Towards development of a whole life costing based model for evaluation of building designs

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ABSTRACT

Frequently, procuring services is based on the notion that the least expensive technically compliant bidder is the most acceptable to the purchaser. The question today however is, "over the life of the facility, what is the comparative cost incurred?" Selection between different design and construction alternatives on the initial construction cost alone is insufficient. The research objective was to develop a Whole Life Costing (WLC) based software model for evaluating building designs of schools and health centres and to specifically; investigate the use of WLC in Uganda, develop the software model and test model performance to variances in certain pre-set parameters. Information received from respondents and theoretical analysis provided the background for the development of the software model and was tested with three classroom block designs. Respondents intimated that they performed WLC analyses within the last four years with the primary driver being the requirement from development agencies to have low Operation, Maintenance, and Replacement (OMR) cost designs. On average, 25% of projects undertaken involved generating design alternatives, with the preferred tool for value engineering being cost benefit analysis. However, due to value of money differentials being dependant on cash flow timing, net present value analysis was the tool for model design. The software model, WLC, is a trial version available at, http://applications.antsms.com/wlc. The benefits of utilising the model will be better management of OMR costs, improved professionalism at design stage and the development of a database that can be used in evaluation processes during procurement of works and services.

Keywords: Discounted Cash Flow; Evaluation Model; Net Present Value; OMR costs; Whole Life Costing

1.0 INTRODUCTION

The award of construction contracts based simply on the lowest capital cost bid is no longer recognised as good practice and best value for money must be taken into account (Kirkham *et al*. 2003). Recorded data of construction, refurbishment and maintenance costs of buildings in Germany show that over a 50 year period, the total costs amount to approximately twice the investment costs (without the financial costs) (Kohler *et al*. 2001). The ability to influence cost decreases continually as the project progresses, from 100% at project sanction to typically 20% or less by the time construction starts, furthermore, 80 – 90% of the cost of running, maintaining and repairing a building is determined at the design stage (Fabrycky and Blanchard, 1991). Office buildings will consume about three times the initial capital costs over a 25 year period, and yet more attention is paid to the initial capital cost (Flanagan and Jewell, 2005). It is a great concern that with rising operation and maintenance costs, there is no system incorporated in procurement of works and services in Uganda that seeks to minimise the OMR costs.

2.0 LITERATURE REVIEW

WLC is a tool used in engineering economics and management accounting to find the cost-wise best solution for an investment over the whole life span of a facility and to find the lowest WLC before design decisions are made (Royal Institution of Chartered Surveyor (RICS), 2003). The three key stages of the life of the facility dependant on time that need to be considered during the decision and procurement processes include; acquisition (including pre-construction and construction), OMR and disposal (sale or demolition). WLC can be conducted at any stage of the procurement of building works, services or goods. Its application at inception is most suitable so that in the final analysis the most economically suited design is selected from among alternative projects. Two costing methods have been identified in WLC implementation; systems costing and detailed costing (Kirk and Dell'Isola, 1995). System costing allocates funds to the various functional elements of a facility and allows the designer to make early cost comparisons among alternatives, while the detailed costing approach breaks down the facility into its constituent elements whose costs can be distinctly defined and put into a WLC-oriented Cost Break down Structure (CBS). The complexity and detail of the CBS depends on the scope and objectives of the WLC exercise. The application of WLC is however hindered by a lack of incentive on behalf of those responsible for construction to reduce the subsequent costs-in-use because the capital costs and operating expenditure are usually met by different parties (Bull, 1993). This is compounded with the difficulty in long term forecasting of factors such as life cycles, future operating and maintenance costs, and discount rates (Ferry and Flanagan, 1991). The RICS foundation (Kishk *et al*., 2005) broadly categorised barriers facing WLC implementation as; industry-related practices, client-related practices, analyst-related and analysis tools employed.

3.0 METHODOLOGY

This was applied research that proposed a process of evaluating viability of building projects in Uganda by analysing designs using a WLC based model. The main assumption in the methodology used for the model is that the buildings mentioned (schools and hospitals) are similar in more ways than just functional requirements and their design and construction costs, operating and maintenance costs can be determined during the design phase. The survey population composed of architects, building contractors, engineers and construction works procurement officials who participate in the design, construction and management of building facilities even after commissioning. This group composed of persons who advertently or inadvertently practice WLC during the course of their professional careers. The sampling frame comprised registered practitioners who were selected because they are mandated to practice and could influence change regarding WLC theory and application in construction management.

Selecting a sample that is representative of the population involved looking at the registers of each of the professional bodies. For a balanced view from all sections of practitioners, an equal size of sample units from each of three professional bodies was selected. The three professional bodies were the Uganda Society of Architects (USA), the Uganda National Association of Building and Civil Engineering Contractors (UNABCEC) and the Engineers Registration Board (ERB). Sample selection was done by determining the professional body with the least number of registered professionals and setting at least 10% of its members and selecting equal units from the other two bodies and 5 units comprising local government procurement officials. The USA had the least registered active practicing professionals, about 150 architects, and therefore, 15 units each were obtained from the three professional bodies. 5 units comprising local government officials were added to the already determined 45 units. This set the sample size to 50 respondents. A closed ended research questionnaire was adopted and information obtained partially enabled structuring of the software model being proposed for evaluation of building designs. The software model was developed with the assistance of a programmer who used Creative Suite 4 language by Adobe Systems. Initial tests and inputs to the model were from projects that had a component that catered for construction of classroom blocks and financed by the African Development Bank (ADB), European Union and Uganda Government.

4.0 ANALYSIS AND DISCUSSION

4.1 Profile of respondents

As mentioned, 50 respondents formed the research sample, however, a total of 32 respondents comprising architects, engineers, contractors, private developers and district health and education officers participated and filled in the questionnaire that was revised following pre-testing. This represents 64% of total intended sample size with the majority respondents, 41%, being engineers and minority respondents being district health and education officers. WLC was theoretically understood by the practising professionals but they agreed to a general lack of experience and exposure to its use in Uganda. 72% of the respondents said they begun implementing WLC studies and/or analyses within the last four years, with the majority of them being in the last two years. The primary driver for this present trend was the requirement from development partner agencies to have efficient low maintenance facilities that do not burden the tax payer. The respondents were also asked to review the percentage of projects they have been involved in where generation of design alternatives was considered or even undertaken, to which 72% said that on average, up to 25% of projects undertaken involved generating design alternatives. However, the majority being architects said that the main reason for generating design alternatives was assessing construction costs of designs produced for their clients. It was not for the purpose of determining possible OMR costs, which is why 78% of the projects in which the respondents were involved did not apply OMR cost implications to their design.

4.2 Review of WLC analysed projects

WLC analysis for public sector projects was conducted largely, (84% of projects identified), for institutional building facilities such as schools, hospitals and health centres, recreational centres such as buildings to parks. With regard to the private sector, WLC analysis was done to a below-average scale on both commercial (47%) and residential (41%) infrastructure. 59% prescribed a 20-year maximum for lifetime of educational buildings, while 56% prescribed the same for medical buildings. 50% of them chose CBA as the preferred tool for value engineering of buildings, 34% preferred NPV and 13% selected Discounted Cash Flow (DCF). However, because values of money differentials over time are dependent on timing of cash flows, two concepts are integral to understanding WLC; DCF and NPV. The design of the model has been based on NPV analysis. A majority of 63% of respondents intimated that lack of reliable and efficient information needed to undertake a WLC analysis was the most critical hindrance to application of WLC in design evaluation. Crucial data such as standard scale of fees applied by professionals, operation and maintenance costs of various categories of infrastructure and financial statistics such as escalation indices, are not easily accessible and are not authenticated by the official bodies. When asked what the major constraint was to WLC application in procurement and evaluation, 38% mentioned lack of accurate input data, while the majority, 72%, cited financial constraints within their establishments and from their employers.

4.3 Recommendations for improved WLC practice

When asked to suggest options for incorporating WLC analysis in the present procurement practices, approximately 72% recommended that all practising professionals carry it out and charge for it. The remaining 28% suggested that present public procurement regulations be amended to make it mandatory for practising professionals to use such analytical tools. Respondents were asked to determine, from seven factors, which goals are important for WLC studies. 62.5% mentioned extending the useful life as being very important, together with reduction in OMR costs. In an effort to have WLC considered in all facets of the building process, various factors were categorised into decision, component and operational factors. Decision based factors were; size of building facility, functional usage and ease of alterations or replacement of building facility components. Component based factors were; interior finishes, windows and doors, exterior finishes and/or roofing and structural elements of a facility. Operational based factors were; materials and equipments, better usage of utilities, OMR activities, energy optimization and disposal and/or deconstruction of building facilities. The majority of respondents preferred the application of WLC to operational based factors.

5.0 DISCUSSION ON WLC BETA VERSION SOFTWARE

5.1 The NPV formula for determining WLC

WLC beta version is a web-based software system developed to initially generate data on various public projects, which data will be stored online. The NPV formula in equation 1, is used for the determination of WLC.

$$NPV_i = C_{i0} + \sum {}^dO_{it} + \sum {}^dM_{it} - {}^dSAV_{iT} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where; C_{i0} = initial construction costs of alternative i

$\sum {}^dO_{it}$ = sum of discounted operation costs at time t

$\sum {}^dM_{it}$ = sum of discounted maintenance costs at time t

${}^dSAV_{iT}$ = discounted salvage value = ${}^dRV_{iT} - {}^dDC_{iT}$

${}^dRV_{iT}$ = discounted resale value at the end of the analysis period

${}^dDC_{iT}$ = discounted disposal costs

T = analysis period in years

i represents the alternative design under analysis and *d* denotes discounting.

5.2 Data input and processing

The detail tabulated below defines the parameters against which user input is captured.

STAGE A: ANALYSIS & INPUT OF PRE-CONSTRUCTION & CONSTRUCTION COSTS	

1. Capital costs	
a.) Land & related costs	b.) Statutory fees

2. Consultancy related costs	
a.) Design fees	c.) Modeling & Analysis costs
b.) Supervision fees	d.) Tender costs

3. Works execution costs (as per quantity surveyor's / cost engineer's bills of quantities)	
a.) Substructure	h.) Internal wall finishes
b.) Superstructure	i.) External wall finishes
c.) Roof construction	j.) Plumbing and drainage
d.) Windows	k.) Sanitary installations
e.) Doors	l.) Electrical installations
f.) Ceiling finishes	m.) Other items
g.) Floor finishes	

4. Site improvements	
a.) Road works and paving	c.) Fencing / boundary walling
b.) Landscaping	d.) Other items

5. Furniture, fittings and fittings (FFF)	
a.) Fixed FFF	c.) Other items
b.) Loose FFF	

STAGE B: DISCOUNTING POST CONSTRUCTION COSTS	

6. Building maintenance	
a.) Cleaning costs	c.) Re-installations costs
b.) Service maintenance	

7. Building repair and remodeling	
a.) Repair costs	c.) Service overhaul costs
b.) Remodeling costs	

STAGE C: BUDGETARY ALLOWANCES FOR UNDERLISTED ITEMS

8. Preliminaries and general items
9. Contingencies
10. Value Added Tax (VAT)
11. Other

Data capture and its eventual processing are done through sequential processes involving:

Step 1. Defining project details. For example, project name and description, proposed contractor, building facility life, applicable discount and value added tax (VAT) rates.

Step 2. Providing annual "Operations and Maintenance" and "Repair and Remodeling" costs based on the building life. These will be discounted by the system.
Step 3. Inputting the "Preconstruction" and "Construction" phase costs.
Step 4. Viewing final computation rendered by the system.

5.3 Logical flow of model

The logical flow of the model is as summarized in Figure 1 below.

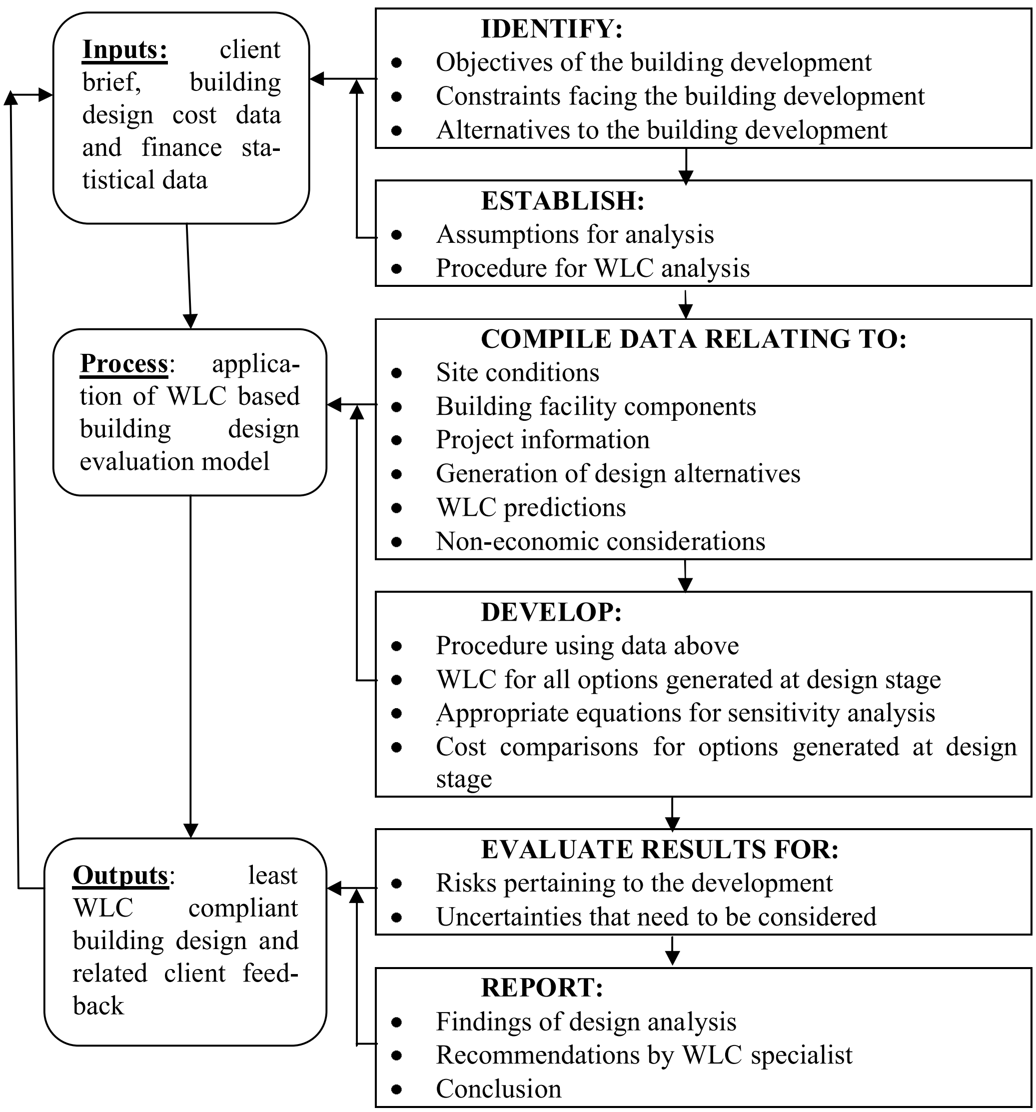
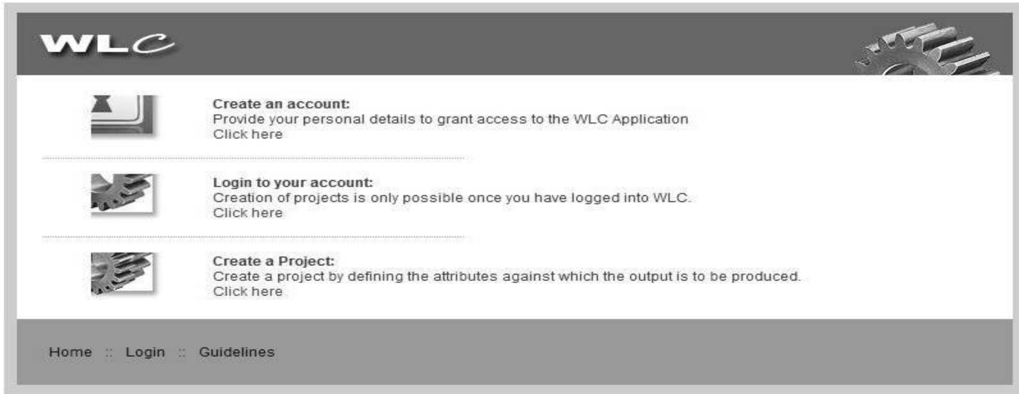


Figure 1: Logical flow of WLC based evaluation model

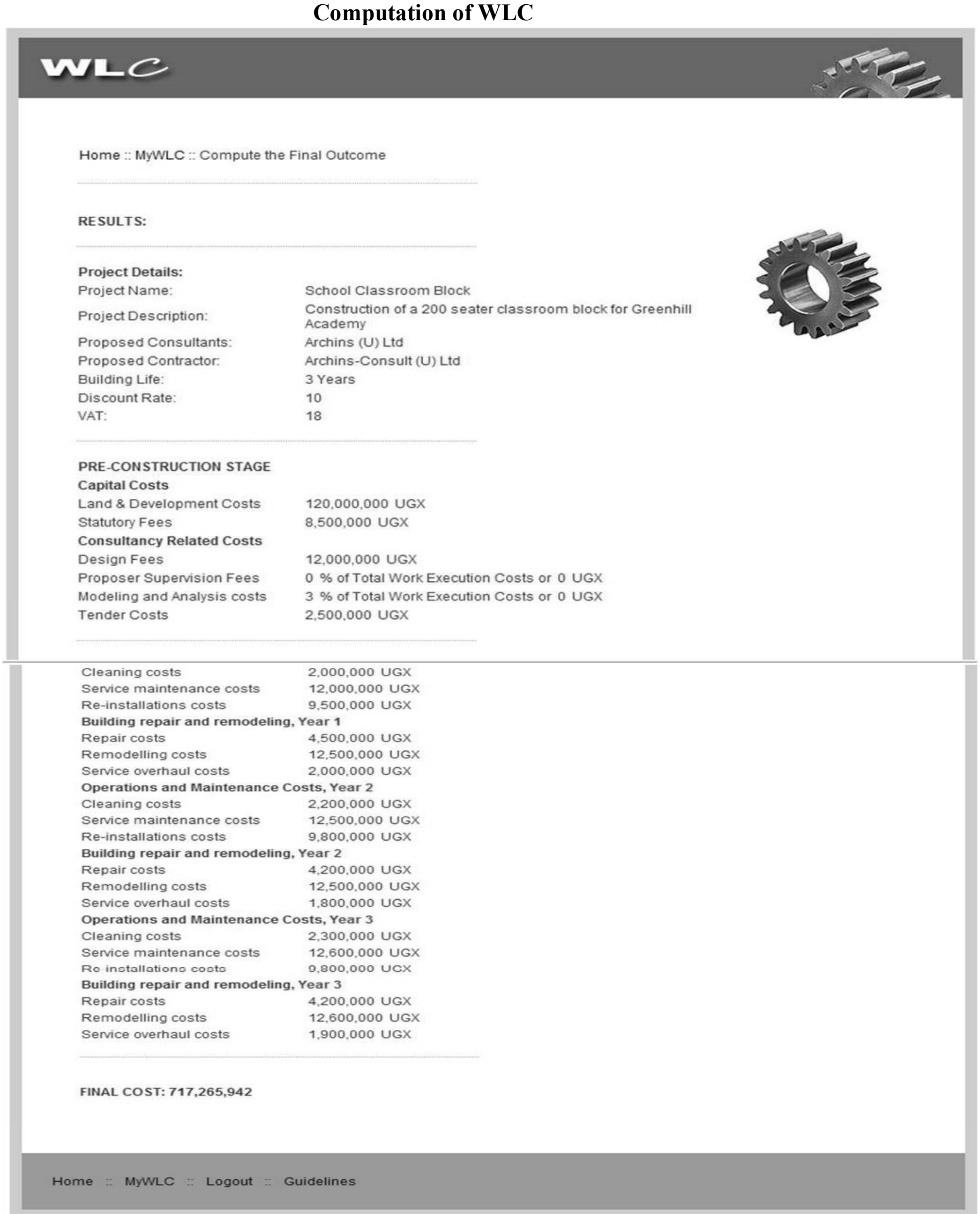
5.4 WLC screenshots

Screenshots of the WLC home and final computation pages are shown below. However, for more interaction with and improved visual display of the WLC beta version, please visit http://applications.antsms.com/wlc.

WLC Home Page



Computation of WLC



6.0 CONCLUSIONS AND RECOMMENDATIONS

The problem identified was the inability of building professionals to address concerns, such as OMR costs, in the evaluation of an appropriate design and design team and selection of a least WLC compliant contractor for building projects. In competitive environments, low initial construction costs tend to overshadow the importance of long-term savings. The result has been an abundance of low-cost, high-maintenance buildings. A major limitation to more widespread WLC use is lack of practitioners available in conjunction with limiting software related to input data and consistent methodology. WLC practitioners could be better educated in formal WLC as part of continuous professional development courses offered by professional associations. New WLC software tools are under constant improvement, and as advances are made, many of the constraints faced to more widespread practice might be lessened. As architects and engineers work together to integrate design and product decisions with these factors in mind, cumulative WLC savings can be achieved. The construction of a database to house crucial information of building systems would facilitate the implementation of WLC during the design stage. The database developed should be made available to the public through professional bodies/associations. The project database could then be utilised by another WLC management application to facilitate management of the building during the occupancy stage, which feedback would be beneficial in assessing the accuracy of estimates used at the evaluation stage. Future research would be helpful in examining the specific requirements of WLC practitioners regarding software applications, in order to reduce cost and time involved in performing WLC.

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