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In-Depth Bid Assessment for Unit-Priced Contracts

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Abstract
Both at the design and specification stages and when assessing submitted bids, the client bears great responsibility for ensuring a high standard of workmanship, fair competition, economic efficiency, and the greatest possible benefit for management and operations. Public-sector clients use in-depth bid assessment as an effective tool to eliminate bids that are implausible or that bidders cannot sufficiently justify in related discussions. To ensure project success on all levels, it is crucial for the client to identify the chance/risk ratios associated with each of the bidders. Conversely, to ensure the continued existence and operation of its business, it is very important for the contractor to be aware of the chance/risk ratio on which the bid price is based. In either case, the selected baseline value determines the specific ratio of chances and risks. For reference purposes, the client can rely on cost estimates provided by experts, such as construction cost indicators adjusted to the specific region and project, whereas the contractor is in a position to apply full costing free of speculative elements (break-even costing).
This paper describes the models and calculations that enable a transparent breakdown of cost risks in the specification and award process. For this purpose, Monte Carlo simulations and associated histograms for the interpretation of results are used in order to systematically consider uncertainties and ranges of values in the bid assessment.

Keywords
Management of chances and risks; bid assessment; unit-priced contract; Monte Carlo simulation; chance/risk ratio; costing; histogram

1. 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. 1).

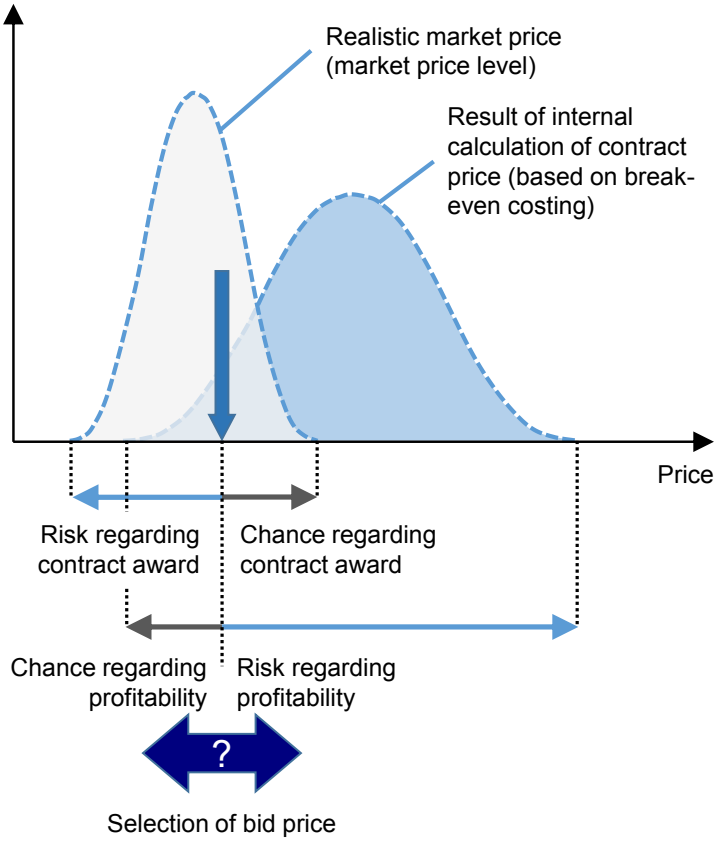

Figure 1: Selection of bid price with respect to working profitably and winning the bid (Kummer 2015)

2. Chance/Risk Ratio Relative to Pricing

Any results generated in the form of histograms enable conclusions regarding the chance/risk ratio for each of the selected deterministic values. We can thus determine the specific chance/risk ratio for items, work categories, and the selected bid price. In so doing, we use the calculation results of the break-even costing exercise as a reference. Histograms are generated for the calculation results relative to the unit price – through the input parameters partially/fully fraught with uncertainties. For final pricing purposes, the final unit price is entered as a deterministic value in the histogram, which makes the associated chance/risk ratio transparent for the specifier/decision-maker. This exercise can be repeated for each item within a single work category as part of a bottom-up analysis (see Fig. 2).
The bidder/contractor also needs to be aware of its cost histogram to be able to grant discounts or include markups. For instance, the influence of a 10% discount on the chance/risk ratio will vary depending on the curve of the histogram. If the histogram includes a very small spread, an exceedingly high discount may give rise to an intolerable risk because the chance to perform the work at an even lower price would decrease rapidly. Thus, in histograms with a small spread, percentage discounts relative to the price have a greater influence on the chance/risk ratio than in

the case of distributions with large spreads. Without knowing the distribution, no conclusion is possible as to whether the risk would still be tolerable after granting a discount or whether the new chance/risk ratio is in line with the chance/risk policy of the business.
Conversely, when starting from a chance/risk ratio, a reverse calculation can be performed to determine the maximum tolerable discount. For instance, if the contractor wants to deviate from the mean by up to one standard deviation for the purpose of preparing its bid, the discount permissible up to this specific chance/risk ratio can be identified.

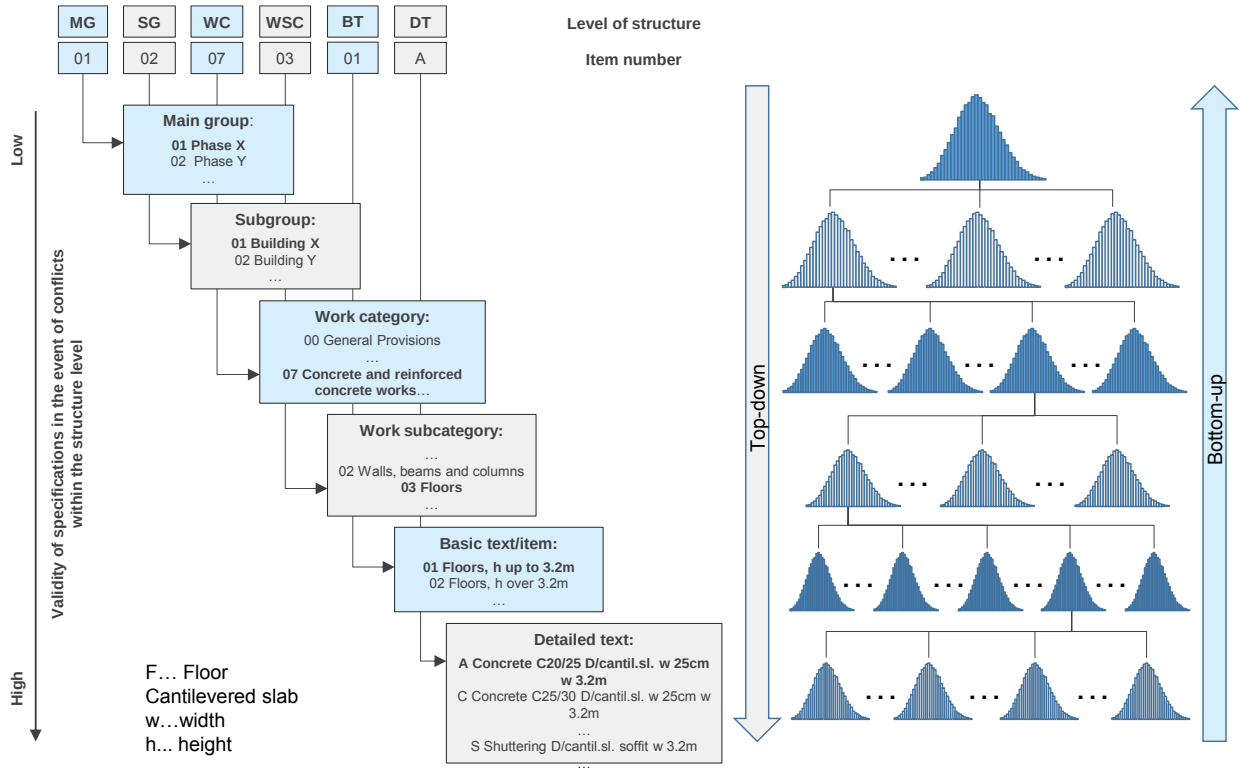

Figure 2: Top-down and bottom-up approach for selecting the basis relative to a bill of quantities

3. Systematic Consideration of Uncertainties in the Bid and Award Process

It is important for the client to be able to quantify future costs of construction works even though costs can still be influenced to a relatively large extent in early project phases – for two reasons: first, to intervene in, and adjust, the planning and design to the available budget; second, to quantify project funding and to be able to assess chances and risks.
Depending on the degree of design detail and project progress, various methods are available for calculating future costs of construction works, including commonly applied use- and building/structure-related methods that rely on cost indicators. Depending on the applied method, level of knowledge and specificity, a greater degree of detail can be achieved by refining the respective consideration or exercise.

The cost estimate is used to determine the cost for the contract award, as well as a basis for cost control (target/actual comparison with costing). It forms the basis for deciding upon the detailed design and award preparation. This costing exercise is performed prior to providing the bills of quantities, on the basis of the detailed design, building specifications, and schedule of work execution.
This paper includes a worked example to demonstrate how Monte Carlo simulations are used to account for uncertainties when performing calculations for the cost estimate. (Kummer and Hofstadler, 2013) The associated in-depth analysis involves any applicable ranges of item prices and provides the opportunity to subsequently correct items included in the bill of quantities prior to publishing the request for bids. Even before opening the bids, the client will thus be provided with an overview of possible bid price ranges.
The price histograms derived from the simulation are subsequently used for bid assessment purposes, thus enabling judgment as to whether the prices quoted by the bidders are plausible and/or to determine the chance/risk ratios associated with quoted prices.

4. In-Depth Bid Assessment

As part of the building specification, the bill of quantities is essential for the bidder/contractor to carry out costing and pricing exercises (but always in conjunction with the entire set of tender documents). The client must describe all conditions and circumstances of work performance in such a way that the bidder is in a position to prepare its bid on the basis of appropriate interpretation of the objective explanations contained in the documents.
Vis-à-vis the client, the contractor must justify all assumptions (i.e., costing assumptions and/or risks) made on the basis of the tender documents for the purpose of pricing and work execution, as well as all dispositions within its remit and the risks associated with the suppliers and subcontractors selected by the contractor.
According to the above process, the client usually prepares the bill of quantities, and the bidder performs the costing exercise for its bid and derives related assumptions. For instance, if the client blends several types of work for various structural components, trades, types of floor, rebar diameters etc. into a single item, and if the bases for the costing of these mixed items are not disclosed, the bidder is forced to make unsupported cost assumptions so as to be able to complete its costing exercise in the first place.
Any change in the proportions of the specified types of work “blended” in the single item in relation to the cost assumptions made by the bidder will also change the pricing structure, which may result in higher or lower costs relative to the bid price.
The building specification forms an essential basis for the contractor to be able to perform its costing and pricing exercises. Relative to the planned construction works, this means that specification details must be assessed or interpreted in line with how the bidder understands the explanations provided in the tender documents when objectively evaluating the situation or conditions. According to this approach, the bidder or entity performing the costing exercise should trust the documents provided, and will incorporate their content as well as the conditions for work performance communicated or expected in its costing and pricing.
In a unit-priced contract, unit prices and quantities are listed together with item prices, which are added up to get the total price. Not only an exceedingly low total price may indicate speculative elements; comparatively higher prices quoted by bidders can also include such components. The

following sections outline how to systematically review unit prices when performing an in-depth bid assessment for a unit-priced contract.

4.1 Task

Using the rebar reinforcement specified for a construction project (i.e., an engineering structure), a bidder has quoted corresponding price components for wages and other items (see Fig. 3). At first glance, the unit price appears to be markedly low. In the next step, a breakdown is carried out to perform an in-depth assessment of the wage and other components. The wage component [€/t] results from multiplying the labor consumption rate [wh/t] with the mean wage price [€/wh]. Dividing the wage component [€/t] by the mean wage price of €40/wh quoted in the bid gives the associated labor consumption rate of 4 wh/t (see Fig. 3).
For the in-depth bid assessment, the labor consumption rate of 4 wh/t resulting from a reverse calculation from the bid is shown in a labor consumption rate histogram based on pertinent literature whilst considering existing uncertainties. This comparison subsequently reveals the risk the bidder has taken when submitting its bid and/or where its calculated labor consumption rate is located within the calculated range of plausible labor consumption rates.
Values confirmed by practitioners should be taken from pertinent literature (or benchmarks from site analyses or final costing exercises should be used) to arrive at a representative basis for the in-depth assessment.

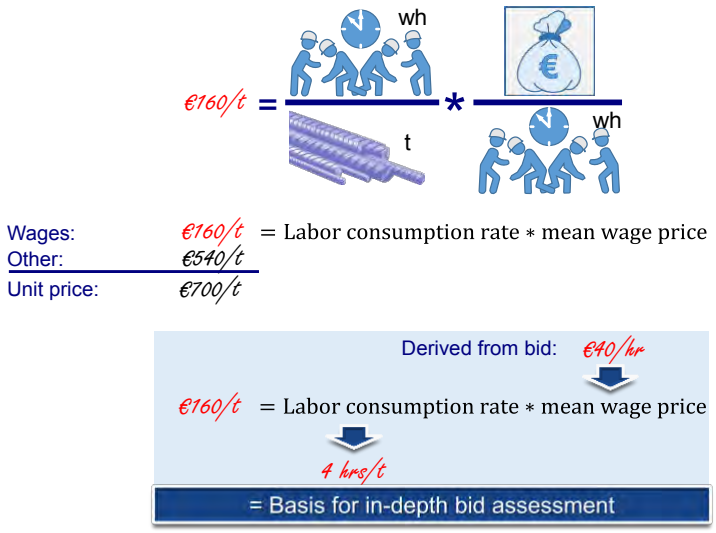

Figure 3: Calculation of the labor consumption rate from the wage component

4.2 Modeling

The definition of uncertain input parameters includes the quantity proportions of diameters, bend shape proportions, and labor consumption rates per diameter and bend shape. In the computation model, the mean wage price is included as a deterministic value (following from the quoted amount of €40/wh).

In the modeling exercise, quantity and bend shape proportions must be normalized to 100% to ensure that the simulation does not result in any over- or underrun of specified reinforcement ratios (the quantity used for the in-depth bid assessment is identical to the quantity stated in the bill of quantities).
To calculate the mixed labor consumption rate, the quantity proportion of each bar diameter is multiplied by the weighted bend shape proportions (i.e., straight, simple bend, and complex bend) and by the distribution functions (see triangle symbols included in Fig. 4). For each diameter and bend shape, this calculation step gives labor consumption rate proportions shown in histograms. The derived labor consumption rate proportions are then added up to form the histogram representing the mixed labor consumption rate. This histogram is used as a reference to check the plausibility of the labor consumption rate included in the bid price. This comparison also requires a reverse calculation of the quoted mixed labor consumption rate from the unit price and/or from the wage component (Fig. 4 includes arrow symbols for deterministic parameters). For this purpose, the wage component [€/t] is divided by the mean wage price. The resulting deterministic mixed labor consumption rate included in the bid (i.e. 4 wh/t) can then be used to check appropriateness and plausibility.

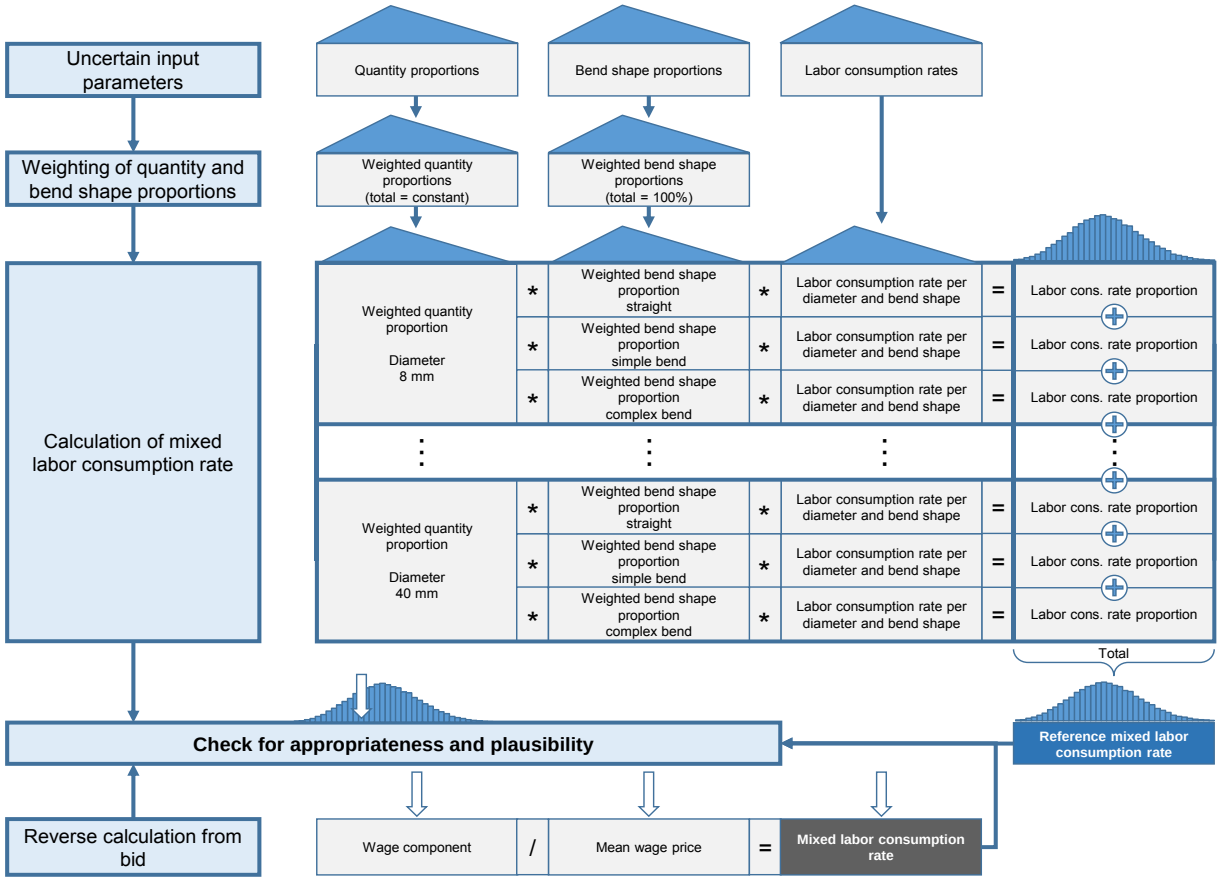

Figure 4: Schematic representation of the modeling sequence (Hofstadler and Kummer, 2017)

4.3 Calculation and Interpretation of Results

Fig. 5 depicts the histogram resulting from a Monte Carlo simulation performed to calculate the mixed labor consumption rate for reinforcing works in an engineering structure. In this histogram, the median amounts to 10.91 wh/t, whereas the X_5 quantile and the X_{95} quantile equal 10.40 wh/t and 11.47 wh/t, respectively. The X_5 quantile of 10.40 wh/t is used as a basis and 10% are deducted to define the minimum labor consumption rate for the assessed construction project. The marginal labor consumption rate of 9.36 wh/t determined in this calculation is identified as the absolute minimum in the course of the in-depth bid assessment. All bids quoting a labor consumption rate below 9.36 wh/t must thus be eliminated because there is a 0% probability of underrunning this labor consumption rate. This value is not achievable during actual construction work since higher labor consumption rates are achieved in 100% of real-world cases.
In the next step, the labor consumption rate of 4 wh/t used as a basis for the bid is compared with the range of plausible labor consumption rates. Fig. 6 also clearly visualizes the fact that this value lies considerably below the achievable range. The difference to the minimum amounts to approx. 57% [= (9.36 wh/t - 4 wh/t) / 9.36 wh/t * 100%)]. In other words, the limit for a plausible labor consumption rate is about 234% (= 9.36 wh/t / 4 wh/t * 100%) above the quoted labor consumption rate of 4 wh/t.

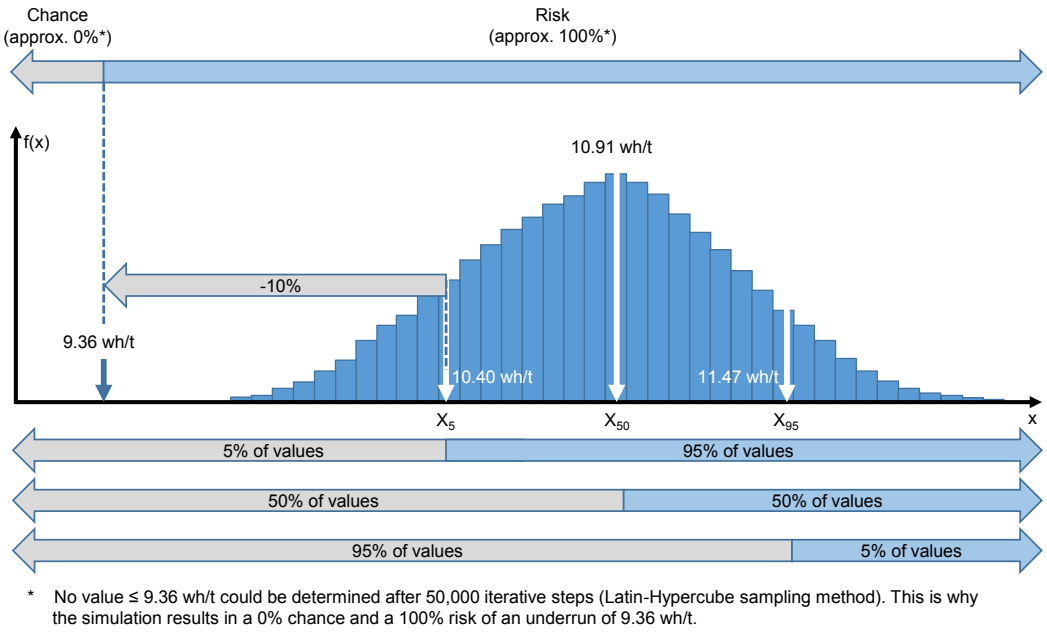

Figure 5: Distribution as a result of a Monte Carlo simulation performed to illustrate the determination of a minimum labor consumption rate for reinforcing works

This example demonstrates very clearly that the labor consumption rate, and thus the wage component, lie far outside the range of covering possible costs. The quoted price is thus inappropriate and lies significantly below the minimum price limit. The above labor

consumption rate (i.e., 4.00 wh/t) cannot be achieved even if assuming efficient construction management and economical business operations; it would not permit a high standard of workmanship, including liability for any defects.
In the case at hand, this exceedingly low price would put the liquidity of the business at risk, provided workers are paid wages in compliance with the law. At any rate, this bid clearly contradicts the principle of economic plausibility of prices.

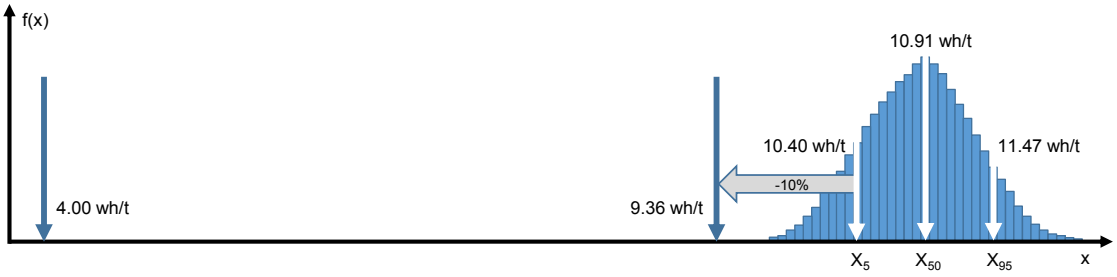

Figure 6: Distribution as a result of a Monte Carlo simulation performed to illustrate the determination of a minimum labor consumption rate for reinforcing works – comparison with the quoted labor consumption rate of 4 wh/t

According to the principle of economic plausibility, prices should at least cover primary costs/expenses such as wages and salaries, materials, equipment repairs and/or subcontracted services. These costs are largely variable; they are definitely incurred and cannot be earned through other works or services or construction projects. As is generally known, labor consumption rates determine the variable cost base and must thus be considered at an appropriate, profitable level in the wage component.
The unit price of €700/t quoted in this case (and particularly the wage component of €160/t) does not fully cover related costs because it is far below the plausible or justifiable variable cost base. Nor is the bidder in a position to explain this gap between the quoted price and the above-mentioned insufficient price in the course of a related discussion, which is why this bid must be disregarded.

5. Conclusions

For the client, the greatest benefit lies in the representative, plausible reference base for assessing the labor consumption rates determined in a reverse calculation from quoted unit prices. The client can thus ensure that it has followed a systematic approach that is sound both from a construction management/economics and legal point of view when conducting the in-depth bid assessment.
A minimum labor consumption rate specific to the building or structure and specification exists for any type of construction work. There is no way of working more quickly or productively because there are limits to the workload that can be imposed on employees, as well as manufacturing and technological limits to the other production factors, i.e. equipment and materials. Other influential factors that increase the labor consumption rate include the shape and

dimensions of structural components, and ambient and weather conditions. This situation inevitably causes labor consumption rates to lie (far) above the stated minimum depending on the specific project conditions.
If calculated labor consumption rates are greater than the minimum required in terms of construction management (including main and ancillary works, idle time, breaks, loss and distribution periods, and off-peak hours) that was determined applying the above method, related work items can be considered to be plausible whilst considering the specific requirements for work performance.
Adherence to this systematic approach (labor consumption rate = wage component divided by the mean wage price; subsequent comparison with the probabilistic minimum) in the course of assessing the bid for all major labor-intensive items can uncover wage and/or social dumping. When evaluating the agreed compensation, the wage component must be considered independently of the "Other" item. This differentiation is necessary to separate labor-intensive work from equipment- and material-intensive types of work, thus preventing/reducing commingling of various bases for pricing. Analyzing the wage component makes it possible to identify calculated working hours for the entire building or structure, work categories, or individual items, depending on the aim of the analysis.
This principle is comparable to track and field sports, where, for example, times that are plausible (achievable) in a 100 meter race are subject to physical, biomechanical and medical limits – there is just no quicker way to finish. The same applies to construction management since any work requires a certain minimum consumption rate to be performed. It is not possible to assume fewer paid working hours even if only the generally assumed, average quality standard and characteristics are specified.
In conclusion, only bidders quoting plausible labor consumption rates should be considered for construction contracts in order to prevent wage and/or social dumping. In contrast, bids with exceedingly low prices and associated labor consumption rates below the minimum determined for a specific type of work should be disregarded. This approach would protect the construction industry in the country in which the project is to be completed against illegal practices whilst also enabling the award of contracts for projects to lawfully operating businesses posting employees there.

6. References

Hofstadler, C. and Kummer, M. (2017). "Chancen- und Risikomanagement in der Bauwirtschaft – Für Auftraggeber und Auftragnehmer in Projektmanagement, Baubetrieb und Bauwirtschaft", Springer-Verlag, Berlin, Heidelberg.

Kummer, M. (2015). "Aggregierte Berücksichtigung von Produktivitätsverlusten bei der Ermittlung von Baukosten und Bauzeiten – Deterministische und probabilistische Betrachtungen", Ph.D. Thesis, Graz University of Technology, Graz, Austria.

Kummer, M. and Hofstadler, C. (2013): "Einsatz der Monte-Carlo-Simulation zur Berechnung von Baukosten", *bau aktuell*, Vol. 4, No. 5, pp 178-188.