# A SIMPLIFIED MODEL FOR PREDICTING RUNNING COST OF OFFICE BUILDINGS IN SRI LANKA

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Usually, 80% of running costs of a building are influenced by 20% of initial costs. Therefore concerns for running cost need to begin at the outset of building design. A simplified model that could predict running cost from early project phase would facilitate design development and give due consideration to life cycle costing (LCC) accuracies. Historical data on running cost for office buildings are inconsistent in Sri Lanka and affect prediction accuracies. However the current research proposes a model using simple variables to facilitate the prediction of running cost of office buildings in Sri Lanka. The study uses a mixed method approach to collect data through eight semi-structured interviews and analyses of eight office building documents. The model developed was subsequently validated using another set of eight buildings. The analyses show that operation and maintenance cost account for 75% and 25% to total running cost respectively. Major operational cost comprise utility and administration, while maintenance comprise cleaning and building services. The model primarily depends on average floor area and number of floors. These parameters are responsible for over 98% of the model accuracy and could provide a speedy and accurate estimation of running cost for office buildings.

Keywords: life cycle, cost, modelling, forecasting, office buildings

## INTRODUCTION

The main motivation for Life Cycle Costing (LCC) is to increase the possibility of cost reductions during operation while spending a little more during planning and development stage (Dell'Isola & Kirk 2003). LCC consists of the estimation of initial cost of acquisition together with operation and maintenance costs to ensure clients the most value for their investments (British Standard Institution BSI 2008). Running costs as part of life cycle cost comprise the sum of maintenance and operating costs, which is experienced during the operational phase of buildings (Lai & Yik 2008). Often, emphasis is placed on keeping initial costs of buildings to a minimum with little consideration to any long cost implications. Kehily (2010) confirms that reduction in capital costs could lead to expensive maintenance, operation, and disposal costs in buildings and the building users are very often burdened with these costs. Tuhus-Dubrow and Krarti (2010) indicated that the running costs of commercial buildings in the USA (with 30 years estimated life and a discount rate of 5%) accounts for 66% of total life cycle costs while the remaining 34% is capital cost. In another

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situation, the life cycle cost is shared equally (50%) by capital and running costs (Tuhus-Dubrow & Krarti 2010).

Most recently, Goh and Sun (2015) conclude that commercial buildings consume higher running costs than residential, institutional and other industrial buildings. In Wang, Wei and Sun (2014) study, residential buildings came second with running costs accounting for 69% of total life cycle cost. Further, Kshirsagar, El-Gafy and Abdelhamid (2010) indicated that the running costs of institutional buildings fall within the range of 52 to 61%. For industrial buildings running costs vary between 40 to 54% (Gurung&Mahendran2002). However, Wong, Perera, and Eames (2010) study found that amongst commercial buildings, running cost for office buildings varies between 72 to 81% of total costs. It can be presumed that this difference of running cost might occur due to the assumed discount rates (4-10%) and life cycles (50-60 years) of the residential, industrial and office buildings. Nevertheless, the foregoing differences in running cost contribution drove to develop a mathematical model which can explicitly quantify the running cost of office buildings in Sri Lanka at the early stage.

Considering the previous works on developing mathematical models for prediction of life cycle cost or running cost, Langdon (2006) was of the opinion that parametric models with regression analysis play a vital role in predicting running cost. In the parametric method to life cycle cost estimating, the cost drivers are related to cost by costs estimating relationships through regression analysis. For example, Kirkham, Boussabaine, and Grew (1999) applied regression technique to model the energy cost of sport centres. In the regression models, the floor area and the number of users are two independent inputs. However, its application is limited to that particular cost component. By applying this model, energy cost of sports facilities can be calculated using only two variables, the building area and the number of users at the early stage of the sports facilities.

Moreover, Krstić and Marenjak (2012) argued that a large number of life cycle cost models have been developed with different cost classification systems. For example, Al-Hajj and Horner (1998) proposed a model which contains eleven elements of cost, which can predict the total running cost of buildings to an accuracy about 1.13%. Al-Hajj and Horner (1998) opine that LCC models need to cater for actual practices and requirements of buildings, ensure accuracy, ease of use and provide estimates from different levels of available data and information. However, the foregoing model is applicable at the running stage of buildings, where there are adequate historical running cost data are available. This kind of models therefore seems less accurate and restricted to a specific life cycle. The existence of many different costs data collection systems and many different types of equipment, devices, and systems limit the establishment of a simplified model for predicting running costs at the early stage.

In Sri Lanka, the operation and maintenance support costs are viewed within a limited range where energy cost is the primary concern. It is estimated that the energy cost is 20-60% of the annual operations and maintenance cost of office buildings (Weddikkara 2001). Similarly, electricity consumption in office buildings accounts for 20% of the total electricity consumption in Sri Lanka (Sri Lanka Sustainable Energy Authority SLSEA, 2014). Energy consumption of air conditioning systems accounts for more than 75% of electricity energy balance in typical buildings in Sri Lanka (SLSEA 2014). However, there seems to be lack of estimations for total running cost of office buildings in Sri Lanka. The lack of reliable and consistent data makes it impossible to establish running cost behaviour at the early stage of buildings. This research therefore analyses running cost of office buildings in Sri Lanka and develops a simplified regression model based on basic building parameters for predicting running cost. The study believes such an information could help to determine the optimum pay off between capital and running cost at the early stage of office building development in Sri Lanka.

## METHODOLOGY

The research was approached using mixed methods involving semi-structured interviews and document analysis. Eight office buildings were considered in both situations. The objective of the interviews was to determine the purpose of LCC, types of LCC data used, difficulties faced by the practitioners in determining LCC and strategies for overcoming those difficulties. Content analysis was used to analyse the interviewees' opinions. Subsequently running cost and physical data of eight buildings were collected from building information/documents. Information collected include: organization's annual reports, administrative expenditure budget records, and operating expenses reports. Standard cost categories suggested by Building Maintenance Cost Information Service (BMCIS) were modified using generic cost classification of life cycle cost introduced in BS ISO part 5 of British Standard Institution (BSI).

This was used to collect running cost data. The modified cost categories considered rent, utilities, insurance, administrative cost, and taxes and subsidies as elements of operational costs while decoration, fabric, services, cleaning, external works, and replacements of major components constitute maintenance costs. Physical data collected included: building floor area, height and number of floors. The running cost data was analysed using descriptive statistics to identify the contribution of running cost in office buildings. Regression analysis was performed in SPSS to find the relationship between running cost and building characteristics. As a first step in developing the regression model, the total running cost of each building was escalated at assumed inflation rate and then discounted for the base period. The analysis was carried out for 50 years as most of the selected buildings were estimated for 50 years of life span. The discount rate used was obtained from the Central Bank of Sri Lanka (6.5%). After the NPV calculation, a stepwise regression analysis was performed. Finally, another set of eight office buildings completed in different years were selected to verify the accuracy of the developed regression model.

## DATA ANALYSIS AND FINDINGS

As stated above, first part of the data collection involved interviewing professionals employed in the selected office buildings. One professional who engaged in operation and maintenance activities of the organization and practicing LCC was considered from each building. Table 1 presents the profile of the selected buildings and participants. As observed from Table, selected buildings represent different sectors: property development, banking, mixed development, finance, and administration and office. According to Table, 50% of interviewees are electrical engineers while 38% are from the mechanical engineering field. Only one participant is from the field of facilities management. In terms of these professionals' experience, 50% of participants have 10-20 years of experience while another equal percentage of 25% are in the age group of less than 10 years and more than 20 years.

## Use of LCC Approach in Office Buildings in Sri Lanka

The first part of the research explored: purposes of LCC, types of LCC data used, difficulties faced by practitioners in using LCC and strategies to overcome those difficulties. Participants indicated that the LCC is used occasionally in their organizations during operational phase of the buildings. However, the payback analysis was preferred over LCC.

*Table 1: Profile of Buildings and Participants*

| Building | Sector of the Industry | No of Floors | Floor Area (m2) | Life Span (Years) | Interviewee | Profession | Work Experience (Years) |
|---|---|---|---|---|---|---|---|
| B1 | Property development and management | 37 | 117054 | 50 | I01 | Electrical Engineering | 21-30 |
| B2 | Property development and management | 13 | 15400 | 50 | I07 | Electrical Engineering | 11-20 |
| B3 | Property development and management | 17 | 17651 | 50 | I08 | Mechanical Engineering | 21-30 |
| B4 | Banking | 23 | 46450 | 100 | I02 | Electrical Engineering | 11-20 |
| B5 | Banking | 32 | 53882 | 50 | I03 | Electrical Engineering | 11-20 |
| B6 | Mixed development | 34 | 48000 | 50 | I04 | Facilities Management | 1-10 |
| B7 | Institution in financial sector | 16 | 55740 | 50 | I05 | Mechanical Engineering | 11-20 |
| B8 | Customs administration | 13 | 17000 | 50 | I06 | Mechanical Engineering | 1-10 |

Participants further indicated that engineering, maintenance, procurement and finance departments use LCC more while other departments such as housekeeping, human resource and administration use it to a limited scale. There is no evidence of the usage of the LCC during design phase of office buildings, despite world trend to use LCC at the design stage. Table 2 presents the summary of views of participants on questions asked.

On the purpose for which LCC is used in participants' organizations, majority (62.5%) stated that LCC is used to select the best option among competing systems or suppliers of goods and services. Another 37.5% opined that the LCC is used to determine the affordability of major capital expenditure with significant operation and maintenance costs while 25% of interviewees used LCC for valuation.

In terms of availability and maintenance of LCC data, all participants indicated that they maintain operation and maintenance costs data of their buildings. Two of the interviewees (25%) stated that an asset registry integrated with operation and maintenance costs data is maintained by their organizations while energy databases and capital asset management systems are other ways of maintaining LCC data in organizations according to I01 and I04 respectively.

On difficulties faced in the use of LCC. All interviewees indicate that lack of accurate and inconsistent data and inconvenience involved in collecting historical data are the main difficulties faced by practitioners. A few of the participants indicated that unpredictability of the cost variables (37.5%) and lack of universal methods and standard formats for maintaining life cycle cost data (25%) are other difficulties for the LCC use. Finally, participants were further questioned to identify the strategies to overcome these difficulties. Majority (87.5%) of the interviews suggested that the conduct of awareness programs on knowledge and significance of LCC through case studies and success stories. Another set of interviewees (62.5%) suggest providing knowledge on LCC variables that calculations, account depreciation and costing. 37.5% of interviewees was of the opinion that maintaining running cost databases could overcome difficulties. 25% of participants suggest the acquisition of quality data for the LCC analysis and improvement of the databases. Only one interviewee (12.5%) mentioned the integration of LCC analysis into procurement procedures.

*Table 2: Practice and Use of LCC*

| Aspects of LCC | Interviewees' opinion | Source | Frequency |
|---|---|---|---|
| Purposes of LCC | Alternative evaluation | I01, I02, I03, I04, and I05 | 62.5% |
| | Affordability | I06, I07 and I08 | 37.5% |
| | Building valuation and revaluation | I05 and I08 | 25% |
| Data for LCC | Operation and maintenance costs data | I01, I02, I03, I04, I05, I06, I07 and I08 | 100% |
| | Asset registry integrated with costs data | I01 and I04 | 25% |
| | Energy databases | I01 | 12.5% |
| | Capital asset management systems | I04 | 12.5% |
| Difficulties faced by the practitioners when using LCC approach | Lack of accurate and consistent data | I01, I02, I03, I04, I05, I06, I07 and I08 | 100% |
| | Inconvenience involved in collecting historical data | I01, I02, I03, I04, I05, I06, I07 and I08 | 100% |
| | Unpredictability of cost variables | I01, I03 and I07 | 37.5% |
| | Lack of universal methods and standard formats for maintaining life cycle cost data | I01 and 105 | 25% |
| Strategies to overcome difficulties | Awareness programs on LCC knowledge and significance of LCC by case studies and success stories | I01, I02, I04, I05, I06, I07, and I08 | 87.5% |
| | Knowledge on LCC variables affecting for calculations, account depreciation and costing | I01, I02, I03, I07 and I08 | 62.5% |
| | Maintaining running cost databases in organization | I02, I07, and I08 | 37.5% |
| | Acquisition of information from regent vendors, manufacturers, and service providers | I01 and I03 | 25% |
| | Use of in-house operation and maintenance data | I01 and I06 | 25% |
| | Acquisition of data from similar industries | I01 and I06 | 25% |
| | Defining reference projects by responsible parties | I07 and I08 | 25% |
| | Implementing and maintaining CMMS | I05 and I04 | 25% |
| | Integrate LCC analysis into procurement procedures | I05 | 12.5% |

The foregoing analyses indicate that most of the organizations (5 out of 8) use LCC among competing alternatives. Yet, lack of accurate and consistent data and the inconvenience involved in collecting historical data of the buildings are major concerns. The various strategies should be implemented to mitigate the difficulties faced by the practitioners when using LCC approach in the context of Sri Lanka.

## Analysis of Running Cost of Office Buildings in Sri Lanka

The running cost of office buildings was analysed according to standard cost classification systems of BMCIS and BSI. The components of running cost is slightly deviated from the BSI system where rental is not part of the operational cost as most of the office buildings are occupied by the owner or managed by the developer. The rental forms part of their income. The BMCIS system divides maintenance cost into decoration, fabric, building services, cleaning, and external works. Similarly, the maintenance cost of office buildings in Sri Lanka differs from BMCIS elements. The cost of decorating and fabric maintenance is categorized under general building maintenance of office buildings in Sri Lanka.

A significant difference was observed between maximum and minimum values of running cost of selected buildings. Hence, it was not accurate if considered the mean value of the sample to analyse the running cost of office buildings in Sri Lanka. Thus, the median value of the sample is considered. The difference between the median and the actual running cost of each building was calculated and considered to select the best samples to illustrate the composition of running cost. Table 3 represents the deviation (%) of running cost of each building with respect to median cost.

*Table 3: Deviation of Running cost of Each Building with Respect to Median Cost*

| Building | Actual Running cost (LKR) | Median Value (LKR) | Median - Actual | Difference % | Category |
|---|---|---|---|---|---|
| B4 | 353,125,841.00 | 378,280,222.00 | 25,154,381.00 | 7 | Category 1 |
| B5 | 403,434,602.00 | 378,280,222.00 | -25,154,380.00 | -7 | |
| B6 | 434,450,822.00 | 378,280,222.00 | -56,170,600.00 | -15 | |
| B2 | 96,164,244.00 | 378,280,222.00 | 282,115,978.00 | 75 | Category 2 |
| B3 | 119,448,300.00 | 378,280,222.00 | 258,831,922.00 | 68 | |
| B8 | 116,542,177.00 | 378,280,222.00 | 261,738,045.00 | 69 | |
| B1 | 833,246,551.00 | 378,280,222.00 | -454,966,329.00 | -120 | Category 3 |
| B7 | 722,973,123.00 | 378,280,222.00 | -344,692,901.00 | -91 | |

As observed from table 3, that there are three different ranges of cost deviations found among selected buildings. The running cost deviation of B4, B5 and B6 ranges around ±10% on average, while the deviation of B2, B3, and B8 ranges between 65 - 75%. The buildings B1 and B7 indicated a very high deviation compared to running cost of other buildings and ranges around -100% on average. Further, physical characteristics of the selected buildings are considered, B1 consists of highest number of floors and largest gross floor area (table 1) amongst selected buildings. Therefore B4, B5 and B6 (category 1), and B2, B3, and B8 (category 2) were considered for further analysis while B1 and B7 belong to category 3 were eliminated from the analysis due to major deviations. Table 4 indicates the composition of running cost for the mean value of selected two categories of office buildings.

According to Table 4, the running cost mainly consists of operational and maintenance costs. For both categories of buildings, the % contribution of operational and maintenance costs to the running cost is equal, 75% and 25% respectively. In both categories of building, utilities and administrative cost are highly contributing elements to the total running cost with nearly 30-40% contribution. Amongst the utility cost, the electricity cost consumes higher proportion than the other energy costs such as fuel, gas, and water. The administrative cost on the other hand, includes a higher proportion of staff cost than the other administrative costs such as property management, sundries, porterage, and waste disposal costs. The cleaning is another cost component which contributes nearly 10% to running cost in both categories of buildings. In both buildings, the general building maintenance and building services together are responsible for nearly 15% of total running cost.

*Table 4: Contribution of Each Element to the Running cost*

| Element | Category 1 | | Category 2 | |
|---|---|---|---|---|
| | Mean Value LKR | Contribution to Running cost % | Mean Value LKR | Contribution to Running cost % |
| Running cost | 397,003,755 | 100.00 | 110,718,240 | 100.00 |
| 1 Operation Cost | 296,590,098 | 74.71 | 82,623,354 | 74.62 |
| Insurance cost | 4,255,343 | 1.07 | 1,661,413 | 1.50 |
| Utilities | 115,007,740 | 28.97 | 42,273,008 | 38.18 |
| Administrative cost | 114,587,513 | 28.86 | 38,117,559 | 34.43 |
| Taxes and Subsidies | 62,739,502 | 15.80 | 6,197,041 | 5.60 |
| 2 Maintenance Cost | 100,413,657 | 25.29 | 28,094,886 | 25.38 |
| General Building Maintenance | 24,383,333 | 6.14 | 9,866,265 | 8.91 |
| Building Services | 32,506,575 | 8.19 | 6,756,218 | 6.10 |
| Cleaning | 42,671,016 | 10.75 | 10,857,509 | 9.81 |
| External Works | 852,733 | 0.21 | 614,894 | 0.56 |

## Simplified Model for Predicting Running Cost of Office Buildings in Sri Lanka

Initially the regression model was fixed with selected independent variables such as gross floor area, no of floors, average floor area, building height, average storey height, electric power demand, cooling capacity, and water demand and dependent variable, running cost. All the independent variables indicated a positive linear relationship with the dependent except the average story height, which was more towards to a non-linear relationship. Therefore, without further transformation of the independent variables, the stepwise multiple regression analysis was performed. Accordingly, the regression analysis offered two models and the Table 5 represents the coefficients of the two regression models.

*Table 5: Coefficients of the Regression Model*

| Model | | Un-standardized Coefficients | | Standardized Coefficients | Collinearity Statistics | |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | Tolerance | VIF |
| 1 | (Constant) | -2128539441 | 1491968284 | | | |
| | Average Floor Area | 4078359.034 | 710830.151 | 0.920 | 1.000 | 1.000 |
| 2 | (Constant) | -4964009161 | 648774047.6 | | | |
| | Average Floor Area | 3607150.063 | 249055.810 | 0.813 | 0.925 | 1.081 |
| | No of Floors | 161567613 | 23361898.36 | 0.388 | 0.925 | 1.081 |

According to collinearity statistics shown in Table 5, the tolerances are large and the Variance Inflation Factor (VIF) is considerably low. This evidences the non-existence of multicollinearity. However, there is no formal criterion for determining the bottom line of the tolerance value or VIF. A tolerance value of less than 0.1 or VIF greater than 10 generally indicates a significant multicollinearity (Chatterjee & Hadi 2012). The commonly used measure of the goodness of fit of a linear model is R2 (the coefficient of determination) which ranges between 0-1. The best model is identified by its highest adjusted R2. Table 6 provides the statistics of the two models for predicting the running cost. Among the two models, the model with the highest R2 is selected as the best fit model. According to the R2 of the model, the goodness of fit of the model is over 98%.

*Table 6: Summary of Model*

| Model | R | R2 | Adjusted R2 | Standard Error of the Estimate | Change Statistics | | |
|---|---|---|---|---|---|---|---|
| | | | | | R2 Change | F change | Sig. F Change |
| 1 | 0.920 | 0.846 | 0.820 | 1742400153 | 0.846 | 32.918 | 0.001 |
| 2 | 0.993 | 0.985 | 0.980 | 587201089.6 | 0.140 | 47.829 | 0.001 |

Based on the statistics, the running cost of office buildings is represented by:

Running cost = -4964009161+ 3607150.063*(Average Floor Area) + 161567613*(No of Floors)

The selected independent variables directly contribute to the running cost of office buildings and according to predictors of the model, the running cost of office buildings can be predicted to make informed decisions at the building acquisition stage.

## VALIDATION

The above model was validated with a set of equal number of buildings of the sample size used to develop the model. The results of the validation exercise are given in Table 7.

*Table 7: Validation of the Developed Model*

| Building Number | Actual cost (LKR) | Predicted cost (LKR) | Difference | Accuracy (%) |
|---|---|---|---|---|
| 1 | 1,189,158,069.52 | 1,236,797,641.82 | 47,639,572.30 | 4.01 |
| 2 | 1,606,666,073.03 | 1,543,141,309.00 | (63,524,764.03) | -3.95 |
| 3 | 6,290,814,282.27 | 6,624,397,792.29 | 433,583,510.01 | 5.30 |
| 4 | 2,485,690,132.00 | 2,615,121,376.73 | 129,431,244.73 | 5.21 |
| 5 | 5,241,438,949.96 | 5,358,136,753.81 | 316,697,803.85 | 2.23 |
| 6 | 1,883,131,797.39 | 1,788,784,866.66 | (94,346,930.72) | -5.01 |
| 7 | 6,936,920,738.37 | 7,033,400,654.77 | 96,479,916.40 | 1.39 |
| 8 | 8,023,889,819.69 | 7,972,043,159.28 | (51,846,660.41) | -0.65 |
| | | | Mean Value of Accuracy % | 1.07 |
| | | | Standard Deviation of Accuracy % | 3.97 |

The validation of the model is established based on the difference between actual cost and predicted cost, and the level of accuracy. The closer the value of accuracy is to zero, the more accurate is the model. The results demonstrate that the accuracy of the predicted running cost values ranges between -/+5 % of office buildings in Sri Lanka. The mean value of accuracy is 1.07%, while the standard deviation of accuracy is 3.97%. The validation considers the mean value of accuracy rather than the mean absolute value of accuracy. Because the mean absolute value do not lend themselves to further mathematical manipulation.

## DISCUSSION AND CONCLUSIONS

As researchers suggest, the LCC is traditionally used for various purposes such as alternative evaluation, affordability, repair level analysis, warranty and repair costs, design trade-offs, and suppliers' sales strategies(Barringer & Weber 1996; Dell'Isola & Kirk 2003; Langdon 2006). However, this research indicated that the LCC is used for selecting alternatives and determining affordability in Sri Lankan office buildings. In line with the view of Gluch and Baumann (2004) that the lack of reliable and consistent data limits the application of LCC in the building sector at the early stage of buildings, authors found that availability of accurate and consistent cost data and inconvenience involved in collecting historical data of the buildings are identified as the major difficulties faced by the LCC practitioners in office buildings. In order to address the above concerns, the research proposed a simplified model which is based basic on building parameters for predicting running cost of LCC in Sri Lanka. As Krstić and Marenjak (2012) suggest, although the data used to develop the model can be very preliminary and marginally accurate, yet the model is very helpful for focusing designers on the areas of higher costs at the design development stages. The mean value of accuracy of the developed model for predicting running cost of office buildings in Sri Lanka is much improved compared to the mean value of accuracy (1.13%) reported by Al-Hajj and Horner (1998) in their general running cost model.

Moreover, Al-Hajj and Horner (1998) determined the precision of their model by the scatter of the individual accuracies which represented by the standard deviation of accuracy. However, the standard deviation of accuracy of the developed model by this research is increased compared to the standard deviation (3.70%) reported by Al-Hajj and Horner (1998).For large building projects, the consideration of LCC needs to be given at the outset of design phase and continued throughout design. At this stage all the significant cost elements or the main characteristics of the project should be examined to determine the optimal savings on costs with a reasonable expenditure of LCC efforts. Thus, the research also analysed the contributing elements for running cost of the office buildings in Sri Lanka. The cost categorizations used are in line with BSI and BMCIS standards. Accordingly, the main cost elements of the office buildings include insurance, utilities, administrative, taxes and subsidies, general building maintenance, building services maintenance, cleaning, and external works. As per the analysis, the contribution of utility and administrative cost vary between 30% - 40%, while taxes and subsidies, cost for the cleaning, building services maintenance, and general building maintenance vary from 5% - 15%. The study therefore concludes that this proposed simplified model together with the knowledge on composition of running cost could enable the prediction of running cost and thereby ensure the effective use of LCC in the industry.

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