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A COST-DRIVEN DESIGN OPTIMIZATION FRAMEWORK

HYOUNG-JUNE PARK[1] and JULIANN CHEN[2]

[1,2] *University of Hawaii, Honolulu, U.S.*
{hjpark, jschen }@hawaii.edu

1. Introduction

A design optimization framework is proposed for integrating an early stage design synthesis of a high-rise condominium to its construction cost estimation when its design alternatives are constrained by design factors known for optimizing maintenance fee. In this paper, construction cost estimation refers to conceptual estimation at the early stage of design process, which belongs to the category of design estimation compared to bid estimation and control estimation (Hendrickson & Au, 1989).

2. Design Optimization Framework

Net Present Value (*NPV*) is defined as the sum of the total project cost including construction cost (T) and annual cash flow discounted to its present value. When *NPV* becomes zero, the rate of return of the project, including all future cash flows, is represented by the Internal Rate of Return (IRR). The authors propose maintenance fee (M_p) per a condominium as a unique selling point to increase its annual cash flow. The outcomes from the analysis of maintenance fee performed show that the design factors such as 1) double loaded corridor, 2) interior elevators preferred, 3) five elevators (four interior and one exterior), and 4) maximum 35 floors are crucial to optimize the maintenance fees of the analysed condominiums. The design factors are defined as constraints for the construction of the condominium for generating design alternatives in the optimization process. The fitness function on the design alternative is focused on minimizing $f(_i)$ with respect to the input variables for the total construction cost (T_i) of the design alternative with subject to the set of construction tasks constrained by the design factors and the input variables necessary for each construction task. Given i = index of task, p = project id, D = total direct field cost, and H = total overhead cost,

$$f(i) = M_p + \sum_{i=1}^{n} T_i \tag{1}$$

$$T = \sum_{i=1}^{n} T_i = D + H \tag{2}$$

$$T_i = \{F_i + Q_i(M_i + E_i + W_i L_i)\} + H_i \tag{3}$$

Computation of the fitness function starts with gathering the cost of individual task. The input variables of individual task include field supervision (F_i), materials (M_i), equipment (E_i), labor (L_i), wage rate (W_i), overhead (H_i) and labour cost per each field work (Q_i) (Waier et al, 2009). The cost of the individual task (B_i) is calculated according to "Building Construction Cost Data" in MasterFormat 2009, which provides a master list of 50 divisions to explain a facility’s construction requirements and associated activities. In the middle of the computation, various design options including size, numbers, types, and construction methods per each task are searched for minimizing the total cost. The combination of the design options generates the optimized alternatives (Papalambros & Wilde, 2000; Park, 2008; Levy, 2012).

3. Discussion

The proposed design optimization framework will be further developed with 1) wide range of database with GIS, 2) UniFormat, a systems-based organization of building content, for its integration to BIM applications, 3) search algorithms for finding various design options per each task, and 4) parametric modelling scheme to provide more design freedom for its user.

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