

## **Support Tool for Comparable Life Cycle Oriented Decision Taking**

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### **Abstract**

Up until now, the calculation of life cycle costs has generally taken no account of the uncertainties associated with the individual costs. The ensuing, purely deterministic aggregate cost is submitted to the decision-maker and generally also selected for the delivery. Using this type of calculation, there is no way of knowing whether, and with what probability, this figure will be correct. In contrast, the model for the analysis of the life cycle costs (LCCA model) developed at the Institute for Construction Engineering and Management at the Swiss Federal Institute for Technology Zurich makes it possible to provide much more in-depth advice, and, given a competent interpretation of the results, it can serve as a worthwhile decision-making aid for investors, property developers and, in the future, life cycle system providers. It is divided into three elements: structural framework of costs, forecasting, and simulation model. The ensuing probability density resp. probability distribution functions for the aggregate life cycle costs enable the various alternatives to be evaluated with a view to their probability of occurrence, and the associated costs to be assessed for investors, property developers and life cycle service providers.

### **Keywords**

LCCA, Life Cycle Orientation, Comparison, Decision Taking

### **1. Introduction**

On average, a building is utilized over a period of between 40 and 60 years. Given that, generally speaking, the costs incurred for operation, maintenance and repair are equally as high after just six to eight years as those spent on building the property in the first place, by the end of the period under review the investment costs will only account for somewhere between 10% and 25% of the total life cycle costs incurred over the entire useful life of the building (Staudt et al, 1999). As such, just optimizing the investment costs will not provide the economically best possible overall solution by any means; on the contrary, the combination of investment and subsequent costs and their interaction need to be analyzed in order to select the best possible delivery model in terms of optimized costs (Boussabaine and Kirkham, 2004).

When evaluating the various alternative delivery methods in terms of the overall life cycle, experts need to make estimations, given that the costs and cost developments over such lengthy periods are largely unknown at the time of conducting the analysis; these estimations are subject to uncertainties. Instead of

referring to individual, deterministically calculated figures, the decision-makers can now gain access to probability density and probability distribution functions enabling them to incorporate not just the level of costs, but also the stability of costs into the calculation of the various alternatives.

The reliability, resp. accuracy of the results depends to a large extent on the assumptions that have been made, and their relation to reality, so that the major part of the cost risk associated with the investment remains with the investor (client) unless the contractor offers to build the structure with life cycle guarantees, such as propagated by Dreyer and Girmschied for Public Private Partnership (PPP) projects (Dreyer and Girmschied, 2005).

## **2. Methodology**

Once intensive literature research on the fundamental principles of life cycle costs had been concluded, a cost structure model for planning, constructing and subsequently operating structures was drawn up. Hypothetical forecasts were defined for each cost group, with a simulation model combining the individual forecasts, since the complexity of the construction task and the multitude of individual hypotheses for the cost groups and their forecast development made it impossible to gain a mathematically precise solution using just analytical methodology. The results of the simulation model are presented as probability density, resp. probability distribution functions, which can be used as the “principal tool” for evaluating the various structural solutions.

## **3. Fundamental principles of life cycle costs**

Life cycle costs are analyzed on the basis of the time value of money, i.e. the fact that costs, which are incurred at different points in time, are not of equal value (Mearig et al., 1999). A life cycle cost analysis (LCCA) discounts or accrues all economic factors, which might affect the period under review, to a common point in time, thus producing comparable cost estimates for various approaches to delivery. On the basis of this understanding, the method is suitable as an aid for investors and engineers when selecting the most effective and, as such, optimized alternative for investments, maintenance and renewals (Dell’Isola and Kirk, 1981). Where different alternatives offer the same benefit, one need only study the costs; income figures can be ignored in such cases.

Systematic procedures are crucial in order to ensure that all costs are captured. This is achieved by dividing the life cycle of a project into three phases: development, delivery and utilization. The development phase comprises all the work processes arising prior to the commencement of construction. These include, for example, all analyses to determine the needs and requirements, and the cost-efficiency, together with rough planning and the first steps towards delivery planning (Brandenberger and Ruosch, 1996). The start of construction works triggers the commencement of the delivery phase, which covers not just the actual construction of the building but also all other measures that are necessary, whether directly or indirectly, to build the structure. The utilization phase commences once the building has been approved, which usually happens at the same time as the building goes into commission, and lasts through to the end of the analysis period.

## **4. The LCCA-model**

The programs that are already available in the marketplace for calculating life cycle costs adopt various approaches to including the cost uncertainties, respectively to incorporating the time scale and the uncertainties associated with this latter. The BLCC program (Fuller and Petersen, 1996) could be used as an example; this program indicates precise figures for future developments over the next 30 years as percentages with two decimal places, totally disregarding the uncertainties existing in real life. Other

models or programs (e.g. Spider diagram (Flanagan et al., 1987)) ignore the temporal development, claiming that certain parameters behave the same for all elements and therefore do not need to be taken into account. On closer inspection, these approaches do not seem to be mature, as yet, which is why the LCCA model adopts the benefits offered by each individual model, combines them, and enhances them with suitable forecasting models.

#### **4.1 Basic development steps**

The LCCA model substantially comprises three basic elements: the cost structure framework, the hypothetical forecasts, and the simulation model. It was developed in three phases, in line with these elements. The principles of the LCCA model for one delivery alternative are shown in Figure 1.

##### **4.1.1 Development of the cost structure framework**

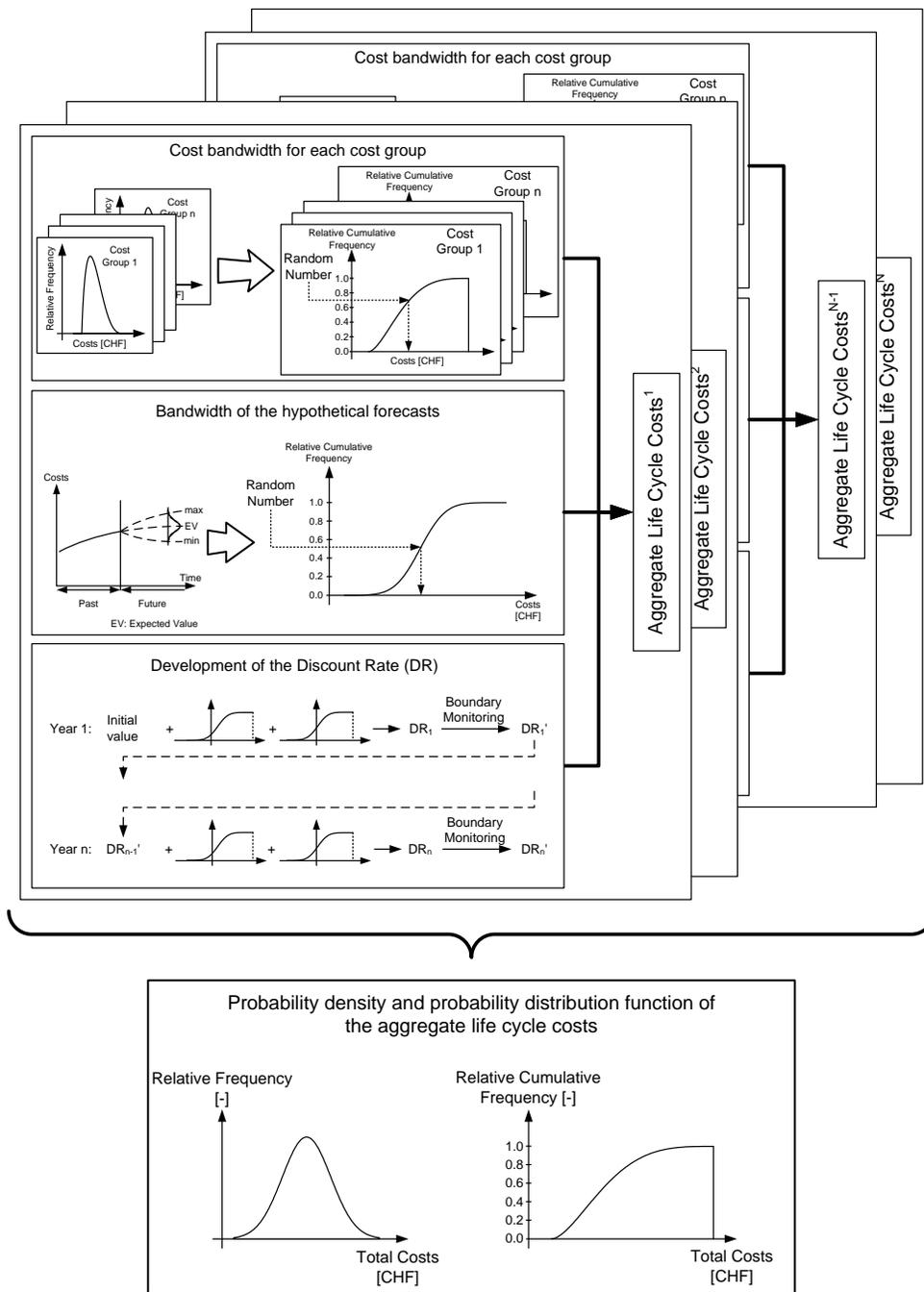
Although pertinent norms and work instructions already include a multitude of itemized cost groups, a new structure was necessary since the existing itemization is too detailed. Such attention to detail is, firstly, not necessary at the start of the LCCA where the focus is on an initial rough estimate, and, secondly, not possible.

The spreadsheets that have been drawn up on the basis of the cost structure then need to be completed with figures for the individual cost groups. In doing so, cost bandwidths and – where known – the relevant probability density functions need to be entered, instead of deterministic figures, in order to illustrate the uncertainties associated with the individual cost groups, and to be able to incorporate these into the subsequent simulation.

##### **4.1.2 Development of the hypothetical forecasts**

Over the time scale, the individual factors adhere to different rules in their development. Ideally all cost groups and factors should be analyzed in detail, but since time and cost reasons preclude such efforts, we must rely on expert estimations that are reviewed and modified for use as the basis of future analyses. In order to keep the workload within reasonable limits the cost groups are classified for the purposes of the forecasts by the criteria of origin (wages, material, and other costs) and periodicity of the costs.

Prior to sub-classifying any further – for example into different wage groups (high wages/cheap labor) or types of material, the ensuing benefit should first be weighed against the effort required. Given the extensive impacts of the forecasts on the overall results it is definitely better, in principle, not to allow any forecasts to be fed into the simulation if they are known to be false.



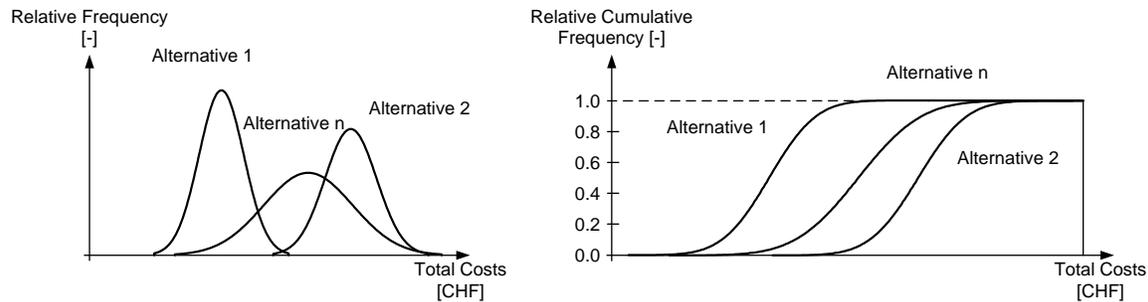
**Figure 1: Principles of the LCCA model for one delivery alternative**

#### 4.1.3 Simulation model

The Latin Hypercube was chosen as the simulation model. The simulation is based on a random generator that selects the level of a cost group using the probability distribution function on the basis of a randomly chosen figure ranging between 0 and 1. This process is conducted each simulation run for each probability distributed variable, its forecast and discount rate. The ensuing figures are used as a basis for subsequently calculating the aggregate life cycle costs, which can be illustrated as probability density and probability distribution functions after N simulation runs.

## 4.2 Evaluating the results

The results and, as such, the various delivery models are evaluated on the basis of the probability functions revealed by the simulation model. Whilst the density function (Figure 2 left-hand side) offers a good overview over the expected levels of aggregate costs, the distribution function (Figure 2 right-hand side) gives a simple illustration of the probability of undercutting respectively exceeding these figures. Incorporating a standard deviation allows an assessment of the cost stability of the individual delivery models. Moreover the model allows any number of parameters to be varied, whilst at the same time offering a clear illustration of their impact on the overall result.



**Figure 2: Probability density and probability distribution function of the aggregate costs of various delivery models**

## 5. Conclusion

When calculating aggregate life cycle costs, the LCCA model takes the uncertainties associated with the relevant costs into account. Whilst this model is no more able to eliminate the constraints faced by each and every LCCA – the uncertainty of statements about the future – than any other approach, it does, however, illustrate the uncertainties associated with the statements, thus enabling them to be consciously incorporated into the decision-making process.

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