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Building life cycle optimization tools for early design phases

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ABSTRACT

The early building design phases play crucial role for the determination of building's life cycle performance in terms of resources and energy consumption and development of LCC (life cycle costs). In this stage the optimization potential is still very large, at very low cost. In the latter planning phases the change possibility rapidly decreases with simultaneously increasing costs. The investors and planners are increasingly requiring design tools as decision support instruments, which would enable simulation and optimization of LCC already in the early planning phases. This paper will present a comparative study of three commercial software-tools for LCC-calculation, and test their fitness for the implementation in the early design phases. Using a Case Study of an energy efficient building, LCC were assessed employing the three tools and the deviations of the results were compared. The analysis showed, that the tested tools cannot be employed in the early design phases without adoption and customization, lacking of benchmarks and extensive data representing the largest problem for a reliable LCC calculation and optimization. In further step, a strategy for investors for the assessment of LCC in the architectural competitions as decision support was developed and verified on a real-life project.

1. Introduction

1.1. Research motivation

Buildings consume energy and resources, as well as financial assets throughout the whole life cycle, causing not only significant environmental but economic impact as well. The issue of affordability is increasingly gaining on significance in the context of sustainability [1]. Literature implies that one of the main obstacles in reaching the EBPD (Directive on the energy performance of buildings) [2] aims in achievement of nearly zero energy buildings are the investment costs for technology and construction [3,4]. Therefore, a decision-making framework for the investors, allowing assessment of not only costs, but also of life-cycle savings and benefits is necessary, moving the focus from the decision-making based exclusively on the construction costs towards life cycle costs [5,6].

The aim of this paper is to extend the existing body of knowledge on LCC (life cycle cost) analysis for energy efficient buildings. The LCC approach has been widely used by the academics for the evaluation of the building energy supply and energy systems, yet seldom using the building design approach and incorporation construction costs and relevant standards. The novel approach introduced in this paper is building design-oriented LCC analysis in the earliest, for future life cycle building performance crucial design stages, when low-resolution design information is available, using the obligatory standards for cost assessment.

The early planning phases (programming and pre-design) play crucial role for the future performance of a building throughout the life cycle – here the optimization potential is almost infinite, at a very low cost. Bogenstätter points out, that early design stages determine up to 80% of building operational costs, as well as of environmental impacts [7]. In the latter planning phases the change-possibility rapidly decreases with simultaneously increasing costs (Fig. 1). The operational costs exceed the construction costs by a multiple; whereas the exact exceeding point as well as the ratio of initial to following costs depends on the quality of construction, the use-intensity and the building-type, as well as on considered life duration. Both academic research and industry claim that integrated planning process, including life cycle costing

List of Abbreviations: CG, cost group; CS, costs for construction structure; CE, costs for construction engineering (HVAC); CF, costs for construction finishing; CC, construction costs (CS + CE + CF); EC, energy cost; OC, operational costs (energy, water, utilities, cleaning); MSC, maintenance and service cost; RC, regular costs (OC + MSC); IC, irregular costs (replacement, renewal), occurring after expired expected life duration of an element or component; DC, costs for demolition or disposal; FC, following cost (RC + IC); LCC, discounted present value of CC + FC + DC; BIM, building information modelling.

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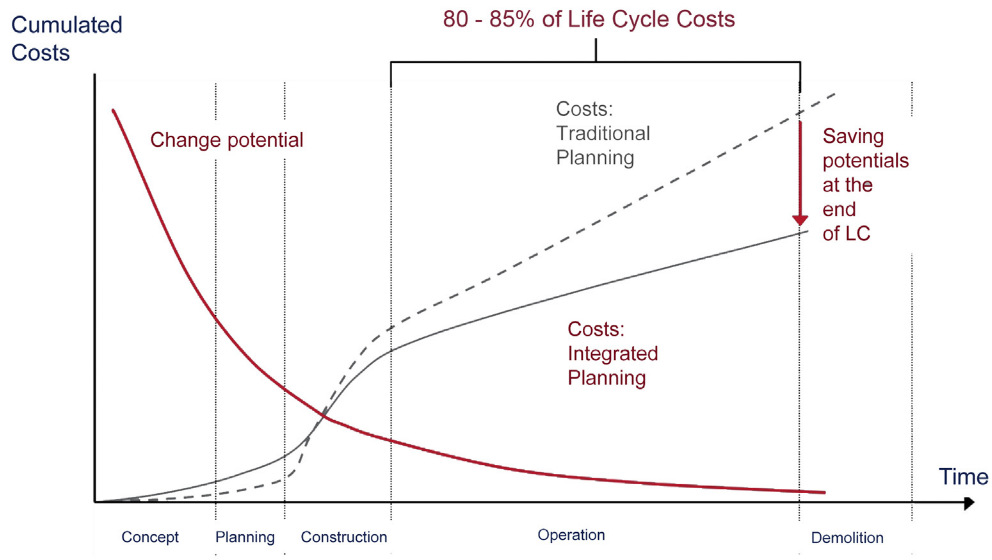

Fig. 1. Cost development vs. change potential over building life cycle [10].

and optimization can significantly decrease the following costs [8,9]. The application of LCC analysis allows early assessment of the operational saving potentials or compilation and evaluation of variant-study [8] (Fig. 2).

However, the AEC industry is facing a problem, which has already been known from other industries, that the early planning phases are characterized by lack of information, data and tools [11]. Therefore, investors and planners are increasingly requiring planning tools as decision support instruments, which would enable simulation and optimization of life cycle costs already in the early planning phases (pre-design).

1.2. Life cycle costing in construction: state of the art

The whole life cost or whole lifecycle costing – as a total cost of ownership over the life span of a building is despite a long history of more than 40 years, a still relatively novel approach in the AEC industry. Before the 1970s the decision-making in construction was solemnly made upon capital costs. The first movement which questioned this approach, advocating the benefits of higher capital investments for better value in the operation was so called "terotechnology" [12]. This movement was followed by the organized data assessment for the actual operation of the buildings, initiated in 1971 by RICS. In the 1970s the thought of optimization of running costs arises and appears in literature, such as cost-in-use, only in the late 1970s the LCC methodology appears. However, its practical implementation is hindered by the lack of reliable data. Finally, in the year 2000 the ISO 15686 [13] appears defining LCC, as well as the principle of whole life costs (also whole lifecycle costing) for management of long term cost assessment of capital projects [12]. Outside of the AEC industry, the lifecyclecosting methodology was largely applied by the US Department of

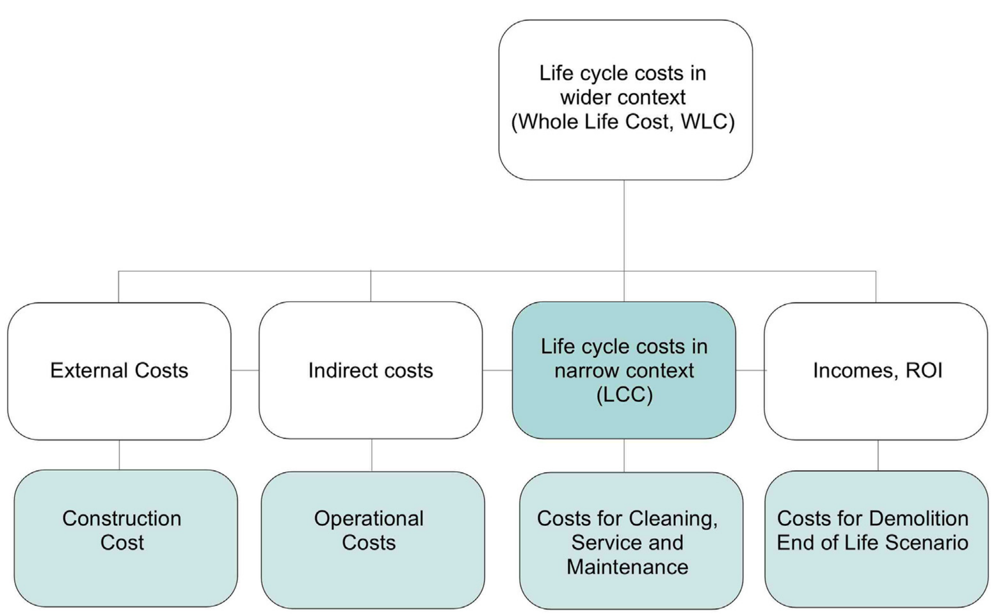

Fig. 2. Whole life cycle costs, after ISO 15686 [13].