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Significance of Life-Cycle Costing for Selection of Building Construction Materials

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***Abstract*— The construction industry is one of the ever growing and leading sectors, which contributes to the economic growth of any nation. One of the current challenges in this industry is to ensure compliance with the norms and standards pertaining to the construction process, building quality, performance, and most remarkably, the environmental impact. The materials used in construction have a crucial role in meeting the above requirements, and in line with this, substantial researches are in progress, in implementing scientific techniques for the selection of construction materials. Material selection is often influenced by budget constraints, local availability, and lack of technical expertise/advice. Some materials that are attractive in terms of initial cost, can have adverse effects on quality, reliability and performance, and even a catastrophic impact on the environment, during the life span of the building. So the present article tries to convince the importance of selecting material based on Life Cycle Costing (LCC), which performs the cradle-to-grave assessment of a building, at the design stage itself. The existing methods of material selection, and the introduction of LCC with details of each steps involved, and concluding remarks, are presented on the basis of review of the related literature.**

Keywords— Life cycle cost, Selection of material, construction

I. Introduction

Building Construction is the process of preparing and forming buildings and building systems. Construction starts with planning, design, and financing and continues until the structure is ready for occupancy. Buildings have a significant impact on economy and natural environment. The construction industry is facing increased demands from society [1], is developing rapidly, and has become one of the economic backbones of any country. Development should be made to meet current and future needs for achieving sustainability of economic development, social and environmental responsibility for the prosperity without compromising the needs of future generations. Therefore, to ensure the objectives, the construction industry has to implement effective and efficient methods to construct the structures and infrastructure projects in such a manner that it will not cause losses to the industry.

Each stage of construction project involves planning, design, construction, operation, maintenance and demolishing, and the associated costs should be considered to ensure the overall project costs are known. The materials used in construction have a crucial role in meeting the above requirements, and in line with this, substantial researches are in progress, in implementing scientific techniques for the selection of construction materials. Various methods have been reported for the selection of construction materials. Materials play an important role during the entire design process. At the early design stage, materials may achieve some of the required functions. Hence, designers may need to identify materials with specific functionalities in order to find feasible design concepts [2].

Construction clients ask for high quality building, lower cost and shorter lead-time. The clients, who have to pay the bill, have actually very little influence over time, cost and quality. Buildings represent a large and long-lasting investment in financial terms as well as in other resources. Most commonly, initial cost (construction cost) is the main cost factor in construction and is often set to the minimum, which does not necessarily improve the lifetime performance of buildings. However, a higher initial cost might decrease total life cycle cost (LCC). It is important, therefore, to show the construction client in the early design phase the relationship between design choices and the resulting lifetime cost [3].

The material selection problem has been treated extensively in the literature through many approaches, such as multi-objective optimization, ranking methods, index-based methods, and other quantitative methods like cost–benefit analysis. However, current literature in the building domain lacks a standard method that may help the decision-maker to select the appropriate materials while at the same time looking at the accomplishment of environmental goals and meeting design and budgetary requirements. This gap is observed in spite of cost being a common reason for the bankruptcy of many GB projects given that materials reach up to 20–30% of the total building cost [4].

Therefore, the construction industry has to implement technique for the selection of material in the design stage, which performs the cradle-to-grave assessment of a building to avoid unnecessary cost. So the present article emphasizes the importance of selecting material based on Life Cycle Costing (LCC), at the early design stage.

II. Existing methods for the selection of materials

Multiple Criteria Decision Making (MCDM) which yields a comprehensive and systematic structure that employs quantitative assessments for priority construction method selection for each green building project and also aids construction companies with regard to their practical applications [5], whereas questionnaire was prepared to determine the criteria that influence the decisions for selecting the proper construction technique and to determine their overall importance in the decision making process [6].

Analytic Hierarchy Process (AHP) model were used, which identifies some of important potential factors that will impact architects decisions in their choice of green vernacular building materials, during the design-decision making process. The aim is to develop a multi-factorial analytical decision support toolkit to assist architects assess their consequences in terms of whether or not the material option is likely to move towards sustainability objectives [7].

Digital tools for different kind of material selection with their capabilities and limitations were reported by Fang [8] for product design .

In order to help decision-makers with the selection of the right materials, Castro-Lacouture [9] proposed a mixed integer optimization model that incorporates design and budget constraints while maximizing the number of credits reached under the Leadership in Energy and Environmental Design (LEED) rating system [4]. Some professional designers conducted experiment and established a required data table for materials selection [9] & [10].

Ljungberg [11] reviewed certain aspects such as sustainable product, triple bottom line, dematerialisation, recycling, design considerations, ISO 14001 standard and the EMAS (Eco Management and Audit Scheme) regulation, Life cycle assessment, environmental impact, eco-efficiency, environmental space, market contacts, cultural aspects, fashion and trends and proposed the guidelines for materials selection.

The material selection problem has been treated extensively in the literature through many approaches, such as Analytic Hierarchy Process [7], Eco Management and Audit Scheme [11] & [12], index-based methods [6], and other quantitative methods like experimental methods [9,10]. However, these work lack in accessing the performance of building material form cradle-to-grave, at the design stage. Building domain lacks a standard method that may help the decision-maker select the more-appropriate materials for the of the building while at the same time looking at the accomplishment of environmental goals and meeting design and budgetary requirements.

III. Introduction to LCC as a Solution

The Life-cycle cost (LCC) is a solution to meet the above mentioned gaps in the selection of materials. It is the tool to determine the most cost-effective option among different competing alternatives to purchase, own, operate, maintain and, finally, dispose of an object or process, when each is equally appropriate to be implemented on technical grounds. For example, for a highway pavement, in addition to the initial construction cost, LCC takes into account all the user costs, (e.g., reduced capacity at work zones), and agency costs related to future activities, including future periodic maintenance and rehabilitation. All the costs are usually discounted and total to a present day value known as net present value (NPV). This example can be generalized on any type of material, product, or system.

IV. Design steps in Life Cycle Cost Analysis

Life cycle cost components for construction and selection of materials can be broken down into several elements in a hierarchy structure, as shown in figure 1[13]. The first level has the major costs: initial costs, running costs, and salvage value.

Performing an LCC study involves (1) establishing objectives for the analysis, (2) determining the criteria for evaluating alternatives, (3) identifying and developing design alternatives, (4) gathering cost information, and (5) developing a life cycle cost for each alternative [14].

Step 1. Establish Clear Objectives

To be successful, an LCC study must have clear objectives, and they must be objectives that this type of study is well suited to address. LCC can capture cost variations between alternatives and show which option will have the lowest overall cost. It can only address values quantifiable in money. For example, an LCC study of high-performance glazing can capture the overall cost-effectiveness of different options as compared to a base case. LCC is not the right tool to explicitly evaluate improved comfort or occupant satisfaction with the different glazing products.

Step 2. Determine LCC Metrics (total cost and payback)

The two primary metrics to be used and calculated in LCC are the life cycle costs of each alternative and its payback over a certain study life. That is, consideration should be given to total costs and the time it takes to recover an incremental initial investment incorporating the time value of money.

Step 3. Identify the Base Case and Develop Alternative Designs

The LCC approach is geared towards evaluating design alternatives. The alternative that captures the “standard” design or minimum requirements for a project is called the “base case.” The design team must develop alternatives to evaluate against the base case. These alternatives must be developed in sufficient detail to derive good cost estimates, which are required to run the life cycle cost calculations and to capture the incremental cost differences of the options.

An infinite number of alternatives can be developed for any project. The design team should develop the alternatives, using its experience and judgment in selecting relevant building and system component options.

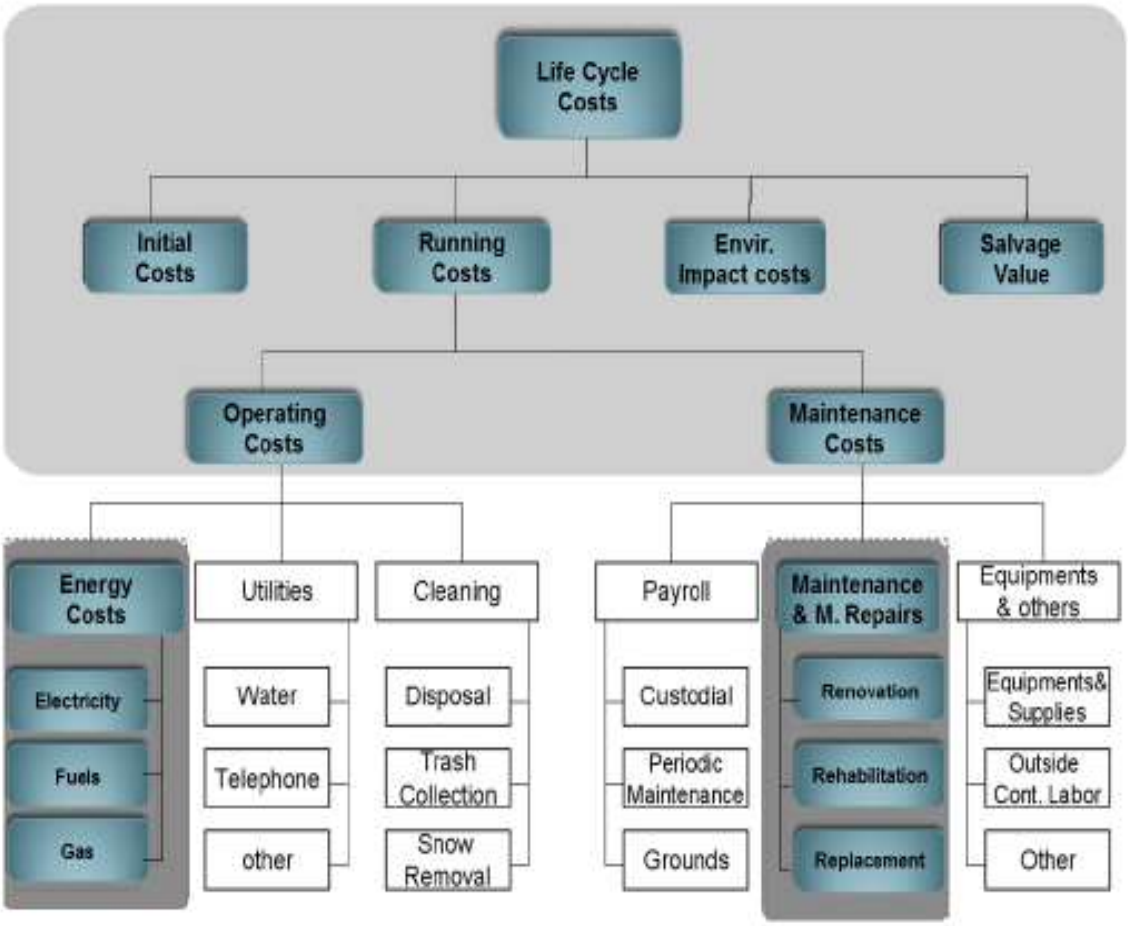

Figure 1: Life Cycle Costs Components [13].

Step 4. Gather Cost Information

Cost information can come from a variety of sources, including cost estimating consultants, contractors, vendors, and designers. For each alternative, gather all of the cost information described below under Cost Components of LCC (e.g., construction, utility, maintenance, service, and in some cases remodeling costs). Identify additional soft cost requirements for the alternatives as well.

Step 5. Perform Life Cycle Cost Calculations

For each alternative, calculate the metrics listed in Step 2 above, using the parameters listed under Life Cycle Cost Parameters below. Test each alternative against the two metrics and make a recommendation on which to incorporate into the design.

A. *Cost Components of LCC*

An LCC may include project, utility, maintenance, service, remodeling, and end-of-life costs, as well as benefits to campus infrastructure.

1) Project Costs

Project costs, sometimes referred to as initial or first costs, include both “hard” or construction costs (labor, materials, equipment, furnishings, etc.) and “soft” costs (design fees, permit fees, etc.). Cost estimates and information from contractors, vendors, and design teams can be used to develop project costs for LCC alternatives.

2) Utility Costs Energy Costs

Stanford’s central utilities provide the majority of Stanford facilities with steam, chilled water, and/or electricity, though Pacific Gas & Electric Company is the provider in outlying areas. For each type of utility service

there is a cost per unit of energy delivered that will be charged to the building. The rates and units for these utilities are listed below under Life Cycle Cost Parameters.

3) Energy Estimating Methods

Typically the mechanical and/or electrical engineers on a design team will estimate the amount and rate of building energy use. The most comprehensive and widely used method of performing these estimates involves detailed hourly computer simulation of building operation with programs like DesignBuilder or Ecotect.

4) Non-Energy Utility Costs

Domestic water and sewer service are two non-energy utility costs that need to be developed when affected by alternatives being modeled.

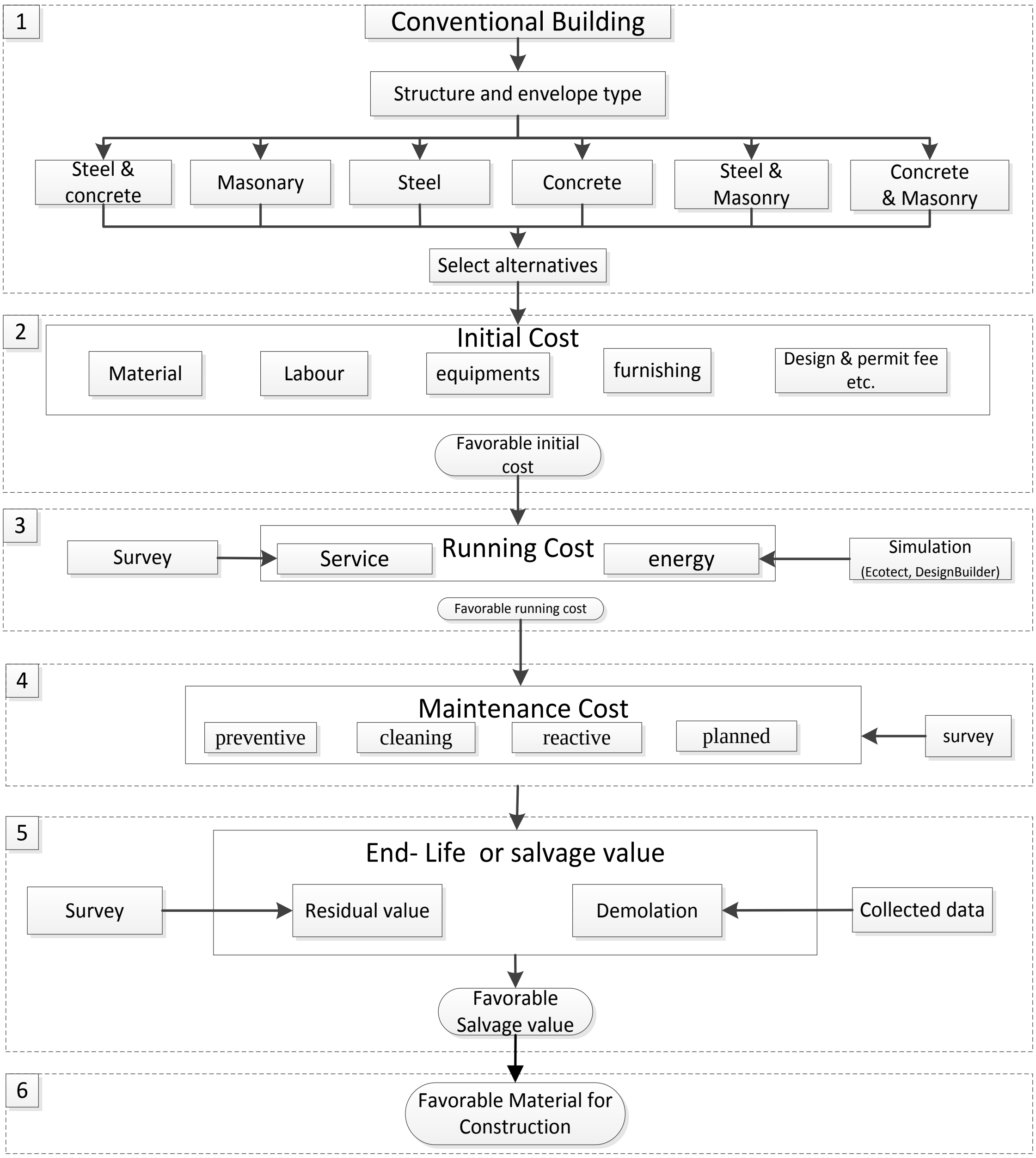

Figure 2: Selection of Building materials Flowchart for Conventional building

5) Maintenance Costs

Maintenance refers to the costs incurred to keep building systems running properly. The wide array of activities performed by Stanford's maintenance staff fall into four cost categories: preventive, reactive, planned, and deferred. These data should be based on historical data provided by facilities operations.

a) Preventive

Preventive maintenance is routine, scheduled activity intended to keep a system running at its best. This maintenance is performed whether or not there are any problems with a system. It is designed to prevent break-downs. Changing filters and lubricating bearings are examples of preventive maintenance activities. Preventive maintenance costs associated with equipment and systems should be incorporated into LCC calculations.

b) Service Costs

Service costs include items such as janitorial services, elevator maintenance etc. Since these costs depend more on the programmatic elements of a building than on the architecture, systems, and other components, they are typically not considered in LCC. However, they should be included if for some reason they differ among the design alternatives.

6) End-of-Life Costs

End of life costs is the combination of two major costs.

a) Residual Value

Assume all buildings have zero residual value at the end of the study life. This assumption may change in the future, but in the interest of keeping the initial LCC studies as simple as possible, it will be used consistently across studies.

b) Demolition

Usually this cost is assigned to the new project on a site. When the extent or nature of the required demolition varies among alternatives, it is appropriate to include these costs.

V. Selection of Building material for construction

The process of the selection of buildings material consists of five stages, as shown in Figure 2. The first stage contains the alternatives, which includes structure and envelope types: steel, concrete, masonry, and combinations of these materials. The second step is to find the initial cost for various alternatives through survey. The third step is evaluating the running costs, including energy, maintenances and major repairs costs and which were adjusted and estimated through simulation for different alternatives. The forth step in this process is to determine the salvage value of a building. The final step is selecting of the favorable building material based on AHP & MAUT. This selection was obtained using deterministic and stochastic approaches, as well risk assessment technique.

VI. Conclusion/ Recommendation

The present article provides an outline of Life Cycle Costing (LCC) for the selection of materials in building construction. Although many methods have been reported, LCC is the only one that incorporates design, budget, and environmental requirements simultaneously during the life span of the building were not considered. The model allows the user to freely include preferred materials and design parameters through design constraints, without enforcing a restrictive solution.

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References

[1] C. O. F. Water, W. Housing, and E. Abstract, “Life Cycle Cost analysis of Sustainable Measures Case of water and wastewater housing,” no. May, pp. 1–16, 2011.

[2] Y. M. Deng and K. L. Edwards, “The role of materials identification and selection in engineering design,” Mater. Des., vol. 28, pp. 131–139, 2007.

[3] R. Fulford and C. Standing, “Construction industry productivity and the potential for collaborative practice,” Int. J. Proj. Manag., vol. 32, no. 2, pp. 315–326, 2014.

[4] D. Castro-Lacouture, J. a. Sefair, L. Flórez, and A. L. Medaglia, “Optimization model for the selection of materials using a LEED-based green building rating system in Colombia,” Build. Environ., vol. 44, pp. 1162–1170, 2009.

[5] W.-H. Tsai, S.-J. Lin, Y.-F. Lee, Y.-C. Chang, J.-L. Hsu, and Jui-Ling Hsu ; Sin-Jin Lin; Wen-Hsien Tsai; Ya-Fen Lee; Yao-Chung Chang, “Construction method selection for green building projects to improve environmental sustainability by using an MCDM approach,” J. Environ. Plan. Manag., vol. 56, no. March 2015, pp. 1487–1510, 2013.

[6] H. L. A. Muhsen, “Decision Making in the Selection of the Exterior Walls Techniques in Affordable Housing Buildings in Palestine,” vol. 3, no. 2, pp. 43–46, 2012.

[7] I. Ogunkah and J. Yang, Investigating Factors Affecting Material Selection: The Impacts on Green Vernacular Building Materials in the Design-Decision Making Process, vol. 2. 2012, pp. 1–32.

[8] Y. F. Yin, “Digital tools for material selection,” ICENT 2010 - 2010 Int. Conf. Educ. Netw. Technol., vol. 31, no. 5, pp. 144–146, 2010.

[9] E. Karana, P. Hekkert, and P. Kandachar, “Material considerations in product design: A survey on crucial material aspects used by product designers,” Mater. Des., vol. 29, pp. 1081–1089, 2008.

[10] I. E. H. van Kesteren, “Product designers’ information needs in materials selection,” Mater. Des., vol. 29, pp. 133–145, 2008.

[11] L. Y. Ljungberg, “Materials selection and design for development of sustainable products,” Mater. Des., vol. 28, pp. 466–479, 2007.

[12] P. Chatterjee, V. M. Athawale, and S. Chakraborty, “Selection of industrial robots using compromise ranking and outranking methods,” Robot. Comput. Integr. Manuf., vol. 26, no. 10, pp. 483–489, 2010.

[13] O. S. D. Alshamrani, “Evaluation of School Buildings Using Sustainability Measures and Life-Cycle Costing Technique,” LAP LAMBERT Academic Publishing, Germany, 2014.

[14] Stanford_University, “GUIDELINES FOR LCC in Buildings,” October, October, 2005.