SHAPING BUILDING-VOLUMES THROUGH LIFE CYCLE COSTS

A constraint based programming approach for building volume optimization

Extended Abstract

ABSTRACT

Due to a general freedom in the architectural design process, a wide range of possible alternatives exist; although building-volume designs must also continue to meet numerous, possibly conflicting design requirements originating from various related disciplines. This research addresses problems that are associated with missing quantitative design aids during the early stages of design. It aims to provide designers with design solutions that provide optimal cost-effectiveness. The demonstrated building-volume optimization model minimizes life cycle costs by determining optimal-volume dimensions, floor number, building orientation and ‘window/wall’ opening ratios while satisfying site and building code regulations and design constraints. Results indicate an optimal solution can be found within a practical timeframe. The proposed, novel approach to introduce cost objectives into the design of building-volumes provides designers with a valuable decision support tool in a design domain that is known to be complex owing to multiple design criteria and constraint influences.

CONTEXT

Architectural design is based on generating realizable solutions for building projects to be planned. With increasing complexity of a designs task, architects require experts for the finalization and validation of their designs. A common planning approach of architects is to design a possible solution first and to improve it with the support of engineers and other building experts in a second step. This may come with the disadvantage that design improvements already depend on the initial draft, excluding significant design changes that may have been more appropriate in reference to the additional design objectives. Besides, the influence and cooperation through building experts in an early stage of design may not always be to advantage of the designer as well.

Moreover, the growing demand to provide sustainable designs requires foreseeing a significant reduction and control of initial and operational costs for projected building designs. Quantifiable design objectives such as consideration of life-cycle costs (LCC) can help to improve initial design steps, when implemented early on. Accordingly, an evaluation and reduction of LCC during the early design stage can be seen as a major economic improvement, also since design decisions made in the early phases of architectural design are significant, irreversible, and can only be changed later with very high costs [1].

Thus, in order to maintain design competency in the hand of architects, effective decision support should enable architects and designers to gain valuable insights and strengthen their ability to make informed decisions before, or without the overwhelming need of additional expertise. The here presented building volume optimization (BVO) model is understood as such that allows for finding optimal design solutions in reference to LCC during the early stage of design.

DESIGN PROCESS – DESIGN OPTIMALITY

In practice, the architectural design process is often understood as a repetitive search procedure, focusing not only on the integration of individual design objectives, but ideally on the improvement of current design-solutions as well. The strategy of finding the best available (or optimal) solution can therefore be considered common practice. Still, when designing manually, the aspect of design improvement cannot be solved completely. The manual search for optimality would be too expensive, not only due to the amount of design complexity, but also due to the design context that is widely understood as incomplete [2]. In the process of design, found solutions therefore represent a currently best solution; concluding that, in architectural design, a currently best solution is to be seen as directive allowing designers to understand design more efficiently and lead the ongoing design process into a wanted direction.

Likewise, designers usually elaborate their ideas on different aspects separately before finally combining them into a design solution [3]. The strategy to isolate and later rejoin design aspects documents that they can be treated individually or in groups. Thus, considering architectural design, the term optimal might be misleading again, because the search for optimal values can only be understood as search for solutions due to selective parts of a design. Nonetheless, designers can still benefit from solutions that provide optimality, as they not only offer understanding regarding existing reference points, but also allow for investigation of existing design influences between selected aspects. Hence, a successful design support system for automated design should employ the potential ability to search for optimality integrating a selectable amount of design variables.

In reference to the demonstrated BVO model, this understanding has been interpreted into an optimization model that allows for consideration of common design aspects during the early stage of architectural design. Consequently, the proposed BVO model not only aims to generate solutions that guarantee constraint fulfillment but, more important, allows for continuous design improvement. In case of the current BVO model, this may be a building volume, based on rectangular footprint, representing the smallest life cycle costs under the consideration of property, topological and design constraints.

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3. Morozumi, M., Shimokawa, Y., and Homma, R.: 2002, Schematic design system for flexible and multi-aspect design thinking *Automation in Construction*, **11**, 147–159,