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BIM-based approach for Estimating life cycle costs of building in conceptual design phase using Iran's national price list

F. Jalaei [1,*], M.A. HamediRad [2], A.A. ShirzadiJavid[3]

[1] Assistant Professor, Faculty of Civil Engineering of Iran University of Science & Technology, Tehran, Iran
[2] M.Sc. Construction Engineering and Management of Iran University of Science & Technology, Tehran, Iran
[3] Assistant Professor., Faculty of Civil Engineering of Iran University of Science & Technology, Tehran, Iran

ABSTRACT: All costs within the life cycle of a building are known as its life-cycle costs. In the design process of a building, the use of a lower initial cost index to select an option among others with similar performance may not lead to an economically optimal choice during the lifecycle. Hence today, building designers and investors require a tool to estimate life cycle costs at the conceptual design phase to elect an economically efficient option. The purpose of this study is to provide a framework to estimate life cycle costs of a building at the conceptual design phase based on Building Information Modeling (BIM). For this purpose, the costs of the building's life cycle, including initial costs (cost of supply and installation based on Iran's national price list and shipping costs), repair and maintenance costs, operating costs (energy consumption) and salvage value at the end of the building's useful life are regarded in the estimation of its life cycle costs. The application of the proposed framework was then evaluated and approved for designing a residential building in Tehran. The application of the proposed framework for designing a residential building in Tehran was assessed and validated on two models, and the results showed that by increasing the initial costs in the second model by 75%, its annual operating costs decreased by 54% and total life cycle costs have dropped by 8% after 18 years. In this way, building designers can estimate the life-cycle costs of a building at the incipient stages of design and improve its design.

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1. INTRODUCTION

A building's life cycle is from the start of the conceptual design stage to the end of its life and all costs within the life-cycle such as operation costs (energy and Consumable resources), repair and maintenance costs and salvage value are regarded as Life Cycle Costs (LCC) [1].

Through a building's design process, the designer might utilize options with fewer initial cost compared to others. In such a case, although the initial cost is approximately less than other options, it is plausible that over the life cycle of the building, other costs like repair and maintenance costs overpass other options' costs. This eventually may lead to choosing an economically inefficient option within the life cycle of the building due to merely taking into account the initial fewer cost [2]. Costs throughout a building's life span can be sometimes even up to multiple times of the initial costs that their proportion is correlated to factors such as construction quality, amount and severity of use, and the building's type besides the considered life span length [3]. The incomplete design stages could determine up to 80 percent of a building's costs during the life span (operation cost) [4].

The purpose of the present study is to provide a framework to estimate Life Cycle Costs (LCC) at the early design stages of buildings based on Building Information Modeling (BIM) concepts. To achieve the main goal, which is the estimation of the LCC of a building, the sub-goals are to estimate initial costs, repair and maintenance costs, operation costs and salvage value at the end of building's life span.

*Corresponding author's email: farzadjalaei@iust.ac.ir

2. METHODOLOGY

"Fig. 1" illustrates the flowchart of the developed framework for providing LCC in buildings. Estimation of material values in the building's model was conducted with the help of BIM tools (i.e. Autodesk Revit). BIM is the procedure of generating and processing a building's elements' digital information.

Initial costs including construction costs are calculated according to the Iranian Price List database. Shipment costs are calculated according to the distance of the construction site and material's provider based on current rate of vehicles. Repair and maintenance costs are calculated based on questionnaire and historical data in form of constant annual cost for each building element of the model for each year. To estimate operation costs including energy consumption costs, energy consumption value is estimated using a BIM

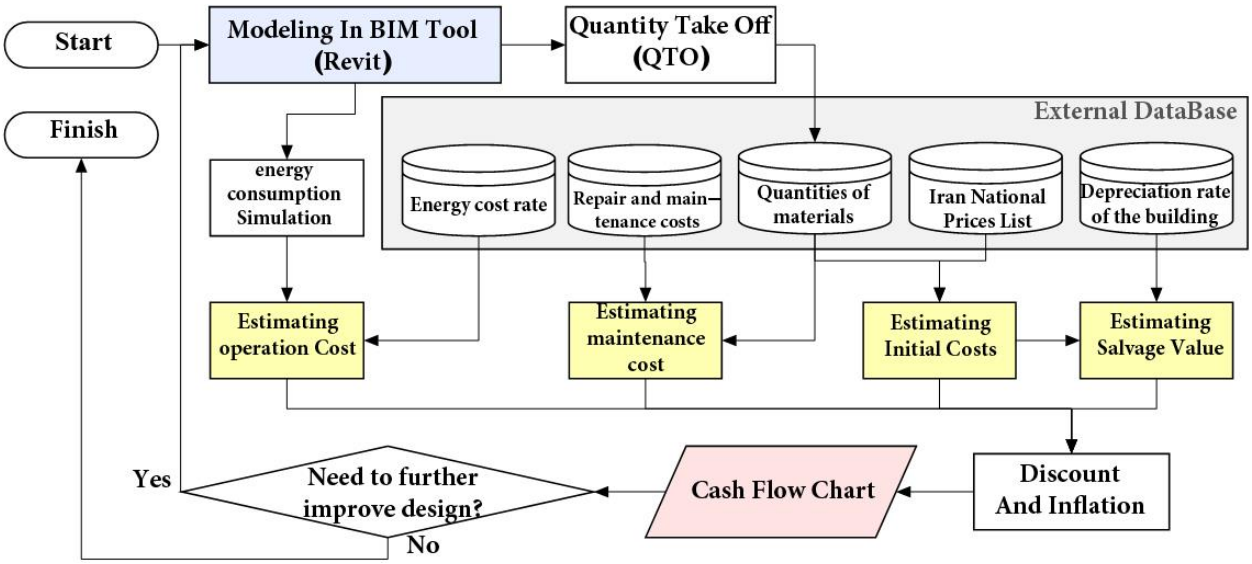

Fig. 1. BIM-based framework for estimating life cycle costs of building using Iran's national price list

Table 1. Details of the costs of building life cycle

Total Costs at the End of Life (Rial)						Model
Total	Salvage Value	Repair and Maintenance	Operation	Material transportation	Preparing and installing materials	
1914565120	0	879417000	717715500	9930420	307502080	First
1765922560	0	879417000	331785200	19152630	535567670	Second

energy consumption simulation in Green Building Studio environment annually. Eventually, this value is estimated as net present value for each year by implying present energy cost rate. GBS is an internet-based and BIM-based tool developed for energy consumption goals supported by Autodesk.

All life-cycle costs are computed based on net present value for the feasibility of comparing a building's life-cycle costs in discount cash flow, for which the discount rate of each country should be used [5]. If the estimated annual cost for each LCC ingredients (e.g. operational costs) is C and its future value in the year n is FVn, the sum of net present value of the life-cycle cost based on the discount rate (i) and inflation rate (j) is as follows:

$$NPV = \sum_{0}^{n} \left(\frac{FV_n}{(1+i)^n}\right) \quad (1)$$

$$FV_n = C(1+j)^n \quad (2)$$

3. MODEL IMPLEMENTATION AND VALIDATION

In the present study, a tool was developed for estimating LCC on the basis of the flowchart's concepts using Application Programming Interface (API) of the BIM tool. This API is eventually used in the Revit software as an add-in. To validate the provided tool, its performance is evaluated by implementing it on a three-story residential building model in Tehran, Iran.

4. RESULTS AND DISCUSSION

For the case example residential building, two models with thinner and thicker elements of the wall, as well as weaker and stronger components (respectively, the first and second models) were produced in the BIM environment (Revit), which eventually completed with the same architectural components as the door and window; therefore, the initial cost of building and installing wall and column materials would differ in two models.

The annual energy consumption of buildings after simulation in GBS indicates lower energy consumption in the second model. On the other hand, due to the constant level of the walls, their maintenance cost would be the same. The residual value of the two models is also zero due to the fact that the length of the life cycle is equal to the useful life of the building. "Table 1" shows the details of the total LCC of the two models at the end of the lifecycle.

To validate the results, the initial costs of each construction model are manually calculated and estimated based on the price list. The results of manual estimation for this project varied from 4% to 5% with the estimates made by the LCC tool developed in this study. The reason for this difference is the more accurate calculation of the BIM tool in estimating the materials quantity. The results of cost estimation in the traditional way have sometimes been considered as error by up to 40% [6]. Therefore, the accuracy of estimating the values of the developed tool is confirmed.

CONCLUSIONS

The application of the proposed framework for designing a residential building in Tehran is assessed and validated on two models, and the results showed that by increasing the initial costs in the second model by 75%, its annual operating costs decreased by 54% and Total life-cycle costs have dropped by 8% after 18 years. In this way, building designers can estimate the life-cycle costs of a building in the early stages of design and improve its design. Initial costs in the first model are 17% and in the second model, 31% of total life cycle costs.

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