A MODEL FOR EARLY STAGE ESTIMATION OF OPERATIONAL EXPENSES (OPEX) IN COMMERCIAL BUILDINGS

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Usually, Operational Expenses (OPEX) consume a substantial share (70-80%) of Life Cycle Cost (LCC) of commercial buildings. Despite its contribution to the LCC structure, often OPEX is given less focus in investment decision making and investors tend to mostly rely on initial cost alone. This is due to lack of reliable historical cost data related to building operations and maintenance. In addition, a varying range of models are available and application of those are limited to the later stage of building life cycle as these models require an extensive set of operational cost data. Therefore, this study introduces a model, which can facilitate the early stage estimation of OPEX in commercial buildings together with OPEX indices for commercial buildings in Sri Lanka. The data related to OPEX and building characteristics were collected from 35 commercial buildings in Sri Lanka. The hedonic regression model developed indicates that 94.6% of variance in the annual OPEX/sq. ft. in commercial buildings could be expressed by working days/week, working hours/day, gross internal floor area, building height, and the number of occupants. These findings would enable an investor to optimise the OPEX by controlling the impact of physical characteristics in commercial buildings. Further, the developed indices will be beneficial for industry practitioners in measuring relative changes in OPEX in commercial buildings over a period of time.

Keywords: cost modelling, hedonic regression, indices, OPEX

INTRODUCTION

It is often said that when the design of a building is finished, although only a 10 to 15% of the total cost has been spent, 80% of the cost has been committed (Kehily 2010). Green (2009) asserts that local marketers will increasingly demand buildings with low operating costs, driving demand for tools and techniques that model a building's operating costs and incorporate and budget for building Life Cycle Cost (LCC). LCC perspective has proved to be most meaningful during the design phase, where the possibilities of cutting down the costs related to operations and maintenance (O&M) are large (Sterner 2000). The mathematical LCC models generally aid design-team decision making in conjunction with analyses of alternatives at the initial stages (Al-Hajj and Horner 1998). Early implementation of cost estimation models is

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therefore essential as it provides explanations of the relationships between cost and design parameters (Durairaj *et al*., 2002). Those models further contribute to cost reduction by identifying high-cost contributors. However, cost estimation during the design phase is not an easy task as there is no adequate cost and building performance data, particularly, which is available during the operational phase. Thus, the application of cost estimation methods and models developed to date are underutilized due to a number of documented barriers to adoption in terms of the quality and availability of data. Notably, these include the use of limited cost data, use of historical cost records maintained based on an available cost structure rather than on the standards cost structure, and absence of data normalisation (Kirkham 2002; Opoku 2013; Krstić and Marenjak 2017). Krstić and Marenjak (2017) further opined that the application of cost-based models is limited to the later stage of building life cycle and ignore some important cost determinants such as building age, location, and number of occupants. For instance, the cost models developed by Kirkham *et al*., (2002) and El-Haram *et al*., (2002) are purely based on cost components and ignore significant factors affecting LCC of buildings particularly, building characteristics (El-haram and Horner 2002; Ungar 2003; Kerama 2013; Perera *et al*., 2016).

Commercial buildings consume higher running cost than residential, institutional and industrial buildings (Lai and Yik 2008; Goh and Sun 2015). Amongst commercial buildings, running cost of an office building varies between 72 to 81% of its total LCC (Wong *et al*., 2010). Similarly, in Wang *et al*., (2014) study, commercial buildings came first with running costs accounting for over 69% of total LCC. Further, the comparison of U.S. private-sector office building OPEX figures indicates a 35% of increase in OPEX from 2009 to 2016 (Building Owners and Managers Association [BOMA] International 2016). Given the dramatic increase in running cost of commercial buildings and limited application of existing LCC estimation models, this research develops an early stage supportive cost estimation model for OPEX in commercial buildings. The developed model uses a wide set of operational and maintenance cost factors, which are known at the early stage of buildings life cycle. A detailed discussion on how the developed model addressed aforementioned limitations is provided in the research methods section of the paper. The study therefore believes such information could help both building constructors and owners to make informed cost decisions over properties.

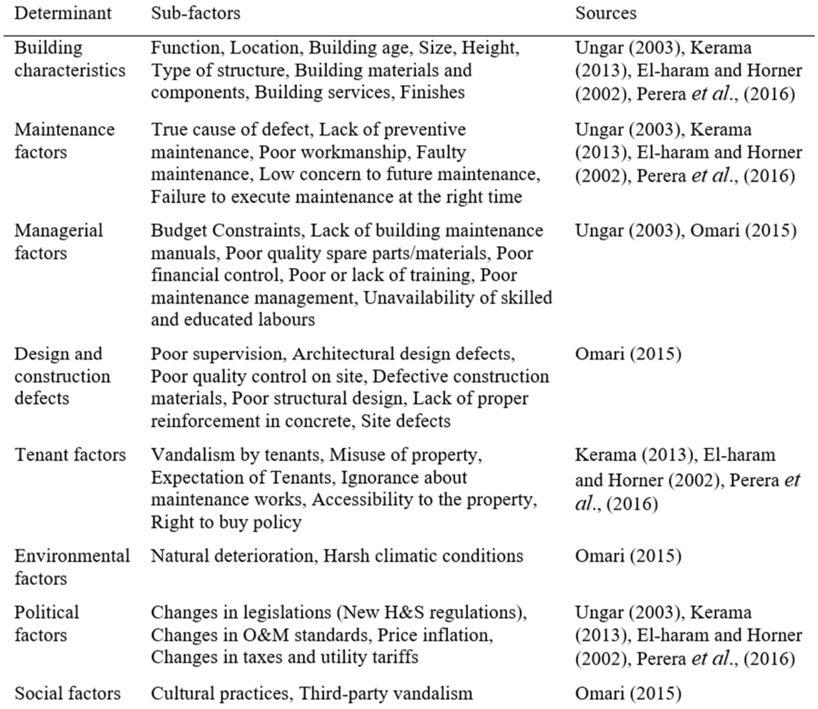
Further, having an index for OPEX allows building developers and owners to monitor changes in the general level of operating costs of commercial building ownership. The academic research published in this arena has primarily focused on models to forecast or predict changes in the general construction price level. Despite several standards and guidelines, i.e. British Standard International Organization for Standardization (BS ISO) 15686-5:2008 standards and RICS new rules of measurement: NRM 3, which provide consistent rules for the quantification and measurement of building maintenance work items, very few studies have taken effort to develop indices for OPEX in buildings. For instance, the New York City Rent Guidelines Board (2017) developed a Price Index of Operating Costs (PIOC), which measures changes in the cost of goods and services used in the O&M of apartment buildings in New York City. Similarly, the BCIS has developed online running cost indices, which provide a central location for those who involved in the O&M of buildings. Goh (2016) designed a whole life building cost index for non-residential green-rated buildings in Singapore. Besides, none of these indices was compiled to provide an indication on the trend of OPEX incurred by buildings based in developing countries like Sri Lanka as there is a huge difference in terms of economy, environment, and social aspects with compared to developed states, which can affect OPEX of commercial buildings. That emphasises the need for regional/locational cost indices and with that motivation, this study further extends to develop OPEX indices for the commercial building sector in Sri Lanka. Accordingly, the information provided by indices can be particularly useful to commercial developers in helping them to capture the price movement of the most significant running cost components of buildings which the existing models and indices fail to measure.

LITERATURE REVIEW

Factors Influencing OPEX in Buildings

The factors influencing OPEX in buildings have widely been discussed under eight broad categories: building characteristics, maintenance factors, managerial factors, design& construction defects, tenant factors, environmental factors, political factors, and social factors as illustrated in Table 1.

Table 1: Factors influencing OPEX in buildings



Determinant	Sub-factors	Sources
Building characteristics	Function, Location, Building age, Size, Height, Type of structure, Building materials and components, Building services, Finishes	Ungar (2003), Kerama (2013), El-haram and Horner (2002), Perera *et al*., (2016)
Maintenance factors	True cause of defect, Lack of preventive maintenance, Poor workmanship, Faulty maintenance, Low concern to future maintenance, Failure to execute maintenance at the right time	Ungar (2003), Kerama (2013), El-haram and Horner (2002), Perera *et al*., (2016)
Managerial factors	Budget Constraints, Lack of building maintenance manuals, Poor quality spare parts/materials, Poor financial control, Poor or lack of training, Poor maintenance management, Unavailability of skilled and educated labours	Ungar (2003), Omari (2015)
Design and construction defects	Poor supervision, Architectural design defects, Poor quality control on site, Defective construction materials, Poor structural design, Lack of proper reinforcement in concrete, Site defects	Omari (2015)
Tenant factors	Vandalism by tenants, Misuse of property, Expectation of Tenants, Ignorance about maintenance works, Accessibility to the property, Right to buy policy	Kerama (2013), El-haram and Horner (2002), Perera *et al*., (2016)
Environmental factors	Natural deterioration, Harsh climatic conditions	Omari (2015)
Political factors	Changes in legislations (New H&S regulations), Changes in O&M standards, Price inflation, Changes in taxes and utility tariffs	Ungar (2003), Kerama (2013), El-haram and Horner (2002), Perera *et al*., (2016)
Social factors	Cultural practices, Third-party vandalism	Omari (2015)

Amongst, literature mostly highlights the effects of building characteristics and tenant factors on OPEX. For example, age of the building is one of the essential elements, which influences the maintenance budget (El-Haram and Horner 2002) as older buildings would invariably require additional maintenance work. Similarly, Shabha (2003) discussed how poor building finishes can cause deterioration or defects in building components resulting in a high maintenance cost for repairing or replacing such components. Further, being one of the building characteristics, building services contributed to 20 to 45% of the total running cost (Ali *et al*., 2010). Authors further stressed that improper material selection over the life of a facility or a building component is one of the dominant factors affecting condominium O&M costs. Refereeing to tenant factors, the demand made by tenants for a better lifestyle or a living environment results in increased maintenance. El-Haram and Horner (2002) too identified ‘use of the property’ as a prominent determinant of condominium running costs due to the unavailability of property operating manuals and proper tenant education about the condominium living environment. Authors further stated that inability to gain access to the property due to privacy or cultural reasons is one of the major factors that affect condominium maintenance costs. Further, early response to building failure would be necessary in order to reduce maintenance costs (Perera *et al.*, 2016).

Existing parametric models for life cycle cost estimation of buildings

Throughout the years numerous LCC models have been generated which are based on either cost or building characteristics. For example, Al-Hajj and Horner (1998) have presented a running costs model for institutional buildings, with eleven cost elements and to an accuracy of 1.13%. Similarly, Kirkham *et al.*, (1999) have developed an energy cost model for sports centres, which based building characteristics such as the number of users and floor area. Subsequently, Kirkham *et al.*, (2002) and El-Haram *et al.*, (2002) have developed WLCC models for hospital buildings where cost components such as facilities management costs, energy costs, maintenance costs, residual costs, and discount rate were determinants of WLCC. However, Dhillon (2010) explained that there is still plenty of reasons for not having a commonly accepted model, including user preference, the presence of various systems of cost data gathering, and many different types of equipment, appliance, or systems. And also, the application of Kirkham *et al.*, (2002), El-Haram *et al.*, (2002), and Al-Hajj and Horner (1998) models are restricted to the later stage of building life cycle as those are based on historical cost records. Further, Krstić and Marenjak (2017) argued that these models are usually not based on adequate historical cost records and based the available cost structure, rather than standard cost structure. Authors further indicated that models developed so far ignore some important factors such as the age, location, level of occupancy, and standards of operation (Krstić and Marenjak 2017).

To this end, there is no simple model for predicting OPEX based on building attributes, operational arrangement and user characteristics (Krstić and Marenjak, 2017). Parametric cost estimation approach is preferred in most of the situations as it essentially correlates cost and product/system parameters describing the items to be costed (Kirkham, 2002; Caplehorn, 2012). However, the application of purely parametric cost estimation methods is limited due to lack of reliable historical cost data and building characteristics, which have a direct influence on its LCC. Giving the limitations of existing models and the limited application of parametric models, the current study introduces a reliable and simple model for estimating OPEX at the early stage of commercial buildings. The study further develops an index, which enables to obtain the changes in OPEX of commercial buildings over the time and predict the future trend.

RESEARCH METHODS

The research was primarily approached quantitatively to develop an early stage supportive OPEX estimation model together with cost indices for OPEX in commercial buildings. The documents including architectural drawings, bills of quantities, historical cost records, and monthly utility bills were reviewed to collect the required data from 35 commercial buildings in Sri Lanka. Generally, a sample size of more than 30 at 5% confidence level is sufficient for many types of research (Altunışık *et al.*, 2004).

A summary profile of selected buildings is presented in Table 2.

Table 2: A summary profile of selected buildings

Function	No.	(%)	No. of floors	No.	(%)
Office	17	49%	3 to 12	22	63%
Bank	13	37%	13 to 25	09	26%
Institution	03	9%	above 25	04	11%
Retails	01	3%			
Multi-purpose	01	3%			
Total	35	100%	Total	35	100%

As shown in Table 2, commercial buildings selected for the study consists of 49% of office buildings and 37% of banks while remaining include educational institutes, retails, and multi-purpose (i.e. hotel + apartment) buildings. Further, a majority of the selected buildings (63%) consists of three to twelve floors while remaining 26% and 11% are thirteen to twenty-five and above twenty-five storied buildings respectively.

Although the review of the literature identified a list of factors, which influence the LCC of buildings, this study has collected data related to thirteen (13) building characteristics, which are quantitative in nature and convertible (nominal data). Further, the OPEX data was collected in accordance with the standards of BCIS, BS ISO 15686-5:2008 standard, and NRM3, for three consecutive financial years: 2014, 2015, and 2016.

Basic data analysis tool employed within the study is statistical analysis tool of SPSS 22. Firstly, the missing data within the collected dataset were imputed with the aid of 'Multiple imputation' analysis technique. Multiple imputation is a simulation-based procedure and its purpose is to handle missing data in a way resulting in valid statistical inference to minimize compromising the validity and reliability of the output due to unavailability of data (Field 2009). Most importantly, the dependent variable: total OPEX were normalised dividing by the Gross Internal Floor Area (GIFA) of respective buildings. Second, both the dependant and independent variables were analysed to check the assumptions that need to be satisfied to run a multiple linear regression analysis as recommended by Field (2009). Subsequently, the hedonic regression modelling was used to develop the cost model as it presents OPEX of the property as a function of its structural and location characteristics where there is no adequate cost data. This approach has been used over the years in economic studies including Feenstra and Diewert (2001), Hill and Melser (2008), and Forenbacher and Husnjak (2016) but not evident in building cost estimation.

Finally, the hedonic price imputation approach along with the Fisher's index was employed for the imputation of OPEX indices. A number of index number formulae are recommended but a good overall choice appears to be the Fisher ideal index since this index can be justified from several different perspectives (Hill and Melser 2008). The Fisher index is the geometric mean of the Laspeyres and Paasche indices, thus eliminates drawbacks of these two key index methods (CPI Manual 2004). Further, Fisher's index is the ideal to be replaced by the hedonic price imputation approach and the combination of these two methods has been used over years, for example, in studies of Ball and Allen (2003) and Yu and Ive (2008).

DATA ANALYSIS AND FINDINGS

An early-stage model for estimating OPEX in commercial buildings

In order to proceed with the multiple linear regression analysis, there is a set of assumptions to be satisfied. Firstly, both dependent and independent variables should be the continuous form of data. In this study, the dependent variable, which is OPEX/sq. ft. and independent variables including working days/week, working hours/day, building age, GIFA, net floor area, circulation area, height, number of floors, window area, Window-to-Floor-Ratio, and number of occupants are scale data. In addition, two dummy variables namely, the grouping of buildings (1=Detached, 2=Attached), and type of structure (1=Steel frame, 2=Concrete, 3=Pre-cast panels) were added to the analysis to represent the nominal data collected. Therefore, satisfied the first assumption.

Next, the Shapiro-Wilk normality test was conducted to explore the normal distribution of residual values. As observed from Table 3, the significance of the standardized residual (ZRESI) is greater than 0.5 indicates that the ZRESI is normally distributed (Field 2009).

Table 3: Test of normality: Shapiro-Wilk

	Statistic	df	Sig.
Standardized Residual	0.954	30	0.211

Finally, a stepwise multiple linear regression analysis was run on the data collected and the analysis offered six regression models. Table 4 provides a summary of the models computed for estimating OPEX in commercial buildings.

Table 4: Summary of models

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.980a	.960	.935	790.28674	
2	.980b	.960	.939	767.20236	
3	.979c	.959	.941	751.77357	
4	.979d	.959	.944	735.93866	
5	.979e	.958	.946	724.10709	
6	.978f	.957	.946	719.88679	
7	.977g	.954	.945	725.32214	2.233

According to the Durbin-Watson statistic (2.233) shown in the table, errors of all estimates are independent of the dependent variable as the rule of thumb is that test statistic values in the range of 1.5 to 2.5 are relatively normal (Field, 2009). Subsequently, among these six models, the best fit model was identified considering the highest adjusted coefficient of determination (R2), as it is more accurate than the R2 and this ranges between 0 and -1. Although both fifth and sixth models yield the highest adjusted R2, which is 0.946, the sixth model was selected as the best model considering the minimum standard error. Accordingly, the goodness of fit of the model is 94.6%, which implies that approximately 95% proportion of variance in the annual OPEX/sq. ft. in commercial buildings could be expressed by five independent variables entered into the model namely, working days/week, working hours/day, GIFA, building height, and occupancy. For more reliability, multicollinearity effect of the selected model was checked using the collinearity statistics shown in Table 5.

Table 5: Coefficients and collinearity statistics of the model selected

Model		Unstandardized Coefficients		95.0% Confidence Interval for B		Collinearity Statistics	
		B	Standard error	Lower Bound	Upper Bound	Tolerance	VIF
6	(Constant)	-899.608	1232.369	-3462.461	1663.244		
	Work. days/week	293.428	254.103	-235.009	821.865	0.508	1.967
	Working hours/day	-132.931	52.237	-241.564	-24.297	0.415	2.409
	GIFA	0.065	0.018	0.027	0.103	0.108	9.288
	Building height	16.024	3.475	8.796	23.252	0.105	9.487
	Occupancy	-0.192	0.112	-0.424	0.040	0.458	2.185

a. Dependent Variable: OPEX/sq. ft.

Although there is no formal criterion for determining the bottom line of the tolerance value or Variance Inflation Factor (VIF), Chatterjee and Hadi (2012) suggest that a tolerance value less than 0.1 or VIF greater than 10 generally indicates a significant multicollinearity. As seen in Table 5, the collinearity statistics, tolerances of greater than 0.1 and the VIFs of less than 10 indicate the non-existence of multicollinearity in this model.

Upon satisfying all the requirements, the annual OPEX/sq. ft. of a commercial building located in a tropical climate is expressed using the hedonic regression modelling. Accordingly,

$$\begin{aligned}&\text{Annual Operational Expenses (LKR/sq. ft)}\\&\qquad= -899.608 + 293.428\,(\text{Working days/week})\\&\qquad- 132.931\,(\text{Working hours/day}) + 0.065\,(\text{GIFA})\\&\qquad+ 16.024\,(\text{Building height}) - 0.192\,(\text{Occupancy}) + 719.88679\end{aligned}$$

With the use of this developed model, the OPEX in commercial buildings can be determined at early design stages. Consequently, can reduce the excessive costs to be incurred during the operational phase of the commercial buildings located in tropics.

Cost indices for OPEX in commercial buildings

Following the model for OPEX, the cost indices for OPEX of commercial buildings in Sri Lanka were imputed for three years: 2014, 2015, and 2016. The first quarter of 2014 was considered as the base as it did not experience any extreme effects such as tariff changes and abnormal inflation conditions. The indices were constructed using the hedonic price imputation approach along with the Fisher's index.

The Fisher's index takes the following form. $P_i = \sqrt{\frac{\sum p_1 q_0}{\sum p_0 q_0} * \frac{\sum p_1 q_1}{\sum p_0 q_1}} * 100$

Where, Pi-price index, p1-prices of the current year, p0-prices of the base year, q1-quantities of the current year, and q0-quantities of the base year.

With the use of hedonic price imputation approach, prices for both base and current years were replaced by the regression coefficients (r) computed through the regression analysis for each variable and the mean value ($\bar{x}$) of each variable were considered as the quantity for both years. Therefore, the Fisher's index formula takes its new form as $P_i = \sqrt{\frac{\sum r_1 \bar{x}_0}{\sum r_0 \bar{x}_0} * \frac{\sum r_1 \bar{x}_1}{\sum r_0 \bar{x}_1}} * 100$

Following the aforementioned procedure, cost indices for OPEX in office buildings, banks and all commercial buildings were imputed and the resulted index values are presented in Table 6.

Table 6: Quarterly OPEX indices for different types of commercial buildings and all commercial buildings in Sri Lanka

Base = Year 2014 (First quarter)

Year	Quarter	Office buildings	Banks	All commercial buildings
2014	First quarter	100.0	100.0	100.0
	Second quarter	96.7	96.7	96.7
	Third quarter	98.1	98.1	98.1
	Fourth quarter	99.5	99.5	99.5
2015	First quarter	116.4	105.2	80.8
	Second quarter	114.1	103.2	79.3
	Third quarter	115.0	103.9	79.9
	Fourth quarter	117.7	106.4	81.8
2016	First quarter	133.2	110.8	62.3
	Second quarter	132.1	109.9	61.8
	Third quarter	132.9	110.6	62.2
	Fourth quarter	133.4	111.0	62.5

As observed from Table 6, index values for offices, banks and all commercial buildings in all quarters in 2014 are similar indicating that there is no change in the trend of OPEX among offices, banks and commercial buildings as a whole in 2014. Further, there are slight increases in OPEX of offices and banks over the time and conversely, a significant decrease in all commercial buildings. Moreover, it is observed that OPEX in first and fourth quarters are slightly high in every year in all categories.

DISCUSSION AND CONCLUSIONS

The study initially developed an early-stage cost estimation model for OPEX in commercial buildings including a wide set of factors influencing the OPEX while previous studies, Al-Hajj and Horner (1998) and Kirkham *et al*., (1999) have ignored some of those important factors such as the building age, location, type of structure, and level of occupancy. Accordingly, the model developed based 05 independent variables: working days/week, working hours/day, GIFA, building height, and occupancy, which are frequently known at the pre-construction stage of buildings. Further, the model developed expressed approximately 95% of variance in the annual OPEX/sq. ft. in commercial buildings. Therefore, challenge the accuracy of Al-Hajj and Horner (1998) model, which provides an accuracy of 1.13%. It implies that a proper combination of these variables will lead to optimising the cost incurred during the operational phase of buildings. Moreover, unlike previous studies, which used multiple linear regression analysis for the model formation, this study used an improved version called the hedonic regression modelling, which offers reliable models for cost estimation of properties purely based on its structural and locational characteristics. The study further provides quarterly OPEX indices for commercial buildings for three recent years. OPEX indices are important since many investors, and also the government, in some way are tied to the commercial building market. Whilst all existing OPEX indices are based in developed countries, the constructed indices can be generalised to nations, which are developing alike Sri Lanka. With the use of developed model along with indices, both construction industry professionals and investors can make informed decisions on implications of OPEX in commercial properties at its early design stages, eliminating excessive costs to be incurred during the operational phase of buildings. And also, the finding of the study may have policy implications for building cost management and resource allocation at the national level.

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