DESIGNING A WHOLE-LIFE COST INDEX FOR NON-RESIDENTIAL BUILDINGS

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ABSTRACT

The study investigates the whole-life costs of non-residential Green Mark certified building developments in Singapore to derive useful information for teaching, research and practice. When industry stakeholders like building owners, architects, engineers, quantity surveyors, builders and facility managers have detailed information about the initial and operating costs of different types of buildings, they would be able to apply whole-life costing to their existing or new projects with the intention of achieving value for money, as well as environmental sustainability. Data is collected from Green Mark certified building projects starting from 2005. Statistical analysis is performed on the collected data to generate the information required to build the cost database. The Paasche Price Index method is used to produce a weighted composite index for Singapore's non-residential building sector by applying 2005 as the base year.

Keywords: *BCA Green Mark Scheme; Price Index; Sustainability; Whole-life Costs.*

1. INTRODUCTION

The Singapore Economic Review Committee, set up in December 2001, had envisioned to remake Singapore through "new challenges and fresh goals", with the aim of transforming her into a dynamic global city (MTI, 2003). Among the goals set for the construction industry to upgrade capability, a new possibility was identified for its domestic enterprises to develop niches in eco-efficient design, environmental technologies, and green products and services. These areas come under Singapore's Green Plan 2012, which is a blueprint for achieving environmental sustainability. In view of the strategic plans, the signal was clear that in order for Singapore to achieve and maintain its position as a global city, the construction industry must among its other goals be able to produce and offer quality and environmentally-friendly buildings as a show of sustainable development.

Responding to the calls for the construction industry to build up expertise in environmental and ecological technology, the Building and Construction Authority (BCA) had developed the Green Mark Scheme as a strategic programme to encourage property developers, building owners, designers and contractors in Singapore to adopt "green building" practices. The Scheme was launched in January 2005 and it would apply to new and completed buildings. In 2006, the Green Building Master Plan was launched to encourage more building owners and developers to own and develop more environmentally-friendly buildings. Since 2005, the number of Green Mark building projects in Singapore has increased exponentially from only 17 in the first year to 1,000 in February 2012. At present, about 13% of the buildings in Singapore have achieved the BCA Green Mark standard. Clearly from this, we have arrived at a stage where there is sufficient project data of green-rated building developments to enable studies of whole-life costs to be carried out on a national basis.

The consideration of whole-life costs in the design and operation of building developments is a key part of sustainable development. It is also a vital component in achieving value for money for the building owner. Whole-life costs can be considered at various stages of the procurement process - at the initial stage of identifying a need and developing a business case, when producing specifications and when awarding a contract to achieve value for money (OGC, 2003). Whole-life costs are commonly divided into three broad categories: initial capital costs, operating costs and disposal costs (refer Figure 1). In essence, whole-life costing will take into account running costs such as energy usage, maintenance requirements, disposal costs

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such as recycling, as well as the initial purchase price. The life span of the product will also need to be considered.

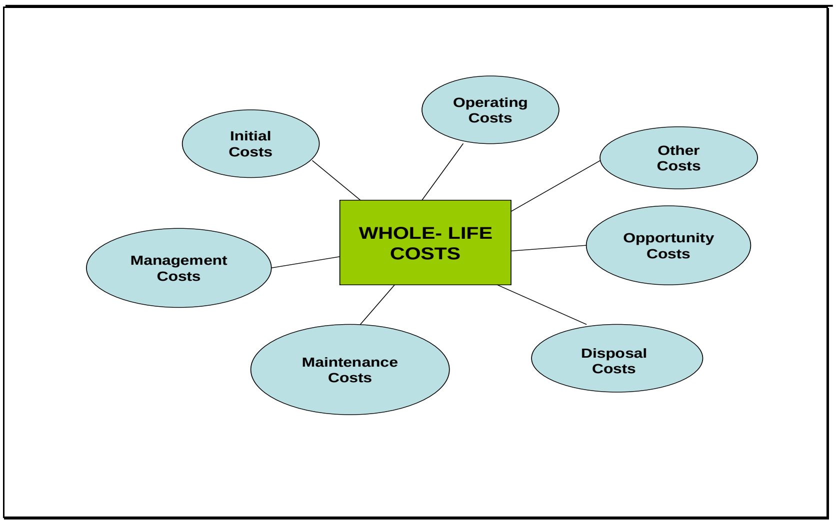

Figure 1: Components of Whole-life Costs of an Asset
Adapted from Addis and Talbot (2001)

2. DEFINITION

Life cycle costing is defined by Kirk and Dell'Isola (1995) as "an economic assessment of an item, area, system, or facility that considers all the significant costs of ownership over its economic life, expressed in terms of equivalent dollars. Life cycle costing is a technique that satisfies the requirements of owners for adequate analyses of total costs."

3. AIM AND OBJECTIVES

The main aim of the study is to design a whole-life cost index for non-residential buildings in Singapore. However, in the course of constructing the index, it involves investigating and analysing the whole-life costs of non-residential Green Mark certified building developments to derive information useful for teaching, research and practice. For instance, when industry stakeholders like building owners, architects, engineers, quantity surveyors, builders and facility managers have detailed information about different types of buildings' initial and operating costs, they would be more willing to apply the concept of whole-life costing to their existing or new projects with the intention of achieving value for money, as well as environmental sustainability.

The four objectives are outlined as follows:

a) To collect data of group building elemental costs that adopts the Singapore Standard Code of Practice CP80: 1999 classification to generate average cost percentages for commercial, industrial and institutional building types. The elemental groups are: (i) Site Preparation, (ii) Substructure, (iii) Superstructure, (iv) Finishes, (v) Fittings, Fixtures and Furnishings, and (vi) External Works.
b) To generate ratios of 'Cost of Building Services' to 'Total Cost of Building' for commercial, industrial and institutional building types. It is to investigate whether a relationship exists between this ratio and the function of the buildings analysed.
c) To construct a Non-residential Whole-life Cost Index on an annual basis. The index series begins in year 2005.
d) To create a Whole-life Cost Database that contains data of non-residential buildings' initial capital costs and operating costs (eg. annual energy and water costs, maintenance and repair costs, replacement costs, residual costs and other costs). The building types include commercial, industrial and institutional developments.

4. SIGNIFICANCE OF CONCEPT

Construction industries in the advanced countries, such as the UK, USA and Australia, have been over the years advocating whole-life costing practices and have developed detailed standards and guidelines to assist industry stakeholders to apply the technique to manage the total costs of building projects. For instance, the internationally well-established Building Cost Information Service (BCIS) owned by the Royal Institution of Chartered Surveyors in the UK has developed and maintained a database of costs pertaining to building operations and maintenance since the 1990s. The National Institute of Building Sciences (NIBS) in the US has produced a standard for life-cycle cost analysis as part of its Whole Building Design Guide to educate industry stakeholders on how to use the technique in order to manage whole-life costs of building assets. In Australia, the New South Wales Treasury has developed a guideline for Life Cycle Costing as part of advocating total asset management in the light of growing pressures to achieve better outcomes from building assets. However, in Singapore, while there is a national Building Tender Price Index Series to guide industry stakeholders on tender prices of public and private-sector building projects, it still lacks a body of knowledge (in terms of a centralised database) concerning whole-life costs, specifically the costs of operating/running a building. Having a Whole-Life Cost Index essentially helps to enhance our knowledge of managing total costs of a typical building which must encompass operating and maintenance costs because it is during the asset's service life that more resources are consumed.

5. APPROACH

Data is mainly collected from Green Mark certified building projects starting from 2005. Non-Green Mark buildings are also used if good/complete data is available. Only non-residential building projects are considered - commercial, industrial and institutional types - because the data of operating costs of these types can be more easily obtained from a centralised source. On the other hand, for residential developments, collecting such data might not be too feasible as it would involve obtaining it from many different households. The Singapore Standard Code of Practice for Classification of Construction Cost Information or SS CP80: 1999 (Singapore Productivity and Standards Board, 1999) is used to classify the group building elements, while the American NIBS' Classification of Life Cycle Cost Components (NIBS, 2010) is adopted to classify the cost components. Statistical analysis is performed on the collected data to generate the information required to build the cost database.

The approach of the study can be presented in two parts. The first part is to study the average cost percentages of the group building elements and to generate ratios of 'Cost of Building Services' to 'Total Cost of Building' for commercial, industrial and institutional building types (refer Figure 2). The second part looks at constructing the Whole-Life Cost Index using the *Paasche* Price Index Method which produces a weighted composite index (refer Figure 3). The weights to be applied are calculated from the average proportions of value of contracts awarded for the three non-residential project types between 1996 and 2005. The buildings must have at least been running for 6 years to contain sufficient data on operating costs. The index series begins in 2005 (i.e. the base year).

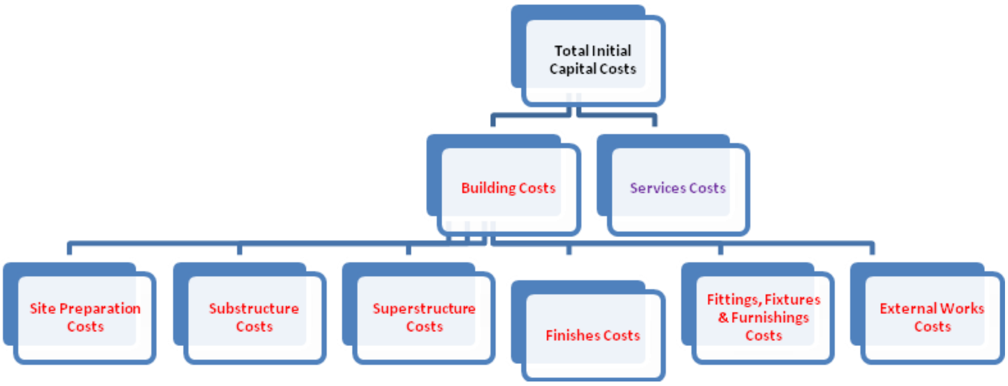

Figure 2: Components of Total Initial Capital Costs of an Asset
Adapted from Singapore Productivity and Standards Board (1999)

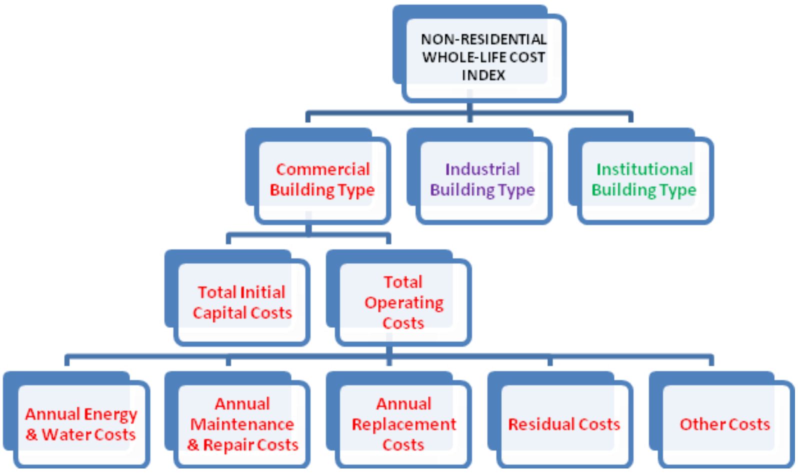

Figure 3: Components of the Proposed Non-residential Whole-life Cost Index
Adapted from NIBS (2010)

6. METHODOLOGY

The proposed Whole-Life Cost Index is a weighted composite index and is constructed using the *Paasche* Price Index Method. The formulation of the *Paasche* Price Index is expressed as:

$$\frac{\sum P_i \times Q_i}{\sum P_0 \times Q_i} \times 100\% \qquad \text{(Eq: 01)}$$

where, P_i = current year price; P_0 = base year price; and Q_i = current year quantity.

In the first stage of constructing the proposed Index, the weights of the two main components of whole-life costs have to be established for each of the three types of non-residential buildings (Commercial, Industrial and Institutional types). The two components are:

- Total initial capital costs; and
- Total operating costs.

A sample of Green Mark certified buildings between 2005 and 2009 is used for this purpose to obtain their average proportions.

Establishing the weights for each building type:

Whole-Life Cost (C) = Total initial capital costs (C1) + Total operating costs (C2) (Eq: 02)

The ratios of C1: C and C2: C are calculated for each sample project. The average ratios are calculated from the sum of ratios for all sample projects divided by the number of sample projects.

The derived weights for each building type are applied in this manner:

Whole-Life Cost Index (WCI1) (Commercial Buildings)

$$= \left[\frac{(\text{Average ratio C1:C}) \times \sum P_i \times Q_i}{\sum P_0 \times Q_i}\right] + \left[\frac{(\text{Average ratio C2:C}) \times \sum P_i \times Q_i}{\sum P_0 \times Q_i}\right] \qquad \text{(Eq: 03)}$$

Whole-Life Cost Index (WCI2) (Industrial Buildings)

$$= \left[\frac{(\text{Average ratio C1:C}) \times \sum P_i \times Q_i}{\sum P_0 \times Q_i}\right] + \left[\frac{(\text{Average ratio C2:C}) \times \sum P_i \times Q_i}{\sum P_0 \times Q_i}\right] \qquad \text{(Eq: 04)}$$

Whole-Life Cost Index (WCI3) (Institutional Buildings)

$$= \left[\frac{(\text{Average ratio C1:C}) \times \sum P_i \times Q_i}{\sum P_0 \times Q_i}\right] + \left[\frac{(\text{Average ratio C2:C}) \times \sum P_i \times Q_i}{\sum P_0 \times Q_i}\right] \qquad \text{(Eq: 05)}$$

where, P_i = current year price; P_0 = base year price; and Q_i = current year quantity.

In the second stage, the weights of the three types of non-residential buildings have to be established. The three types of buildings are:

- Commercial buildings;
- Industrial buildings; and
- Institutional buildings.

The value of contracts awarded for the three types of buildings between 1996 and 2005 is used for this purpose to obtain their average proportions.

Establishing the weights for the three non-residential building types:

Total Value of Non-Residential Buildings (N) = Total Value of Commercial Buildings (N1) +
Total Value of Industrial Buildings (N2) +
Total Value of Institutional Buildings (N3) (Eq: 06)

The ratios of N1:N, N2:N and N3:N are calculated and the derived weights is applied in this manner:
Whole-Life Cost Index = [(Ratio N1:N) x WCI1] + [(Ratio N2:N) x WCI2] + [(Ratio N3:N) x WCI3]
(for All Non-Residential Buildings) (Eq: 07)

7. DELIVERABLES

The main deliverables are as follows:

- Average cost percentages of group building elements for commercial, industrial and institutional building types.
- Ratios of 'Cost of Building Services' to 'Total Cost of Building' for commercial, industrial and institutional building types.
- A Whole-life Cost Index Series for non-residential building developments that begins in year 2005.
- A Whole-life Cost Database that contains data on initial capital costs and operating costs for commercial, industrial and institutional building types.

8. PRELIMINARY FINDINGS

The 36-month research which started in November 2012 is at the stage of data collection. A template that is formatted to contain all the standard building elements has been prepared for this purpose. A simplified version of the template is shown in Table 1.

Table 1: Template for Cost Data

No.	Main Group	Sub Group	Capital Cost ($)	Percent (%)
1.	Development and Construction Costs	a. Substructure		
		b. Superstructure		
		c. Internal finishes		
		d. Fittings and furnishings		
		e. Services		
		f. External works		
		Total:		100%
No.	**Main Group**	**Sub Group**	**Annual Cost ($)**	**Percent (%)**
2.	Operation and Maintenance Costs (Annual)	a. Occupancy (eg. electricity, water, cleaning, security, etc.)		
		b. Maintenance and repair		
		c. Replacement		
		Total:		100%

Building projects that have been awarded a Green Mark rating are obtained from the website of BCA and letters sent to the owners, as well as their project consultants, to solicit help with the data collection. The number of non-residential buildings identified by their year of completion is shown in Table 2.

Table 2: Number of Green Mark Rated Buildings by Year of Completion

Type of Building	2005	2006	2007	2008	2009	Total
Commercial	8	5	11	12	25	61
Industrial	1	1	1	2	9	14
Institutional	2	2	2	7	4	17

The construction of the index applying the *Paasche* Price Index Method involves the re-pricing of each project's bill of quantities (BQ). This document provides the complete information on prices and quantities at current levels (i.e. *Pi* and *Qi*). The method of cost significant items re-pricing is adopted for this purpose as it recognises that a relatively small number of items in any BQ represents a high proportion of the cost significant items. Research has shown that generally about 80 percent of total costs are contained in less than 20 percent of the total number of items in a BQ. Therefore, the index is constructed based on re-pricing those cost significant items in order to save time in the re-pricing process. Across 13 work categories, a group of 68 cost significant items with their respective unit rates is obtained from the relevant publications of Singapore's construction costs (Davis and Seah, 2008; Davis, and Seah, 2010) (refer Table 3). The 2007 and 2008 unit rates published in the cost handbooks have been adjusted using BCA's National Building Tender Price Index (BTPI) to produce the 2005 base year rates.

Table 3: Number of Cost Significant Items for Main Construction Work Categories

No.	Main Work Categories	No. of Cost Significant Items	Unit Rate of Cost Significant Items
1.	Excavation	6	Year 2005 Base Unit Rate (S$) P_0 for Bill Re-pricing
2.	Concrete work	7	
3.	Formwork	5	
4.	Reinforcement	5	
5.	Steelwork	5	
6.	Brickwork and blockwork	4	
7.	Roofing	4	
8.	Woodwork and metalwork	7	
9.	Plumbing	8	
10.	Electrical work	3	
11.	Finishings	10	
12.	Glazing	1	
13.	Painting	3	
	Total	68	

As the start of the second stage where it involves establishing the weights of the three types of non-residential buildings using the value of contracts awarded between 1996 and 2005, relevant information is extracted from the website of BCA. The derived weights for commercial buildings (N1), industrial buildings (N2) and institutional buildings (N3), respectively, are shown in Table 4.

Table 4: Derived Weights for Non-Residential Buildings

Type of Building	Total Value of Contracts Awarded (1996 to 2005) in S$ million	Ratio/Weight
Commercial	13151.18	0.195592
Industrial	28954.43	0.430626
Institutional	25132.37	0.373782
Total	67237.98	1

9. SUMMARY

The concept of constructing a national-level Whole-Life Cost Index for buildings is new. It is an index which measures the actual costs incurred by the building owner. It can be defined as an index that measures the relative change in building ownership costs over time, relative to a base period. Singapore has yet to have a whole-life cost index for buildings and developing one is timely in view of the rapidly growing interests in sustainable design and performance of buildings. The concept and methodology proposed here is similar to the ones adopted by the BCA to construct the National BTPI for Singapore's Construction Industry which started in 1990.

While the study targets Green Mark certified buildings, it does not exclude non-Green Mark buildings if good/complete data is available. The assumption which the study uses is that Green Mark certified buildings would be the source for reliable data, especially on the building's operating costs. The Green Mark Scheme has a re-certification process which requires building owners to keep proper records of the operating costs of the building.

The proposed Whole-Life Cost Index is a forward-looking index series despite being able to only cover about 13% of all the buildings in Singapore at the present time. As the number of Green Mark certified buildings continues to grow, it would be able by 2030 to cover at least 80% of all buildings in Singapore.

10. ACKNOWLEDGEMENT

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11. REFERENCES

Addis, B. and Talbot, R., 2001. *Sustainable construction procurement – A guide to delivering environmentally responsible projects*. UK: Construction Industry Research and Information Association (CIRIA).

Davis, L. and Seah, 2008. *Construction cost handbook: Singapore*, 14th ed. Singapore: Davis Langdon and Seah Singapore Pte Ltd.

Davis, L. and Seah, 2010. *Spon's Asia-Pacific Construction Costs Handbook*, 4th ed. London; New York: Spon Press.

Kirk, S.J. and Dell'Isola, A.J., (1995). *Life Cycle Costing for Design Professionals*, 2nd ed. USA: McGraw-Hill.

MTI, 2003. *New Challenges, Fresh Goals – Towards a Dynamic Global City*. A Report of the Economic Review Committee, Ministry of Trade and Industry. Singapore.

NIBS, 2010. *Life-cycle cost analysis, Whole Building Design Guide*. A Program of the National Institute of Building Sciences. Available from: http://www.wbdg.org/resources/lcca.php [Accessed 22 March 2012].

OGC, 2003. Available from: http://webarchive.nationalarchives.gov.uk/20110822131357/http://www.ogc.gov.uk/index.asp [Accessed 29 July 2013].

Singapore Productivity and Standards Board, 1999. *Code of Practice for Classification of Construction Cost Information, SS CP80: 1999*. Singapore.