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CALCULATION OF THE LABOR CONSUMPTION RATE FOR SHUTTERING WORKS WHILST CONSIDERING UNCERTAINTIES

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This paper focuses on the systematic consideration of uncertainties in calculating labor consumption rates for shuttering works. The magnitude of labor consumption rates results from a production system assessment. This paper outlines the basics of labor consumption rates and important factors that influence their level. A specific value must be selected at the end of any calculation. In labor-intensive activities, labor consumption rates are highly significant for calculating construction time and cost. To make important decisions, it is essential to know the chance/risk ratio relative to key parameters. For any quotation, this ratio illustrates the chances or risks associated with certain works and the entire project. To select the chance/risk ratio, existing uncertainties must be integrated into the probabilistic calculation (using Monte Carlo simulations) by distribution functions. The probabilistic calculation of labor consumption rates therefore creates the basis for any conclusions regarding chances and risks associated with specific costs or prices. Appropriate precautions can be taken as part of systematically managing chances and risks. As a result, the process of preparing and making decisions is characterized by a more systematic and target-driven approach. Furthermore, decision reliability and transparency are improved. An example of calculating the labor consumption rate for shuttering works demonstrates the influence of the selected distribution functions on results. It also illustrates its subsequent effect on the chance/risk ratio of adopted decisions.

Keywords: Monte Carlo simulation, Chance/risk ratio, Histogram, Skewness.

1 INTRODUCTION

Construction management strives to combine production factors in a commercially optimal manner. In this context, the labor consumption rate is a key indicator to enable forecasts in the fields of construction management and economics as well as assessments of labor-intensive activities. This metric establishes a direct relationship to the requirements that can be derived from the production system. Labor consumption rates are of high significance to bidders and contractors as well as property owners and clients when it comes to determining construction time and cost. Labor consumption rates, such as for shuttering works, are mainly influenced by the following factors: general site conditions, general operational conditions, specific structural conditions, and influences arising from the construction method.

On the basis of calculated total hours and specific production quantities required for a certain type of work, a plan/actual comparison or final costing exercise makes it possible to calculate the labor consumption rate of a given activity or process, or groups of processes, such as in relation to shuttering works (Hofstadler 2014). Labor consumption rates CR [WH/QU] result from dividing the total of paid working hours WH by the production quantity QU and are calculated using Eq. (1).

$$CR = \frac{WH}{QU} \tag{1}$$

As part of the situational analysis conducted in the quotation phase, influences on labor consumption rates are analyzed in order to assess the complexity of works. Individual types of work must be clearly delineated from each other in terms of time and activity to arrive at sound labor consumption rate values, avoiding shifts to other works and duplicate data collection.

Sound information regarding structural, site and operational conditions is indispensable to capture data in a systematic manner. This additional information should improve the accuracy of determining (calculating) labor consumption rates on the basis of existing documentation of future projects.

From a contractor’s point of view, influences arising from the entire (internal and external) production system should always be considered when calculating labor consumption rates in the quotation phase. In the quotation process, the final value should always be established whilst assessing the chance/risk ratio. If an exceedingly low value is chosen, the potential chance of achieving or even underrunning this value at the subsequent execution stage will also be very low.

2 PROBABILISTIC CALCULATIONS

Probabilistic calculations (i.e., calculations based on probability theory) systematically integrate existing uncertainties and make it possible to visualize them as histograms when analyzing results. Any expectation of a positive or negative variance from the target will essentially depend on the selected baseline (see Figure 1). Depending on whether this baseline is selected to be higher or lower for costs, the resulting probability of actual costs over- or underrunning the selected baseline will be equally higher or lower.

If, for instance, a histogram has been derived for the labor consumption rate of shuttering works, the median value can be used as a baseline for costing and pricing (see Figure 1, top), which results in an equal probability (50%) of over- or underrunning the selected labor consumption rate. In other words, the probability that the risk of a higher labor consumption rate materializes is equal to the chance of generating a lower labor consumption rate at the execution stage. If, on the other hand, the baseline is assumed to be greater than the median (see Figure 1, bottom left), the chance/risk ratio will shift towards a positive variance from the target. In this scenario, the chance of achieving a lower labor consumption rate is considerably greater than the risk of a higher labor consumption rate. Conversely, the risk will increase if a baseline labor consumption rate is selected that is lower than the median (see Figure 1, bottom right). The chance of achieving a value that underruns the relatively low baseline at the actual construction stage is correspondingly low. The chance/risk ratio depends on the risk attitude of the company and of the decision-maker as well as on strategic considerations. In practice, bidders or contractors are usually closer to the risks rather than the chances because they need to apply a relatively low baseline due to their fierce competitive environment.

Monte Carlo simulations make it possible to include uncertainties of input variables in the calculation process. For this purpose, distribution functions (e.g., triangular distributions) are allocated to the calculation parameters of a deterministic computation model. For each of the iterative steps of the simulation, random values within the ranges of the specified distributions are selected (Latin Hypercube sampling is used in the case discussed in this paper). This process is repeated several thousand times, and the results of the individual iterative steps are represented in histograms (Hofstadler and Kummer 2014). The selection of a deterministic value within the calculated ranges directly determines the over- or underrun probability, and thus the chance/risk ratio relative to the output variables.

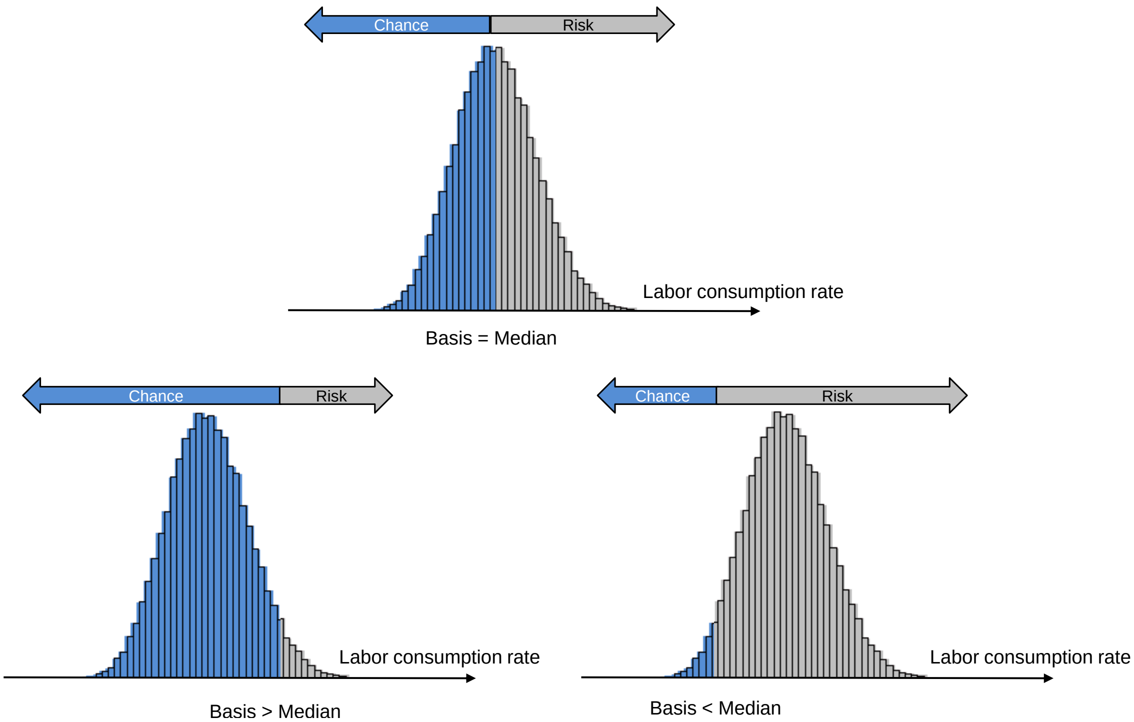

Figure 1. Influence of the selected baseline on the chance/risk ratio relative to the labor consumption rate (Hofstadler and Kummer 2017).

3 CALCULATION OF LABOR CONSUMPTION RATES FOR SHUTTERING WORKS WHILST CONSIDERING UNCERTAINTIES

To calculate the mean labor consumption rate of shuttering works for a given project, the individual standard and infill areas must first be determined and broken down to individual structural component groups. Depending on the specific design stage, these values will usually be fraught with more or less significant uncertainties. In terms of quantities, for example, the question arises whether and to what extent specified quantities will change at the detailed design and execution stages. Furthermore, it is crucial to come up with a realistic estimate of the shares of standard and infill areas.

Figure 2 shows the calculation sequence for determining the labor consumption rate of shuttering works for a complete building. In addition, distribution functions must be applied to labor consumption rates of shuttering works per each group of structural components and divided into standard and infill areas. In this example, labor consumption rates are represented by triangular distributions that are defined by stating three values (i.e., minimum, expected [modal], and maximum values). Three simulations are conducted to demonstrate the influence of the skewness of input parameters and thus the selection of the “right” distribution. In each of the three simulations, quantity distributions are kept constant, as are the minimum and maximum values of the distributions of labor consumption rates. Only the expected (modal) values of the triangular distributions are applied exactly in the center between minimum and maximum in one case and equated with the relevant minimum or maximum in the two other cases (see Figure 3). In the block referred to as "Calculation – mean labor consumption rate" (see Figure 2), consumption rates (of standard and infill areas) are stated as triangular distributions for each group of components. Labor consumption rates of shuttering works are represented by histograms for the individual component groups (not shown in this paper). Thereafter, labor consumption rates are calculated for the individual quantity percentages, and added up. The total of the individual labor consumption rates calculated for each percentage ultimately results in the distribution of the total labor consumption rate of shuttering works for the entire building. Probabilistic calculations are carried out numerically using Monte Carlo simulations (Latin Hypercube sampling with 50,000 iterative steps in each case), assuming uncorrelated input parameters in the example discussed in this paper.

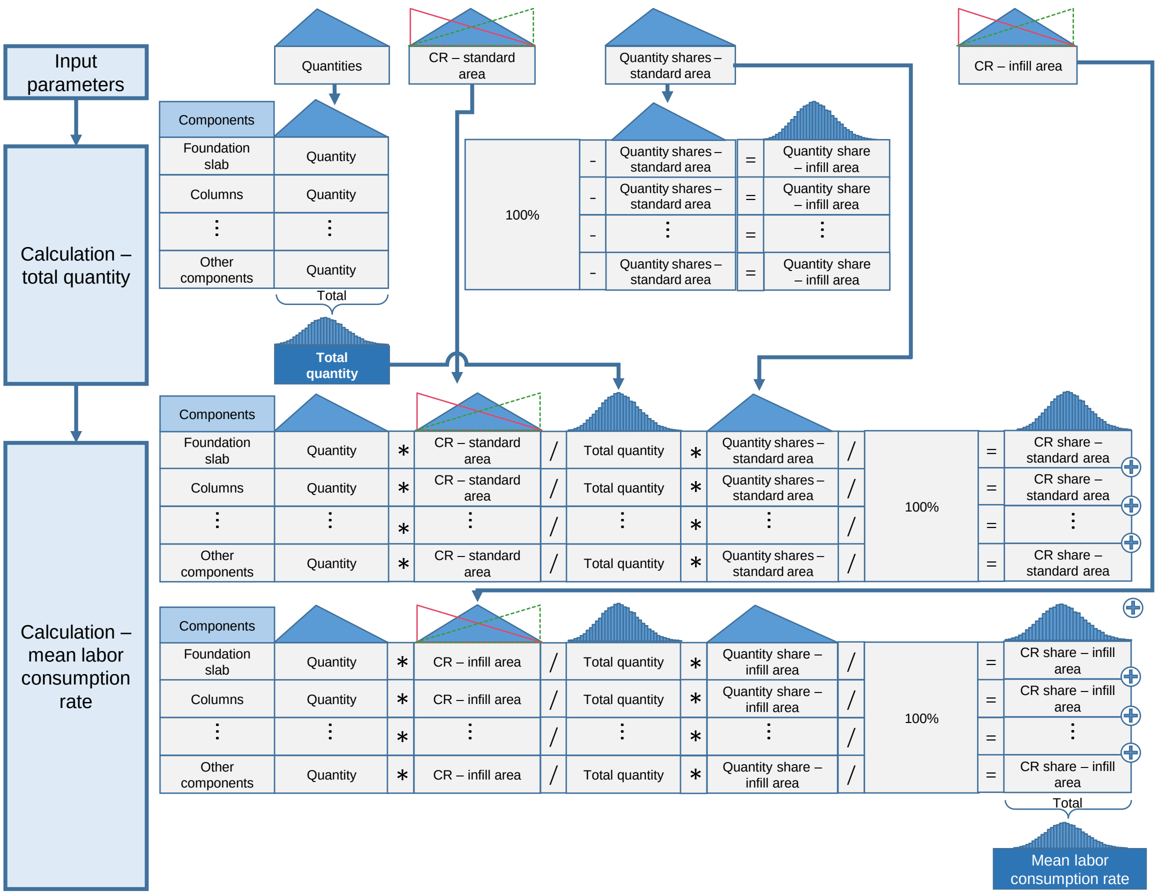

Figure 2. Calculation sequence to systematically account for uncertainties when determining labor consumption rates – application to shuttering works for a complete building (Hofstadler 2016).

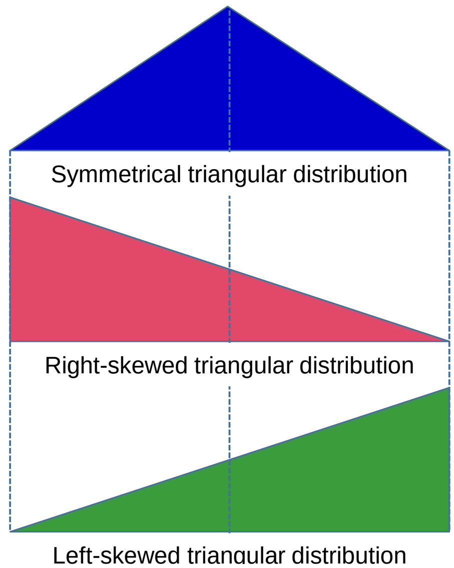

Figure 3. Qualitative representation of triangular distributions for labor consumption rates.

4 INTERPRETATION OF RESULTS AND SUMMARY

Figure 4 shows the histograms of the mean total labor consumption rate of shuttering works for a building construction project for the three simulations. This diagram reveals significant differences in the skewness and ranges of distributions due to the varying weight assigned to input parameters (left-skewed, symmetrical, right-skewed). For each of the three histograms, the chance/risk ratio is shown relative to a deterministic value, which can be derived, for example, from a retrospective calculation of an intended bid price.

If, for instance, this basis amounts to 1.31 wh/m² (see Figure 4), the three histograms show that the risk of the bidder or contractor ranges from 30 to 96% whereas the chance lies between 4 and 70%. This example illustrates that knowledge of the types of distribution of input parameters has a major influence on the output side, which is why it must be duly considered in the interpretation of results.

Distribution functions of input parameters thus need to be selected on the basis of relevant specialist knowledge and expertise whilst also relying on expert advice. If no sound and reliable database exists from which distribution functions of input parameters can be derived, theoretical considerations must be applied with respect to the characteristics of the specific parameter in order to arrive at a decision regarding these distribution functions (Kummer 2015). In any case, the probabilistic calculation of labor consumption rates provides the advantage that inevitable uncertainties can be taken into account in a systematic manner and that possible ranges of output parameters can be visualized and used as a basis for subsequent decision-making. Cost surveyors need not select a value within a given range for each of the input parameters. Instead, they can directly and systematically apply their experience and findings derived from the bid documents. The chance/risk ratio will ultimately depend not only on the selected distribution functions but also on the risk attitude of the company and of the decision-maker as well as on strategic considerations and competitive constraints.

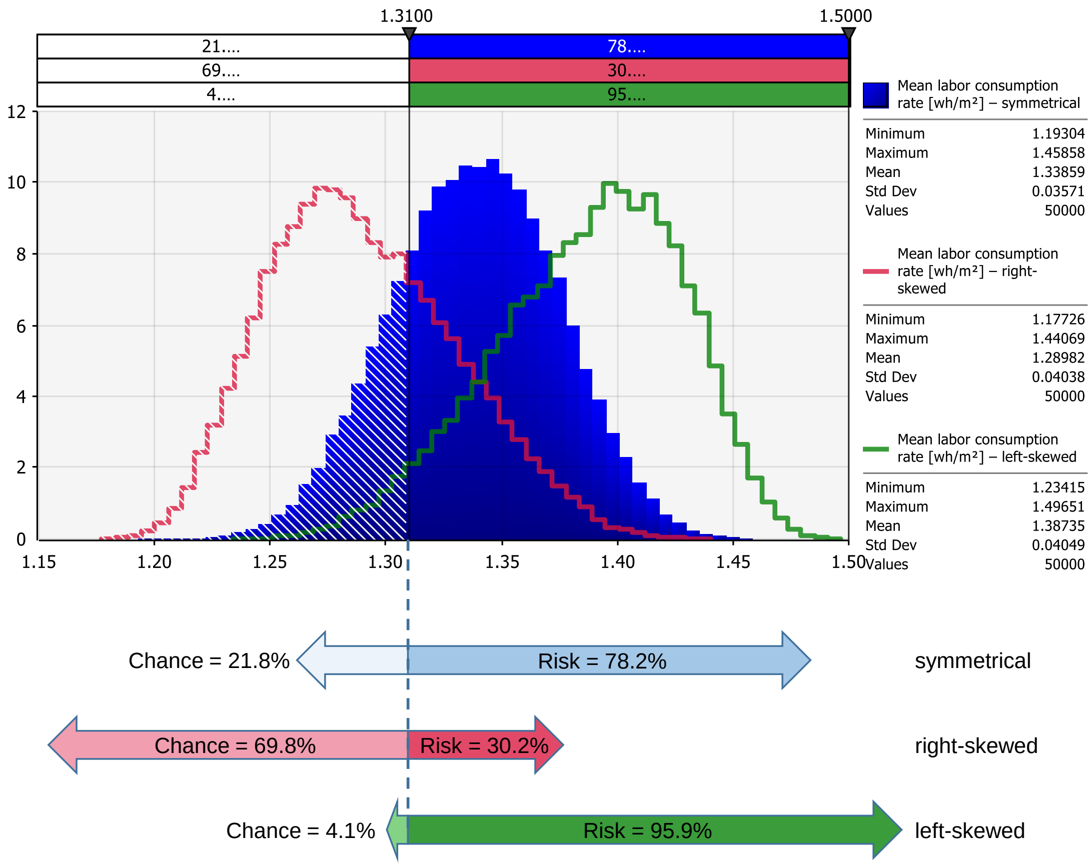

Figure 4. Histograms for the mean total labor consumption rate of shuttering works – chance/risk ratio relative to a selected deterministic value.

References

Hofstadler, C., *Produktivität im Baubetrieb – Bauablaufstörungen und Produktivitätsverluste*, Springer Vieweg, Berlin Heidelberg, 2014.

Hofstadler, C., *Risikomanagement – Systematische Berücksichtigung von Unsicherheiten bei Aufwandswerten für Schalarbeiten*, 26, Kassel-Darmstädter Baubetriebsseminar Schalungstechnik. Kassel, 2016.

Hofstadler, C., Kummer M., *Systematischer Umgang mit Produktivitätsrisiken in der Auftragskalkulation*. In Heck, D., Mauerhofer, G., Hofstadler, C. (ed.), Risiken im Bauvertrag; Proc. 12, Grazer Baubetriebs- und Bauwirtschaftssymposium, Verlag der TU Graz, Graz, 2014.

Hofstadler,C., Kummer, M., *Chancen- und Risikomanagement in der Bauwirtschaft – Für Auftraggeber und Auftragnehmer in Projektmanagement, Baubetrieb und Bauwirtschaft*, Springer Vieweg, Berlin Heidelberg, 2017.

Kummer, M., *Aggregierte Berücksichtigung von Produktivitätsverlusten bei der Ermittlung von Baukosten und Bauzeiten – deterministische und probabilistische Betrachtungen*, Doctoral Thesis, Graz University of Technology, Graz, 2015.