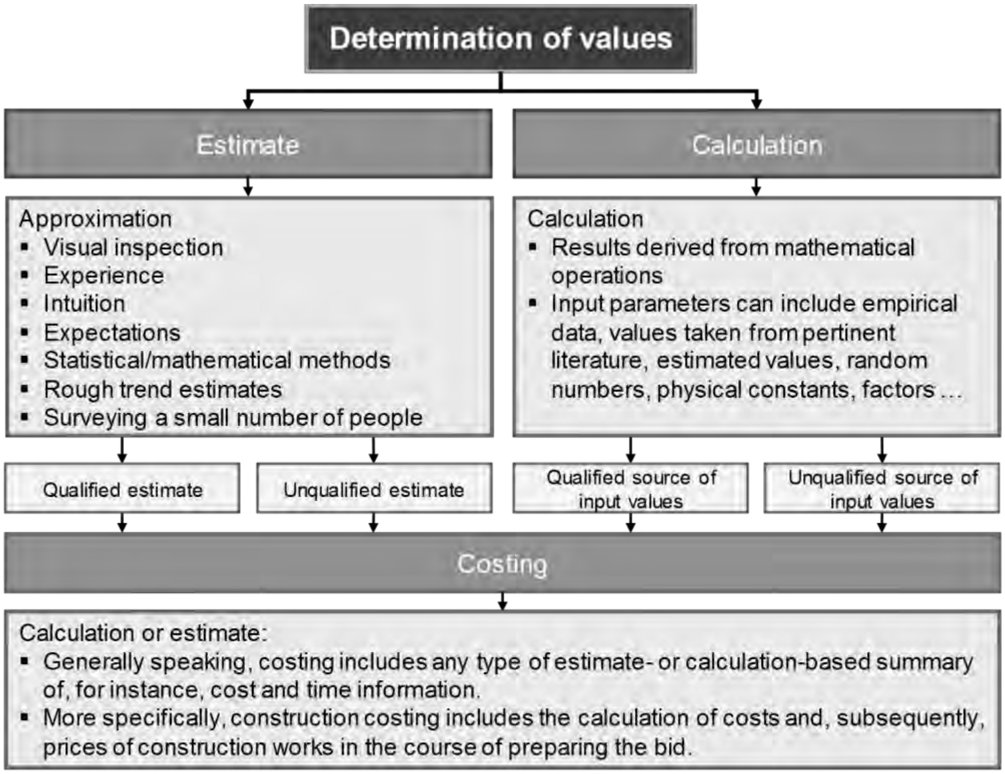

Figure 1: Options for determining cost and price values – estimates and calculations

From a mathematical point of view, the probability for the agreed (selected) bid price to be exactly identical to the invoiced total (even to the last decimal place) is zero. As we all know, the actual construction phase intervenes between the bid price and the invoiced total. At this stage, forecast circumstances and conditions are replaced with actual conditions under which work is performed. Moreover, changes to quantities and modified or additional works cause a difference between the price at which the contract was awarded and the final invoiced total (including all additional cost claims and expert, legal or court fees, if applicable). A low bid price negotiated by the principal or client on the market need not necessarily be equivalent to a similarly low level of the invoiced total. According to John Ruskin and others, at a low contract price, the client cannot expect a high quality standard to be implemented within a short construction period and without disruptions.

A zero-base costing exercise makes it possible to efficiently proceed from costing to pricing. This exercise requires expected values of calculation parameters (labor consumption rates, output values, quantities, material prices, equipment prices etc.) to be determined under the assumption of full cost coverage, excluding speculative elements (Oberndorfer and Jodl, 2001). The resulting values can then be used to derive figures for unit and item prices, and ultimately for the bid price.

However, this deterministic approach does not enable conclusions with respect to the probability of over- or underrunning target values. As is generally known, the magnitude of selected expected values depends on a number of factors, including experience, level of knowledge, attitude towards risks, analytical depth, details provided by the client/principal, and on the assessment of the complexity of the construction project and the proposed production system. Besides choosing expected values, it is thus useful to define ranges combined with distribution functions for key calculation parameters. This method enables the generation of histograms for each unit price, each item and, ultimately, for the bid price after completion of a probabilistic calculation (applying Monte Carlo simulations). These histograms make it possible to derive chance/risk ratios on the basis of selected individual figures.

2. Situational Analysis of the Significance of Probability in Construction Management and Economics

Probabilities are required for taking stock of what happened in the past as well as for forecasts of what will (trends) or could (assumptions) happen in the future. Statements with respect to probabilities are of major significance for all project phases and stakeholders as well as for decision-making during court proceedings. How probable is it for the client to achieve all goals defined for the proposed construction project? The answer to this question essentially depends on how the client, and its agents, comply with their obligation to cooperate in respect of enabling accurate planning and specification and ensuring a responsible contract award. If these efforts actually result in awarding the contract to the best bidder, there is an overwhelming (or high?) probability for the defined targets to be achieved. Conversely, this situation is associated with the favorable (and desirable) consequence of a reduction in the probability of occurrence of process disruptions and additional costs.

The probability of occurrence of forecasts is particularly important when it comes to estimating or calculating values that are used in costing exercises. *Ex post* considerations heavily rely on the aspect of probability when evaluating the documentation of actual construction activity. *Inter actio* analyses are performed during the construction phase and use actual values based on trend analyses to investigate the probability for targets to be achieved with respect to time, cost, quality standards and quantities.
Ex ante considerations rely on existing (disclosed) information and are merged with experience and historical data gathered from similar projects to be fed into forecasts of future events.

The probability for information to be accurate is highly relevant to both the client and the contractor. Prior to entering into the contract, this mainly involves the ability to determine the costs of works to be performed, and thus the transfer of risks and comparability of bids. The client must carry out thorough investigations and analyses to support its quantity and quality parameters, the conditions under which work is to be performed etc. with a high probability (characterized by precision and accuracy). Likewise, the costing assumptions and approaches applied by the bidders should be associated with a high probability of occurrence such that they can be justified at least from a commercial viability point of view. Unit prices tailored to the type, shape and complexity of the specific building or structure that also consider the resulting requirements with respect to quality, quantity, weather, construction time and environmental conditions are associated with a very high probability of accuracy. The quality of the information provided by the client has a direct influence on the quality of the information provided by the bidders, provided a "level playing field" in terms of the competitive environment exists.

Simulations effectively visualize the probability of the information provided by the client. Fig. 2 shows a histogram to illustrate the distribution of the reinforcement ratio for a group of structural components. Input parameters include common reinforcement ratios based on historical data (primarily depending on the structural system, element geometry, acting loads, number/dimensions/shapes of fittings/blockouts/openings etc.) taken from previous projects and/or information supported by pertinent literature. These parameters are subsequently adjusted to the conditions specific to the project and calculated by dividing the amount of reinforcement [kg] by the concrete volume [m³]. Distribution functions (triangular distributions in the case at hand) were used for both reinforcement amounts and concrete volumes. The resulting histogram creates a basis for the client (*ex ante*) to derive reinforcement ratios in the absence of more precise calculations at the specification stage, as well as for *ex post* analyses for the bidder/contractor to assess the quality of client information and to perform costing exercises.

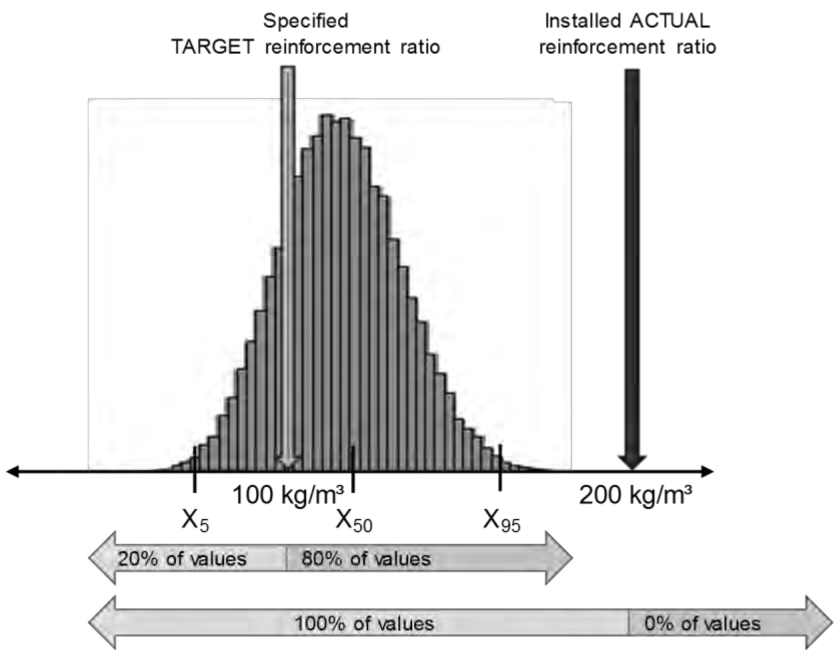

Figure 2: Probability of occurrence of the specified and installed reinforcement ratio

Fig. 2 uses reinforcing works to illustrate a situation in which the specified reinforcement ratio lies within a realistic range for a group of structural components (such as walls), whereas the actual (installed) reinforcement ratio lies outside this range. As shown in Fig. 2, the probability of occurrence of the installed reinforcement ratio is equal to 0%. In other words, there is a 100% probability for the contractor to assume a lower reinforcement ratio than actually installed on the basis of the information provided. Conversely, there is a zero probability of occurrence for the information that the client provided in the specification documents. The contractor adjusted its assumptions with respect to the bend shape distribution and mean rebar diameter to the specified reinforcement ratio. This is why the labor consumption rate that the contractor had accurately determined using the costing input parameters provided by the client can no longer correspond to the actual (installed) reinforcement ratio.

In the construction phase, it is important that contractors prepare and select their evidence (data, information, performance indicators, quantities etc.), for example for invoicing work performed and claiming additional costs (cause/effect relationships with temporal, spatial and resource-related references), such that their occurrence is associated with the (overwhelming, sufficient or high?) probability required for the specific case. In the interest of value retention, the chance/risk ratio derived from the costing exercise (i.e. the probability of over- or underrunning target values) should also be applied and adjusted to additional cost claims.

3. The Major Significance of the Reference Base

Any expectation of a positive or negative variance from the target essentially depends on the reference base. This means that any greater or smaller reference base for a labor consumption rate LCR [paid working hours divided by unit of quantity] will also result in comparatively greater or smaller probabilities of the actual labor consumption rate being lower than the defined reference base.

If, for instance, a histogram were derived for the labor consumption rate to be expected for reinforcing works, the median value could be used as a baseline for the costing exercise. In this scenario, the probability of under- or overrunning the selected labor consumption rate is equally distributed (50% for either option). In other words, the possibility that a risk in terms of a higher labor consumption rate materializes is equally high as the chance of generating a lower labor consumption rate during the construction phase. If, however, a reference base above the median is assumed, the chance/risk ratio will shift towards a positive variance from the target. The chance of generating a lower labor consumption rate is significantly greater than the risk of ending up with a higher labor consumption rate. Conversely, the risk will increase if the selected reference base of the labor consumption rate is lower than the median. There is a correspondingly small chance for generating a labor consumption rate, at the execution stage, that is lower than the already small reference base. The chance/risk ratio depends on the readiness of the company to take risks as well as on strategic considerations. In practice, contractors usually operate closer to the risks than to the chances because they have to apply a comparatively low reference base due to the existing competitive environment (Kummer and Hofstadler, 2013). Schubert (1971) already dealt with this topic and illustrated the selection of an appropriate reference base by referring to the example of earthmoving operations.

4. Bid Price and Winning the Bid

Defining or selecting the chance/risk ratio is a practice-driven approach that does not depend on any probabilistic target. The selection of the right chance/risk ratio will ultimately depend on the market price level or market situation, the readiness to take risks and further strategic considerations. Care should be taken to consider the chance/risk ratio both with respect to working profitably after the contract award and in relation to winning the bid (see Fig. 3).

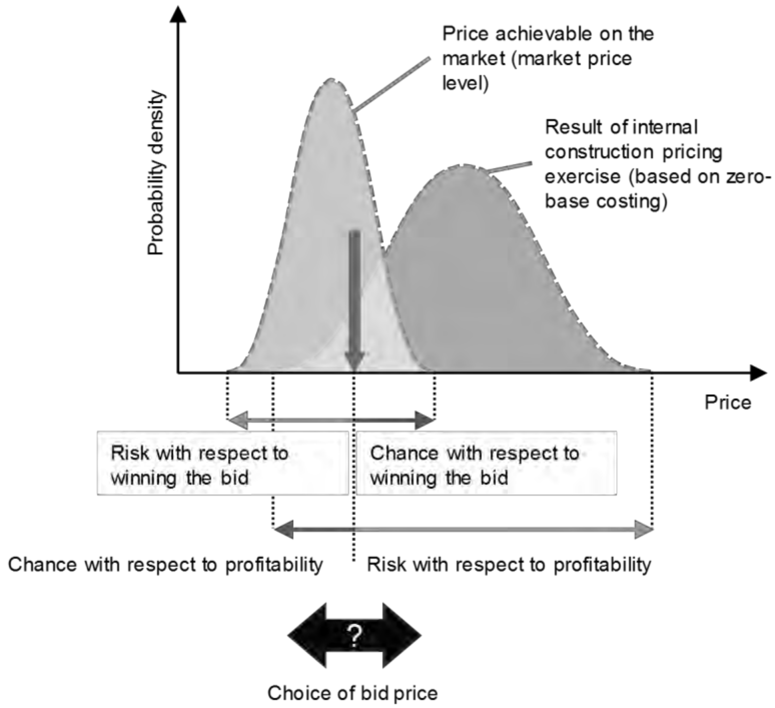

Figure 3: Choice of bid price with respect to working profitably and winning the bid (Kummer 2015)

Due to the nature of probabilistic calculations, it is not possible to accurately predict the outcomes of a construction project, such as with respect to actual construction times and costs. However, conclusions are possible in terms of the chance/risk ratio to be expected. For instance, each bidder arrives at its own estimates of the ranges of input parameters (such as cost, labor consumption rate and output values) when performing bid-related calculations. For one and the same project, this scenario results in different cost or price histograms with varying spreads, skewnesses, mean values etc. In other words, the estimated risk or chance is different for each bidder. These differences are due to varying assessments, different construction processes and methods, varying degrees of knowledge and expertise etc. At identical prices, bidders thus take various risks and enjoy different chances to adhere to, or underrun, the bid price in the construction phase.

When the bids are opened, each bidder will only see the prices quoted by the other bidders, without any information on how they arrived at the underlying values. However, any evaluation of bid prices based on a histogram and the corresponding probabilistic information enables judgment with respect to speculative elements or possible technological advantages. Any bidder that applies probabilistic calculation methods will thus be able to determine if it would have been able to cover its full cost based on its assumptions while executing the contract at the price of a cheaper competitor, and to identify the magnitude of the risk it would have taken.

5. The Dilemma of Pricing – Chance/Risk Behavior and Competitive Intensity

Bid prices are calculated using a zero-base costing exercise to enable a sound assessment of chances and risks with respect to bid pricing and final contract pricing. The subsequent definition of prices is based on the assumption that all production factors are utilized to a standard level and that no losses of productivity should occur from a contract pricing point of view. It is necessary to compute a histogram of the price distribution in the zero-base costing exercise to derive the corresponding chance/risk ratio. For this purpose, in the case of a unit price contract, costing assumptions must be supported by distribution functions wherever uncertainties are assumed in order to be able to calculate unit prices such that the price distribution histogram can be determined by a Monte Carlo simulation, for example.

Fig. 4 shows a continuous distribution where the horizontal axis represents the chance/risk ratio for calculated prices and the vertical axis represents probability density. Fig. 4 illustrates the existing competitive situation by a (randomly selected) dashed line with a gradient of about 20° (Scenario 1). Horizontal shifting of the straight line takes account of the existing competitive intensity (termed "Competitive intensity 1"). The fiercer the competition (many bidders, but only a few requests for proposals), the more the straight line has to be shifted toward the left, with the result that it is increasingly moving into the area of unviable prices[1]. At the same time, the risk potential increases, depicted by the arrow pointing to the right that runs parallel to the x-axis. Thus, there is a decreasing probability that a chance or opportunity can be utilized. It will then be highly improbable that the costs on which agreed prices are based are not overrun.

The slope of the straight line can be equated with a forecast with respect to the essential boundary conditions to costing/pricing associated with the specific construction project ("planning and specification quality = P+S 1"). The greater the accuracy of the calculated prices (as a result of fewer uncertainties in quantities and costing assumptions), the greater the slope of this straight line will be, corresponding to a comparatively tight spread between bid prices. This effect will also materialize if two bidders are farther apart from each other in terms of their chance/risk ratios (the vertical distance between Bidders A and B that represents the chance/risk behavior remains constant). In this example, Bidder B is significantly more willing to take risks compared to Bidder A. One possible explanation for this phenomenon could be that Bidder B urgently requires an additional contract to achieve its budgeted annual sales. Another reason could be that Bidder B wants to prevent Bidder A from entering this market segment by all means.

[1] The limit to unviable prices is identical to reaching the liquidity point. At this point, net revenues are equal to the total of fixed cash costs and variable costs.

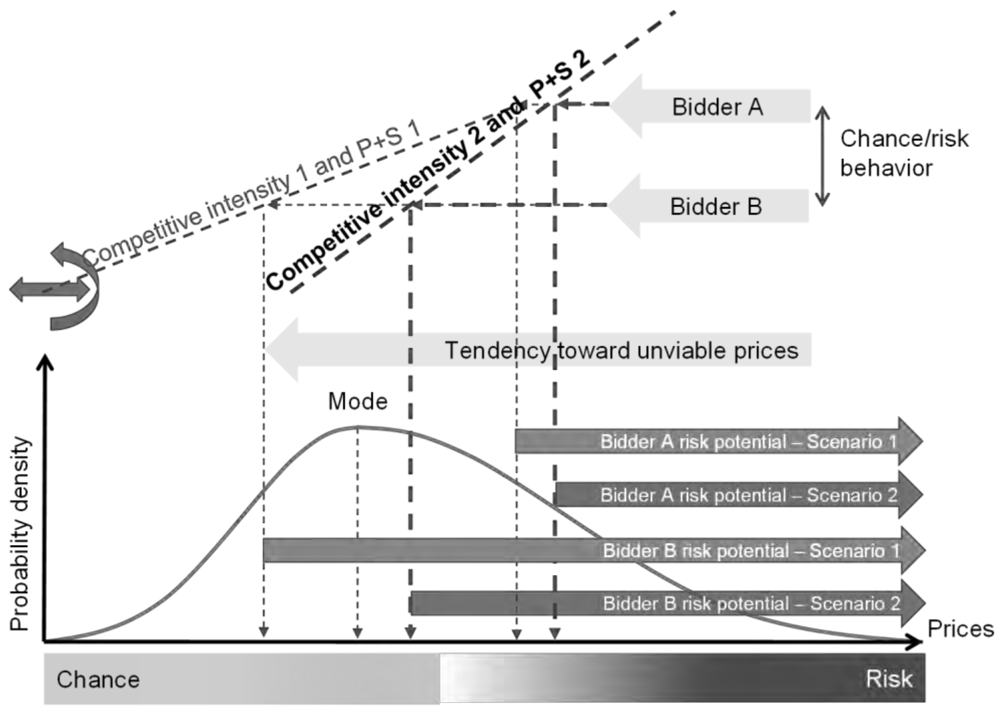

Figure 4: Chance and risk potentials depending on the competitive situation (mainly influenced by competitive intensity and quality of planning/specification) – Scenarios 1 and 2 (Hofstadler and Kummer 2017)

For comparison, Scenario 2 shown in Fig. 4 includes a second competitive intensity and planning and specification quality level whilst assuming an unchanged chance/risk behavior of Bidder A and Bidder B. The straight line was shifted to the right to a greater extent due to a competitive situation that is more favorable for the bidders (termed "Competitive intensity 2"). This scenario represents a lesser degree of competitive intensity, which should result in a tendency toward higher bid prices. Furthermore, the slope of the straight line was increased to consider a higher quality of planning and specification ("planning and specification quality = P+S 2") compared to Scenario 1. This shift reduces the probability of planning and specification errors and thus diminishes the potential for speculation. Overall, the prices quoted by Bidder A and Bidder B are located closer to each other. The bidders thus take less significant risks, and there is a higher probability for them to adhere to calculated construction costs in the project execution phase, as well as an increase in the chance potential for the subsequently selected contractor. For the client, this scenario brings the advantage of a high probability of the building or structure to be completed within the scheduled timeframe whilst complying with the agreed targets in terms of quality and budget.

There are limits to changing the slope of the straight line. Slopes of 0 and 90° are of a purely theoretical nature since they cannot occur in actual construction practice. A vertical straight line would correspond to a fully planned, seamlessly specified, contradiction-free construction project. Moreover, the parties to the contract would have to be in a position to access complete and accurate information, which is virtually impossible in the case of contracts for work in particular. There is thus only a theoretical possibility for a vertical straight line because the bidders would quote different bid prices for this scenario as well, although the documentation and information provided for costing and pricing purposes can be considered to be complete and free from contradictions. This phenomenon is mainly due to the unique nature of construction projects as well as to subjective differences in the assessment of costs in relation to production factors (internal production system). Bidders also arrive at different assessments of the complexity and circumstances of work to be performed (external production system), which is due to varying ways of handling information as well as to differing chance/risk affinities. Cases where construction projects are planned and specified in an entirely inappropriate manner do not (or hardly) occur in practice. Guidelines and standards exist that govern the minimum quality standard of planning and specification, which means that it is equally impossible to end up with a horizontal straight line in the diagram. However, an exceedingly poor quality of planning and specification will result in only a small slope of the straight line, and thus lead to a wider bid price spread. This phenomenon is mainly caused by an exceedingly large room for interpretation that may potentially result in major differences between the assumptions applied by the bidders. This scenario is thus associated with a high degree of asymmetrical information. Even if the results of the (zero-base) costing exercises performed by all bidders are very similar, strategic or speculative considerations may lead to huge differences in the quoted bid prices. Although Fig. 4 includes only an idealized scenario of the key mechanisms between competition, planning and specification accuracy, prices and chances/risks, it enables a very good overview of the economic relationships and interactions prevailing in construction management.

4. Conclusions

Any determination of costs and prices based on estimates and/or calculations will ultimately have to result in a final and binding bid price. Input parameters or costing approaches are associated with comparatively big or small uncertainties depending on the scope and quality of available information and tender documents as well as on the experience and the time available for submitting a bid. These uncertainties should be reflected in the costing exercise by means of probabilistic calculation methods (Monte Carlo simulations), and results should be shown in the form of histograms. It will then be crucial to select a value within the identified ranges that is associated with conclusions with respect to over- or underrun probabilities. The corresponding chance/risk ratio will also change depending on the selected reference base. This ratio can be utilized for both managing and verifying decisions; it can help ensure long-term profitability amidst a fierce competitive environment.

For pricing purposes, bidders should not only rely on their own costing exercise (so-called zero-base costing, i.e. full cost coverage without speculative elements). When selecting an appropriate reference base, such as the bid price, they should also consider the influence of the competitive environment and of the price that can be realistically achieved on the market. Bidders must differentiate their considerations of the chance/risk ratio in relation to winning the bid and working profitably and arrive at a balanced view of these two factors with regard to the chance/risk policy pursued by the company. For all stakeholders, it is essential that they are capable of stating their decisions or selected values relative to a specific chance/risk ratio. Only then will it be possible, both on the corporate and project level, for profits to outweigh losses in the long term, thus ensuring continued liquidity of the construction contractor.

5. References

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