Support tool for comparable life cycle oriented decision taking

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Support Tool for Comparable Life Cyd e 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 correcl. In contrast, the model for the analysis ofthe 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

I. Introduction

On average, a building is utilized over aperiod of between 40 and 60 years. Given that, generally speaking, the costs incurred for operation, maintenance and repair are equally as high atter 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% ofthe totallife cycie costs incurred over the entire usefullife 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 ofoptimized costs (Boussabaine and Kirkham, 2004).

When evaluating the various alternative delivery methods in terms ofthe 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-rnakers can now gain access to probability density and probability distribution functions enabling thern to incorporate not just the level of costs, but also the stability of costs into the calculation ofthe various alternative .

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 rernains with the investor (ciient) 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 Girrnscheid, 2005).

2. **Mctltodology**

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 rnethodology. 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 eycle eosts

Life cycle costs Me analyzed on the basis of the time value of rnoney, Le. the fact that costs, which are incurred at different points in time, are not of equal value (Mearig el al., 1999). A life cycle cost analysis (LCCA) discounts or accrues all economic factors, which might affect the period under review, to a cornmon point in time, thus producing cornparable cost estimates for various approaches to delivery. On the basis of this understanding, lhe 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'lsola 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 ofa project into three phases; developrnent, delivery and utilization. The development phase comprises all the work processes arising prior to the cornmencement 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 Ruoseh, 1996). The start ofeonstruetion works triggers the eommeneement of the delivery phase, whieh covers not just the aetual eonstruetion of the building but also all other measures that are neeessary, whether direetly or indireetly, to build the strueture. The utilization phase eommenees onee the building has been approved, which usually happens at the same time as the building goes into eommission, and lasts through to the end ofthe analysis period.

4. The LCCA-model

The programs that are already available in the marketplaee for ealculating life eyele eosts adopt various approaehes to ineluding the eost uneertainties, respeetively to ineorporating the time seale and the uneertainties assoeiated with this laner. The BLCC program (Fuller and Petersen, 1996) eould be used as an example; this program indieates preeise figures for future developments over the next 30 years as pereentages with two deeimal plaees, totally disregarding the uneertainties existing in real life. Other models or programs (e.g. Spider diagram (Flanagan et al., 1987)) ignore the temporal development, c1aiming that eertain parameters behave the same for all elements and therefore do not need to be taken into aeeount. On eloser inspeetion, these approaehes do not seem to be mature, as yet, whieh is why the LCCA model adopts the benefits offered by eaeh individual model, eombines them, and enhanees them with suitable forecasting models.

4.1 Basic development steps

The LCCA model substantially eomprises three basic elements: the eost strueture framework, the hypothetieal foreeasts, and the simulation model. It was developed in three phases, in line with these elements. The prineiples ofthe LCCA model for one delivery alternative are shown in Figure I.

4.1.1 Development ofthe cost struclure framework

Although pertinent norms and work instruetions already inelude a multitude of itemized eost groups, a new strueture was neeessary sinee the existing itemization is too detailed. Sueh attention to detail is, firslly, not neeessary at the start ofthe LCCA where the foeus is on an initial rough estimate, and, seeondly, not possible.

The spreadsheets that have been drawn up on the basis of the eost strueture then need to be eompleted with figures for the individual eost groups. In doing so, eost bandwidths and - where known – the relevant probability density funetions need to be entered, instead of deterministie figures, in order to illustrate the uneertainties assoeiated with the individual eost groups, and to be able to ineorporate these into the subsequent simulation.

4.1.2 Development of the hypothetieal foreeasls

Over the time scale, the individual factors adhere to different rules in their development. Ideally all eost groups and factors should be analyzed in detail, but since time and cost reasons preelude 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 eost groups are elassified for the purposes of the forecasts by the eriteria of origin (wages, material, and other costs) and periodieity ofthe costs.

Prior to sub-elassifying any further - for example into different wage groups (high wages/eheap 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.

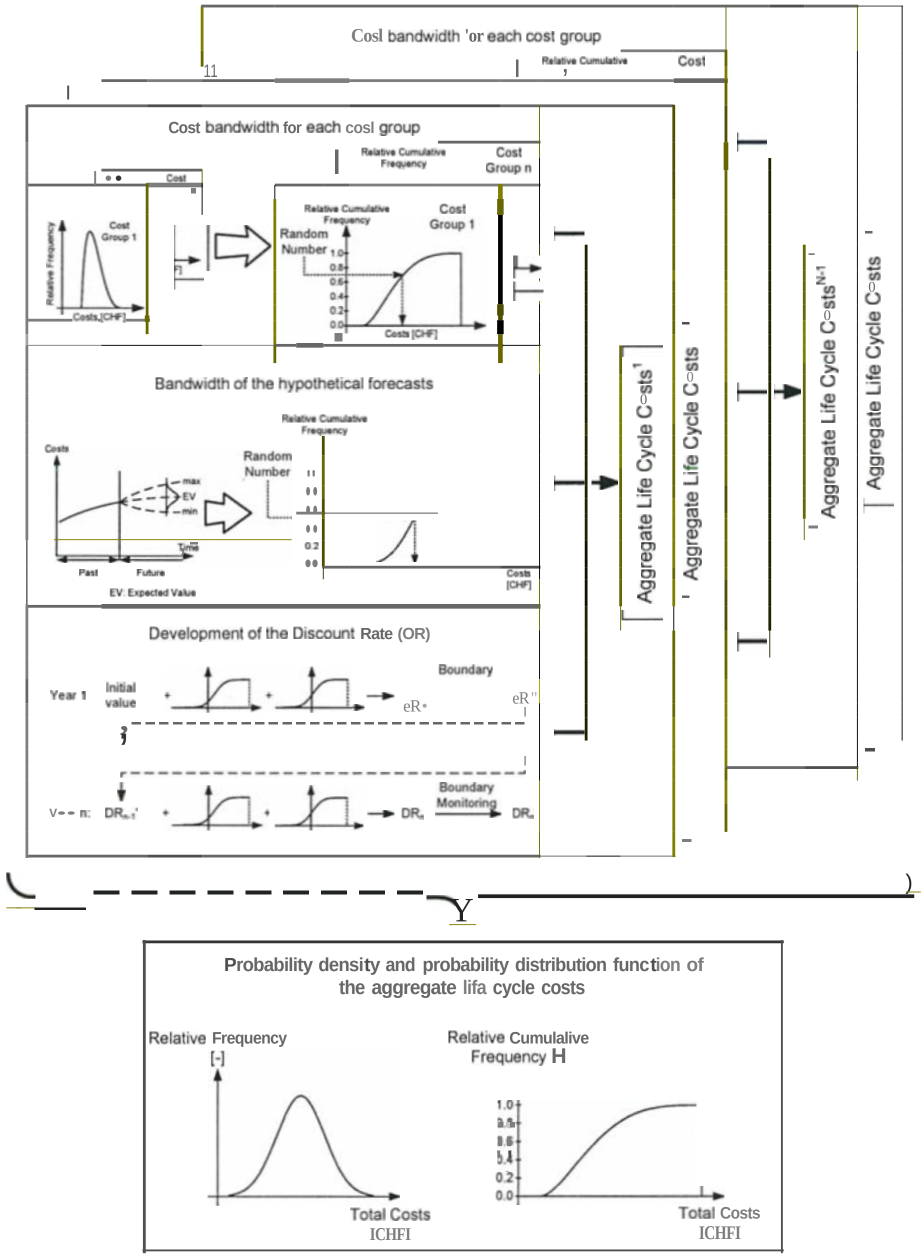

Figure I: Principles ofthe LCCA model for one delivery alternative

4.1.3 Simulation model

The Latin Hypercubc 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 I. This process is conducted each simulation run for each probability distributed variable, its forecast and discouni rale. The ensuing figures are used as a basis for subsequently calculating Ihe 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 resulls and, as such, Ihe various delivery models are evaluated on the basis of the probability functions revealed by Ihe 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 respeclively exceeding Ihese figures. Incorporaling a standard deviation allows an assessment of the cost stability of the individual delivery models. Moreover the model allows any number ofparameters to be varied, whilst at the same time offering a clear illustralion oflheir impaci on the overall resull.

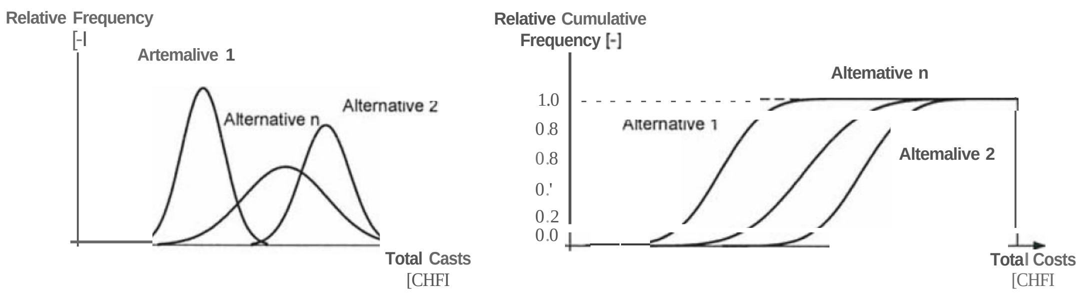

Figure 2: Probability density and probability distribution function ofthe aggregate costs ofvarious delivery models

5. Conclusion

When calculaling aggregale life cycle costs, the LCCA model takes the uncertainlies associated wilh Ihe relevant costs imo accoun!. Whilst this model is no more able 10 eliminate the constraints faced by each and every LCCA - the uncertainty of statements about the fulure - Ihan any other approach, il does, however, illuslrale Ihe uncertainties associated with the statements, thus enabling them to be consciously incorporated into the decision-making process.

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