GREEN BUILDINGS ACTUAL LIFE CYCLE COST CONTROL: A FRAMEWORK FOR INVESTIGATION

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ABSTRACT

Green buildings and sustainable construction operate as a subset of sustainable development. A growing body of literature suggests that green buildings outperform conventional (non-green) buildings in all performance areas, particularly in term of economic benefits which are typically assessed using life cycle costing as an economic appraisal technique. However, reports and studies show a performance gap once buildings are occupied. Therefore, merely relying on performance simulation and modeled design is not satisfactory to convince building owners and real estate investors that green building is a rational economic decision and a cost effective long-term strategy. While unprecedented consensus about several life cycle benefits of green building exists, no standard methods were proposed or developed to monitor and control the actual life cycle cost of green buildings. This paper addresses the issue of green buildings actual life cycle cost performance and suggests a conceptual framework to extend the functionality of Earned Value Management (EVM) Approach to be applied throughout building operating phase. Comparative analysis has been conducted to investigate validity of Earned Value Management (EVM) parameters in building operating phase, as well as to investigate the cost patterns and characteristics in both building construction and operating phase. The results suggest that it is possible to extend the functionality of the Earned Value Management (EVM) technique to be applied during building operating phase, but different criteria and procedures are required to calculate the cost variances and cost performance indices due to significant dissimilarities in the cost control parameters.

Key Words: Green buildings; Actual performance; Life cycle cost; Performance measurement; Earned value Management

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INTRODUCTION

In recent decades, humans concern towards the environment and the various ecological systems have dramatically increased due to the resultant negative impacts of several human activities. Phenomena such as Global Warming and severe global climate changes are indisputable evidences of the occurred environmental damages caused by gas emissions and natural resource depletion. As reparative and preventative measures, sustainable development and green economy have been proposed as strategic approaches to be implemented in various industrial and manufacturing sectors (Brundtland, 1987; UNEP, 2011). Not surprisingly, among the other production and manufacturing sectors, building and construction sector occupies the first place as the largest contributor to pollution and natural resource consumption (Levine *et al.*, 2007; Plank, 2008). As reported by the United Nations Environment Programme (Graham and Booth, 2010) building sector is responsible for 40% of the total energy and resource consumption, 30% of total solid waste production, in addition to 30% of all energy-related greenhouse gas emissions. To control the Greenhouse phenomenon by reducing gas emissions, in the early nineties (Kibert, 2012) "*green*" or "*sustainable*" buildings were introduced as a high potential solution to achieve this target as well as to improve the performance of the built environment in term of economic, health, and environmental aspects. In its principle, green building and sustainable construction operate as a subset of sustainable development (Yudelson, 2008; Alwaer and Croome, 2010). In term of economy, the green building is paying off at all levels (Kats, 2003, 2006, 2010; Madew, 2006; Ries *et al.*, 2006; Davis Langdon, 2007a; Bowman and Wills, 2008; Mcgrow Hill Construction, 2013; Winters, 2014), and therefore, witnessed a paradigm shift since its inception due to a wide range of tangible and intangible benefits. Nevertheless, green building barriers still exist, and it seems that more support and feasibility evidences are still required to increase its widespread throughout convincing real estate investors and building owners to adopt "*greenness*" as business strategy.

GREEN BUILDINGS BENEFITS

From life cycle perspective, unprecedented consensus can be found in the literature regarding several benefits and advantages of green buildings (Kats, 2003, 2006, 2010; Kats *et al.*, 2003; Turner Construction, 2005; Ries *et al.*, 2006; Madew, 2006; Davis Langdon, 2007a; Bowman and Wills, 2008; Yudelson, 2008; McGraw-Hill Construction, 2008; Choi, 2009; Kibert, 2012). These benefits are represented in significant energy and water saving, reduced maintenance cost, increased property value, higher occupant satisfaction, improved productivity, health benefits, in addition to reduced CO2 and waste emissions. In his seminal works, Kats (2003, 2006, 2010) concludes that green buildings save energy on an average of 30%, and he argues that by adding other benefits, such as reduced water consumption, maintenance cost, improved health and productivity, the financial benefits are 20 times as high as the marginal cost of building green which is around 2%. Investigating the literature shows that there is a wide spectrum of empirically based green buildings benefits which promote the concept of green buildings and increase its widespread. However, identifying these benefits is grounded on life cycle approach in which life cycle costing as an economic appraisal technique is adopted to quantify the long term benefits of green buildings. Hence, to increase the credibility of green buildings benefits, standard methods are required to enable building owners and investors to monitor and measure the actual economic performance of their sustainably designed and constructed facilities (Ren and Zhang, 2007; Choi, 2009; Helgeson and Lippiatt, 2009).

GREEN BUILDINGS ACTUAL PERFORMANCE

Buildings, in general, are increasingly evaluated to meet standards and norms related to sustainability, cost effectiveness, comfort, health and safety. It is vigorously argued that designers need feedback and post occupancy evaluation is crucial to promote green buildings (Helgeson and Lippiatt, 2009; Lippiatt, 2011). Thus, it is vigorously argued that merely relying on performance simulation and modeled design is not satisfactory to convince owners and real estate investors that green buildings are economically rewarding and cost effective long-term strategies (Fowler *et al.*, 2005; USGBC Research Committee, 2008; Choi, 2009; Helgeson and Lippiatt, 2009; Meir *et al.*, 2009). Actual performance measures, particularly for cost, are highly required due to the fact that there is a growing evidence that buildings have poor record in performing as predicted (Burnett, 2008; USGBC Research Committee, 2008; Menezes *et al.*, 2012; de Wilde, 2014). In a recent paper, De Wilde (2014) highlights that there is a significant discrepancy between predicted energy performance and actually measured energy use once buildings are occupied. Similarly, Torcellini *et al.* (2006, p. 111) unexpectedly found that low energy designed buildings are using more energy than predicted. This performance gap has a significant magnitude since studies and reports suggest that the actual energy use is somewhat 2.5 times higher than the predicted performance (Menezes *et al.*, 2012). However, energy performance is one aspect of performance areas in buildings. This means that similar gaps most likely exist in other performance areas. As an example, the U.S General Service Administration (GSA) (GSA Public Buildings Service, 2011) conducted a post occupancy evaluation to evaluate the performance of 22 green buildings, they found that some green buildings recorded 25% higher maintenance cost and even higher energy and water consumption than the U.S national average of commercial buildings. Such results highly contradict the anticipated performance in the design. Similarly, Fowler and Rauch (2008) investigated 12 sustainably design buildings and found that three buildings have higher maintenance costs than the industry baseline in the U.S, one building has higher energy costs, and two buildings used more water than the baseline. De Wilde (2014) surveyed the literature that addresses energy performance gap issue and concluded that the root causes for the performance gap are attributable to several factors related to design, construction, and operating of the buildings.

LIFE CYCLE COSTING

Life cycle Costing is an economic appraisal technique used to evaluate the economic performance of a green building throughout its life cycle which mainly includes: construction, operation, maintenance, and disposal (Norman, 1990; Bull, 2003; Boussabaine and Kirkham, 2004; Flanagan *et al.*, 2005; Davis Langdon, 2007b). Typically, it discounts all building related costs and revenues that occur in different times to a single figure known as Net Present Value (NPV) allowing cost comparison among different design alternatives (Cole and Sterner, 2000, p. 368). The method requires computing the life cycle cost (LCC) for different building design alternatives or system specifications to determine which alternative has the lowest life cycle cost over a predefined study period (Kirk and Dell'isola, 1995; ASTM International, 2013).

In building construction, life cycle costing is an economic evaluation tool used to estimate the Net Present Value (NPV) of all current and future costs arise from owning and operating a facility. Although life cycle costing is a well-developed and widely accepted technique to predict the economic performance of green buildings, examining the literature shows that the issue of actual life cycle cost monitoring and control is poorly addressed and very few data published about the actual life cycle cost performance of green buildings (Syphers *et al.*, 2003, p. 1). This is indeed unlike the case in building construction phase in which rigorous cost monitoring and control technique have been developed and widely implemented (Fleming and Koppelman, 2000, 2009; Mubarak, 2010; Hinze, 2011; Bhosekar and Vyas, 2012; PMI, 2013).

Estimating the life cycle cost of a green building is associated with a high degree of uncertainty due to the fact that buildings in general have long life cycle (Norman, 1990; Woodward, 1997; Bourke and Davies, 1999; Cole and Sterner, 2000; Emblemsvag, 2001; Boussabaine and Kirkham, 2004; Gluch and Baumann, 2004; Flanagan *et al.*, 2005; Davis Langdon, 2007c). Besides uncertainty, there are several reasons limiting the application of life cycle costing in the construction sector. The most cited reasons for this limitation evolve around poor perception of the benefits of life cycle costing, poor knowledge related to methodological issues, the lack of standardized cost and performance information about the buildings in use, shortage of reliable information on historical cost and performance (Norman, 1990; Cohen *et al.*, 1991; Bourke and Davies, 1999; Cole and Sterner, 2000; Kishk *et al.*, 2003; Boussabaine and Kirkham, 2004; Gluch and Baumann, 2004; Flanagan *et al.*, 2005; Davis Langdon, 2007c; Ren and Zhang, 2007). Cole and Sterner (2000, p. 373) argue that improving the communication of the benefits of life cycle costing as well as improving the cost and performance data are the most prominent issues in order to increase the use of life cycle costing.

The uncertainty associated with life cycle cost analysis implies that the actual life cycle cost performance of the green building most likely will be deviant than the anticipated performance. Nevertheless, investigating the literature shows that no structured construction management processes were proposed or exercised to control the actual life cycle cost of a green building and to measure its actual economic performance (Cohen *et al.*, 1991; Ren and Zhang, 2007; USGBC Research Committee, 2008; Choi, 2009; Helgeson and

Lippiatt, 2009; Rhodes *et al.*, 2009; Lippiatt, 2011). However, the literature suggests that life cycle costing is a platform for controlling the life cycle cost (LCC) (Cohen *et al.*, 1991; Kirk and Dell'isola, 1995; Woodward, 1997; Flanagan *et al.*, 2005). The uncertainty associated with life cycle costing, and the need for tangible measures about the actual life cycle cost performance of green buildings sheds the light on the need for standard methods and techniques to monitor and measure the actual cost performance of green buildings from life cycle perspective.

LIFE CYCLE COST CONTROL

The term "*cost control*", in Business Dictionary (2014), is defined as the process of controlling cost of an activity, process, or company. It typical includes: (1) investigative procedures to detect variance of actual costs from budgeted costs, (2) diagnostic procedures to determine the causes of variance, and (3) corrective actions to realign actual and budgeted costs. While in business English, according to Cambridge Dictionary (2014), the cost control is defined as "*the process of controlling how much a company or organization spends so that costs are not greater than an agreed budget, or a particular method that is used to do this*".

In the construction sector, the concept of cost control is used to determine whether the actual cost is in line with the budgeted cost, and to measure the magnitude of variance. It is also used to identify the causes of deviation and the course of actions required to realign the actual cost with its cost baseline (Mubarak, 2010; Hinze, 2011; PMI, 2011). Currently, in controlling the cost of construction projects, the most widely accepted and used cost control technique is the Earned Value Management (EVM) (Popescu and Charoenngam, 1995; Fleming and Koppelman, 2000; Mubarak, 2010; Kwak *et al.*, 2012; PMI, 2013). Popescu and Charoenngam (1995) define the earned value management as "*the performance measurement to report the status of a project in terms of both cost and time at a given data date*". The earned value management technique helps in calculating performance metrics not available in any other project management technique (Fleming and Koppelman, 2009, p. 1). It is based on identifying three key parameters which are: planned value (PV), earned value (EV), and actual cost (AC) (Popescu and Charoenngam, 1995; Mubarak, 2010; Bhosekar and Vyas, 2012). Based on these three parameters, an extensive list of performance indicators and metrics can be calculated, among others, cost variance (CV), schedule variance (SV), cost performance index (CPI), schedule performance index (SPI), and to-complete performance index (TCPI). The strength of earned value management is represented in the earned value (EV) as a key parameter, which allows measuring a project's progress and performance against the time and the cost concurrently (PMI, 2005, 2011).

METHODOLOGY

This paper seeks to investigate the validity of applying the currently used cost monitoring and control techniques in the construction phase to be used throughout building operating phase. More specifically, it seeks to extend the functionality of the currently applied cost performance measurement techniques in the construction phase to be applied throughout the whole building life cycle. For this purpose, based on a comprehensive literature review, comparative analysis has been implemented in two stages to identify the differences and similarities between the cost characteristics in both building construction and operating phase. In the first stage, cost characteristics in both building construction phase and operating phase has been compared to ensure that the available cost data in building operating phase can be processed to measure the actual life cycle cost performance as the case in building construction phase. In the second stage, validity of cost control parameters used in building construction phase has been investigated from life cycle perspective.

In addition to key literature sources, the international standards, namely: ISO 15686-5:2008 and ASTM E917-13 are used to identify the life cycle cost pattern and characteristics in building operating phase, while the Practice Standard for Earned Value Management (PMI 2011 and PMI 2005) are used to identify the cost pattern, characterstics, and cost control process applied in building construction phase.

The conducted literature review was critical in order to investigate the currently practiced and applied cost control techniques in both building construction and operating phase and to identify the key parameters and metrics used to measure the cost performance in each phase of the building life cycle.

RESULTS AND DISCUSSION

Unlike the case of building construction phase, investigating the literature shows that no standard methods were proposed to measure the actual economic performance of green buildings throughout its life cycle, and very few data published about the actual life cycle cost performance of green buildings. However, the construction phase, in which the Earned Value Management (EVM) is the most prominent technique to measure the actual cost performance, is a major phase of the green building life cycle (Kirk and Dell'isola, 1995; Flanagan *et al.*, 2005, p. 41). Likewise, the construction cost which typically controlled using the earned value management approach is a significant component of the green building life cycle cost (Kirk and Dell'isola, 1995; Flanagan *et al.*, 2005; ISO 15686, 2008, p. 7). Thereby, rather than developing a new approach to monitor and control the actual life cycle cost of green buildings, it would be more practical to extend the functionality of the earned value parameters to be applied throughout the life cycle of the green building. However, this requires investigating and understanding the differences and similarities of cost characteristics.

As illustrated in table no. 1, the results of investigating the cost characteristics show that the cost pattern in building construction phase generally matches the cost pattern in building operating phase, except the expenditure period and prediction accuracy. The expenditures period is relatively longer in building operating phase due to long building life cycle which highly affects the prediction accuracy which is also affected by the time value of money (Kirk and Dell'isola, 1995; Flanagan *et al.*, 2005). However, these mismatches do not affect the process of cost control since it is not bounded by time and compares the costs in the same time intervals and continues as long as costs are being actualized (PMI, 2005, 2011).

Table 1 Cost characteristics in building construction and operating phase

No.	Cost characteristic	Building Construction Phase	Building Operating Phase
1	Cost is predictable	Yes	Yes
2	Prediction accuracy	High	Moderate
3	Definitive cost components	Yes	Yes
4	Expenditures period	Short	Long
4	Time value of money impact	Low	High
5	Cost can be aggregated and accumulated	Yes	Yes
6	Ability to generate cost baseline	Yes	Yes
7	Ability to track actual cost	High	High

In building construction phase, three key parameters are required to conduct the earned value analysis which are: (1) planned value (PV), (2) earned value (EV), and (3) actual cost (AC) (Popescu and Charoenngam, 1995; Mubarak, 2010; Bhosekar and Vyas, 2012; PMI, 2013). As illustrated in table no. 2, in building operating phase, two of these parameters are valid which are the planned value (PV) and the actual cost (AC). The third key parameter which is the earned value (EV) is not valid in building operating phase due to the fact that after completing the construction phase and starting the building operating phase the input data required to calculate the earned value (EV) is no longer available for the reason that no physical work remains to be quantified and measured.

Table 2 Earned value parameters validity throughout building life cycle

No.	**Building phase**	**Planned Value (PV)**	**Earned Value (EV)**	**Actual Cost (AC)**
1	Building Construction Phase	Valid	Valid	Valid
2	Building Operating Phase	Valid	Not valid	Valid

In principle, the earned value is a critical parameter to measure the cost performance in building construction phase. This is due to the fact that the traditional cost control technique which compares the actual cost with the planned cost is misleading and does not allow measuring the actual cost performance of projects. This is according to the two eminent researchers in projects cost control field (Fleming and Koppelman, 2000, pp. 16–21) attributed to the fact that the traditional cost control technique is a two dimensional approach and does not consider the third dimension which is the value of the physical work performed in reference to its budget (known as the earned value) as a key parameter to measure the actual cost performance. However, from building life cycle perspective, the case seems to be different due to the fact that the third critical parameter which is the earned value (EV) is neither valid nor required after completing the construction phase because no physical works bounded by time schedule remain for quantification (PMI, 2005, 2011; Mubarak, 2010; Hinze, 2011).

Excluding the construction cost for which the earned value is required to be controlled, the other life cycle cost components which are: operation, maintenance, and disposal cost (ISO 15686, 2008, p. 7) can be controlled using traditional methods. Comparing the actual and the planned cost still be useful to evaluate the actual versus the planned expenditures (ANSI, 2007). Accordingly, combining the both techniques which are the Earned Value Management (EVM) and the traditional technique leads to an integrated method that can be used to control the actual cost of a green building along its whole life cycle. The concept of this proposed combination is based on enhancing the strength of the currently applied earned value method and converting the weakness of the traditional approach to an opportunity. While the earned value will remain to control the actual cost during the construction phase of a green building, the traditional technique will be applied during the building operating phase as illustrated in figure no. 1 below:

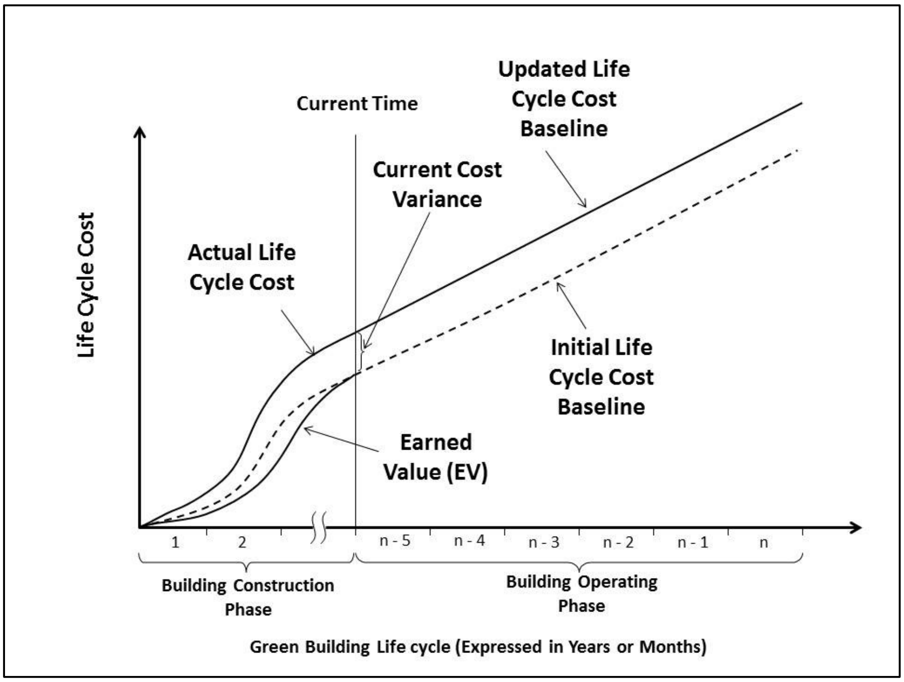

Figure 1 The conceptual Framework of the proposed technique

The proposed approach will provide actual feedback and standardized cost and performance information about the green buildings in use. This feedback is significant to improve future design inputs and to increase the accuracy of future life cycle cost assumptions (USGBC Research Committee, 2008; Choi, 2009; Lippiatt, 2011). Furthermore, the proposed technique can be used to evaluate the actual life cycle cost of a green building, and to examine whether it is in line with the estimate life cycle cost or not. It allows building owners to verify the anticipated benefits by providing tangible evidences that green buildings are paying off. Most importantly, it will enable building owners to track the actual economic performance of their green buildings to detect any deviation or performance gap which might be resulted from design, construction, or operating the building.

CONCLUSION AND RECOMMENDATIONS

From life cycle perspective, the green building has a wide range of tangible and intangible benefits which are typically assessed using life cycle costing approach. Reports and studies show a performance gap once building are occupied. This reported performance gap may erode the credibility of green building merits and benefits. Therefore, it is imperative to monitor and control the actual life cycle economic performance of green buildings.

The Earned Value Management (EVM) is a rigorous cost performance measurement technique widely applied in the construction sector to measure the cost performance throughout the construction phase which is a major component of green building life cycle. As like, the construction cost is a significant component of green building life cycle cost. Therefore, extending the functionality of the currently applied earned value management is more practical than developing a new approach to monitor and control the actual life cycle cost of green buildings.

The cost pattern and characteristics in both building construction and operating phase are generally matching. Accordingly, the authors suggest a conceptual framework to extend the functionality of earned value management technique to monitor and control the actual life cycle cost of a green building. Based on this framework, a set of actual life cycle cost performance indicators and metrics can be developed. This will allow green building owners and investors to monitor the actual economic performance of their green facilities to verify whether they are gaining the anticipated economic benefits or not.

However, in building operating phase the earned value (EV) as a critical parameter required to measure the cost performance in building construction phase is neither valid nor applicable in building operating phase. Nevertheless, comparing the actual life cycle cost and the baseline cost may still be useful to evaluate the actual life cycle cost performance against the anticipated cost performance in the baseline. As a result, the authors suggest combining the earned value management with the traditional cost control approach to develop a standardized technique to measure the actual economic performance along the life cycle of a green building.

The suggested technique will enable economists, designers, and building owners to measure and monitor the actual life cycle cost performance of green buildings, as well as it will enable them to evaluate the magnitude of cost deviation from a predefined life cycle cost baseline. Yet, the concept still in its infancy, and therefore, more work is still required to empirically validate the proposed framework, and to describe a structured and practical procedure for its usability and application. Empirical data is required to examine appropriate methods to calculate and identify meaningful cost performance indicators and metrics. After validating the proposed technique, research is required to identify potential challenges in putting the proposed technique in practice. Applying the proposed method requires significant methodological changes in the currently practiced cost estimation techniques by professionals to include life cycle cost in their estimate.

ACKNOWLEDGEMENT

The proposed technique is being developed and validated through multiple-case studies as a PhD research financed by the Malaysian Ministry of Higher Education, and supervised by Dr Kherun Nita Ali in Quantity Surveying Department at Universiti Teknologi Malaysia (UTM). The authors acknowledge the financial support from the Malaysian Ministry of Higher Education and the technical support provided by Universiti Teknologi Malaysia (UTM).

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