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CONSIDERATION OF RUNNING COSTS: CONVENTIONAL BUILDINGS VS. GREEN BUILDINGS

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Abstract
'Green Buildings' aim at the efficient use of energy, water and material resources while reducing the impact of the buildings on human health and environment. Green Building reduces the Running Costs (RC) required for the operation and periodic maintenance of a building throughout its life cycles thereby providing significant financial benefits. In Sri Lanka, green buildings are being increasingly constructed, and the lack of understanding about the Life Cycle Costs (LCC) of buildings has resulted in several misconceptions and these contradict the research findings on RC of green buildings. Therefore, this study is aimed at identifying the savings from RC that can be obtained from green buildings, compared to conventional buildings. The research problem was approached through case studies, semi-structured interviews and a document survey. The findings were analysed using content analysis. It was revealed that the RC would vary depending on the function of the building, and that this cost is always less when compared with that of conventional buildings mainly due to the 78% saving on energy consumption cost. Furthermore, sustainable features in the building contribute to reducing energy cost during the running period. Consequently, it is essential to make the stakeholders aware of the RC of green buildings, to encourage them to move towards sustainable development.

Keywords. *Cost Components; Green Building; Life Cycle Cost (LCC); Office Building; Running Cost (RC).*

1. Introduction

Green building has been in the forefront of sustainable development since the dawn of the 21st century as it balances long-term economic, environmental and social health (Ali & Al Nsairat, 2009). Even though , it initally has higher capital costs when compared to conventional buildings,

green buildings ultimately generate a pool of financial and environmental benefits such as reduced energy and water consumption, low Running Cost (RC), improved productivity and health. According to Forster, Carter, Banfill, and Kayan (2011), the building maintenance and operation is well known internationally as an essential mechanism for retaining the cultural heritage and protecting the capital associated with the building fabric.

Meanwhile, RC being the cost required for the annual operation and periodic maintenance of a building during its entire economic life span, the proper design and the selection of materials for building construction would result in lower RCs (Krstić & Marenjak, 2012; Marszal & Heiselberg, 2011; Nalewaik & Venters, 2008). In Sri Lanka, the entry barrier for green buildings is higher than that for conventional buildings in terms of the need for a new design, new technology and lack of understanding about the cost of green buildings (Chan, Qian, & Lam, 2009; Barnes, 2012). Moreover, SGS Economics and Planning Pty Ltd (2008) has highlighted that developer's focus on initial costs, rather than LCC. Even though, a critical problem arises in this regard according to Johnston & Newton (2004), green buildings bring a wealth of practical and psychological advantages while improving ventilation, unsealing hard surfaces, sustaining wildlife and providing shelter and insulation. Jayantha and Man (2013) have emphasized that the cost of constructing green buildings which is 2-4 % higher than that of conventional buildings due to their higher initial capital costs, is balanced in the long-run by their lower RC during the entire life span of a property.

Therefore the arguments generate a clear platform for considering the RC of green buildings through research carried out in the construction industry. Consequently, this research aims at identifying the savings of RC of green buildings compared to that of conventional buildings while identifying the green building concept and LCC, comparing the significant cost components during the running periods of the two types of buildings and ultimately at analyzing the reasons for the difference in costs between the costs of the two types of buildings throughout their lifecycles.

2. Concept of Green Building

Sustainable development facilitates quality of life and thereby allows people to live in a healthy environment with improved social, economic and environmental conditions for both the present and the future generations (Ortiz, Castells, & Sonnemann, 2009; Berardi, 2013). Kubba (2012) has stressed that the concept of green building has emerged with the essential purpose of improving the conventional design and construction practices to ensure sustainability. The Green Building Council of Australia defines the

concept of green building as the building design, construction and operational phases which significantly reduce the negative impact of development on the environment and occupants while increasing social equity, cultural and heritage issues, traditions, human health, and social infrastructure (SGS Economics and Planning Pty.Ltd, 2008; Kubba, 2012).

Hence green building rating system has become the background for assessing building environmental performance and integrating sustainable development into construction processes (GBCSL, 2011). Thereby, GBCSL (2011) has introduced the GREENSL® rating system as an assessment tool to provide a guideline for green building construction. Further Kats (2003) has also elaborated that it provides several benefits to occupants such as, lower RCs, higher returns on investments, healthy interior spaces for occupants, better aesthetic appearance etc.

3. Benefits of Green Buildings

SGS Economics and Planning Pty. Ltd (2008) and Wilhelm (2005) have stressed that the financial, social and environmental benefits that green buildings provide make them more comfortable than conventional buildings. Some of the significant financial benefits that accrue are the savings on RCs which can be used as a marketing tool for potential clients and tenants (Gottfried, 1996; SGS Economics and Planning Pty. Ltd 2008). Apart from that Kats (2003) has stressed that green buildings produce 20% cost savings over the life of the buildings.

On the other hand, Durmus-Pedini and Ashuri (2010) have stated that their environmental benefits include the reduction of the impacts of natural resource consumption, minimising of the negative impact on the environment; conservation of water and energy; prevention of noise, air, water, soil and light pollution and provision of healthier environments. Meanwhile its social benefits include the improvement of employee health and productivity, satisfaction of occupants, indoor environment quality, thermal conditions, and the preservation of water resources foe future generation (Fernando, 2012; Tatari & Kucukvar, 2011). In Sri Lanka, Jayalath (2010) and Bombugala and Atputharajah (2010) have witnessed that in the last few years the concept of green buildings has made considerable growth providing energy efficient buildings.

4. Life Cycle cost

life cycle cost (lcc) is defined as the ‘total cost of a building or its parts throughout its life, including the costs of planning, design,

acquisition, operations, maintenance and disposal, less any residual value' (pelzeter, 2007, s. 117). the author considers the period of lcc not only during the economic life-span but also during the entire period of existence of a building. lcc is especially useful when selecting better project alternatives in fulfilling the performance requirements. according to marszal and heiselberg (2011), the investment cost / initial cost of construction is defined as the sum of the planning cost, designing cost, construction cost including material cost, equipment cost, labour cost for all the works necessary for the construction process and other services required for building operation while rc includes the cost of maintenance and operation during the life span of the building.

5. Running Cost

RCs mainly consider and carefully account for the cost of annual operation and periodic maintenance during the entire economic life span of a building, and replacement of equipment after its service life (Forster & Kayan, 2009). The findings of Wang, Zmeureanu and Rivard (2005) have revealed that maintenance is usually required during the operational stage while transportation is an activity associated with most other stages and El-Haram and Horner (2002) have divided maintenance into two types as shown in

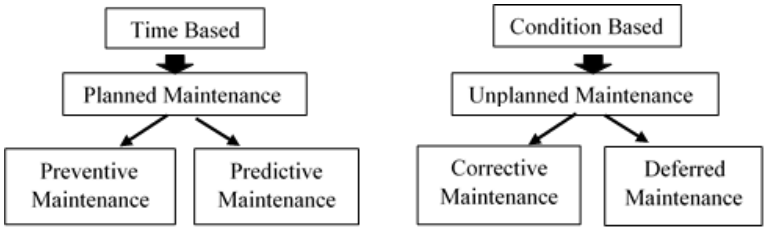

Figure 1, Types of maintenance

On the other hand, Aye et.al (2000) have stated that the operation of the energy supply system is associated with the running of the building systems such as heating and ventilation, air conditioning, lighting and power and vertical transportation. Therefore the cost involved in operating services is called the operation cost (Marszal & Heiselberg, 2011). Operation costs include costs of managing the built environment including administrative support services (Al-Khatam, 2003). The classification is improved in Table 1 where the RC components have been identified as direct and indirect costs separately.

Table 1, Classification of RCs Separately as Direct and Indirect Costs

Direct Cost (Material, Labour, Equipment)	Indirect Cost (Administration)
Main structure, Internal construction, Finishes and fittings, Services(mechanical, plumbing, electrical), Decoration, External work, Sustainable features, Energy Cost and other utilities cost	Staff cost, Planning cost, Training cost, Profit, Insurance, Taxes, Experts cost (consulting cost), Opportunity cost

Source (Maintenance Practice Committee, 1975; Brown & Robertson, 1990; Levitt, 2009; seeley, 1987)

5.1. RUNNING COST OF GREEN BUILDINGS

Properly designed green buildings incur reduced RCs related to heating, cooling, lighting and ventilation, water consumption and proper maintenance (ITU, 2012). Moreover, Nalewaik and Venters (2008) have identified the design of the building, material selection and the site construction as factors affecting RCs and also the fact that between 70% - 85 % of the building RCs can be influenced during the design stage.

5.1.1. Running Cost of Conventional Buildings Vs. Green Buildings

RCs of both buildings cover the cost of energy related to heating, cooling, electricity, gas and water supplies, maintenance work, repair or replacement of equipment, and other related soft costs (Nalewaik & Venters, 2008). In green buildings, energy consumed during the running stage of the building is reduced while conventional buildings consume large quantities of material and human resources (Local governments in Alameda County, 2009). Therefore Barnes (2012) has suggested that if the building is built in accordance with the LEED guidelines, it will become more efficient as far as the occupants are concerned. Meanwhile Fowler and Rauch (2008) have stressed that the conventional buildings do not use natural resources for lighting, air conditioning, electricity and material but that they only use artificial systems while green buildings use natural resources for these systems, i.e solar panels for electricity consumption which reduces the cost of the electricity used, green roof and glazed windows for the cooling system and LEDs for lighting system which consume lower energy. This has been clearly justified by the findings of Kats (2003) and Gottfried (1996) which indicate that green buildings are 28% more efficient than conventional buildings and that they generate 2% of their power requirements at -site from solar.

6. Importance of RC in Green Buildings

Improper maintenance and operation of the green buildings lead to unnecessary energy consumption, poor indoor air quality and environmental

damage (Wu, 2010). Furthermore the RC of a green building plays a vital role since life span of a green building will depend on its quality (Seo & Hwang, 2001). According to SGS Economics and Planning Pty.Ltd (2008) and Ryghaug and Sorensen (2009), the lack of understanding about the LCCs of buildings leads the focus to be mainly on the initial cost of the green building rather than on LCC. However, the effective maintenance and operation of the building facilitate long-term returns on investment through the reduced RC of green building construction (Barnes, 2012). Yet, the RC of green buildings is an under researched area in the construction industry in Sri Lanka which has to be thoroughly investigated if a productive outcome is to be obtained.

7. Research Methodology

In this research, the qualitative research approach which is appropriate for gathering and analysing data for the study of a contemporary phenomenon in its natural context, was followed. Four case studies were conducted using a document survey and semi structured interviews and cross case analysis was done using the data collected from six semi structured interviews done under the case studies. The collected data was analysed using both content analysis and statistical data analysis. Thus the findings were geared towards achieving the ultimate outcome by identifying the saving of RC of green buildings compared to that of conventional buildings

8. Research Findings and Data Analysis

Prior to analyzing the research findings in detail, the pilot survey was conducted by interview with four people of green building experts. The details of the respondents, are given in Table 2.

Table 2, Detail of Respondents in Pilot Survey

Profession	Position	Years of experience
Engineer	Project manager	25 years
Quantity Surveyor	General manager	20 years
Engineer	Mechanical engineer	7 years
Facilities Manager	Senior manager	20 years

The findings exposed significant cost components in building construction in Sri Lanka as shown in Table 3. Thereafter green and conventional buildings were compared in terms of each identified cost element and special reasons behind the increment of cost in green buildings in each cost component were highlighted.

Table 3, Identified components of Direct and Indirect Costs

Direct Cost		
Cost Components	**Cost Comparison**	**Special reasons behind the increment of cost in green buildings**
Main Structure Frame, External walls, Roof structure, Roof covering, Roof lights and glazing, Gutters and rainwater pipes, Windows, External doors and glazing	More in green buildings	• Roof Structure- Due to roof plantation cleaning • Roof covering/ Gutters and rainwater pipes - Due to rain water collection, adequate cleaning system required • Roof lights and glazing- To get the day light regularly, want to clean the high efficiency glazes • External doors and glazing- To reduce the heat, use heat proof stickers
Internal construction Staircase, Floors, Partition walls, Internal doors including glazing	More in green buildings	• Staircase- To maintain salvage timber stair case additional manpower required
Finishes and fittings Ceiling finishes, Wall finishes, Floor finishes, Ironmongery	Same or sometime more in green buildings	• Ceiling & Wall finishes- Maintenance cost is high due to the green certified materials • Floor finishes- Extra cost for maintaining green certified carpet floor
Plumbing and sanitary fittings Cold and hot water supply pipe, valve, Sanitary fittings, Disposal pipe	Same or sometime more in green buildings	• Sanitary fittings- using efficiency fittings (E.g- sensor taps)
Mechanical services, heating and ventilating Lift, AC, Chiller, Fire, Elevator	Same as conventional buildings	• Chiller- Use of energy efficiency chiller
Electrical services Wiring, Main switch board and meter, Appliances and fittings, Lighting protection, Other electrical equipment like fax	Same as conventional buildings	• Appliances and fittings- Use of energy efficiency lamps
Sustainable features PV panel, Solar tubes, Eco roof, Storm water recycling equipment, LED lights	More in green buildings	• Generally only green building have this features • Eco roof- Due to maintenance of roof plantation cost is high • LED lights- use of energy efficiency lamps are high • Storm water recycling equipment -Additional cost for cleaning those equipment
Indirect cost		
Staff facilities, Security staff, CCTV operation	Same as conventional buildings	• Same Cost
Planning or inception cost, Operator, Operational manual	More in green buildings	• Involvement of expertise in maintenance period
Energy audit	Additional in green buildings	• Generally only green building have this features

8.1. DATA ANALYSIS – SEMI STRUCTURED INTERVIEWS

Subsequently, a cross case analysis was done by selecting a green building and a conventional building, to compare its RCs in terms of the previously identified cost components. The details of the four cases are shown briefly in Table 4.

Table 4, Details of Cases

	Case A - Bank Buildings		**Case B - Office Buildings**	
	Green Building (Case A1)	**Conventional Building (Case A2)**	**Green Building (Case B1)**	**Conventional Building (Case B2)**
Employer	Bank	Bank	Office	Office
Project duration	2009-2012	2009-2011	2006-2009	2010-2012
Contract sum	132 Million	150 Million	390 Million	340 Million
Number of stories	2 storey	3 storey	3 storey	4 storey
Gross floor area	10, 000 sq.ft	13,000 sq.ft	100,000 sq.ft	90,000 sq.ft
Procurement method	Measure and Pay	Measure and Pay	Measure and Pay	Measure and Pay
Running period until 2014	2 years	3 years	5 years	2 years

The analysis was conducted for the cost components and cost savings of RC. The cost components were divided in to two categories as direct and indirect costs. In the main structure, differences and similarities of the cost components have been identified and the respondents have stated that the RC for the frame structure, external walls and windows are same for both conventional and green buildings while RC of the roof coverings of green buildings is higher than that of the conventional buildings. Meanwhile, the majority of the respondents have indicated that the RCs for gutters and rain water pipes are higher in green buildings. Even though only one respondent has stated that "*there is a small difference in cost from that of a conventional building because there is door glazing which needs heat proof stickers*", all the other respondents have stated that the cost is same for external doors and glazing in both types of buildings. In the meantime when building appearance mainly depends on the finishes and fittings, the majority of the respondents have indicated that the RC components of the wall, ceiling and floor finishes are same for both buildings. However, one respondent has said that "*the indoor environmental heat in a conventional building is higher than that in a green building thus the cost of finishing of a conventional building will be more than that of a green building making the maintenance cost of a conventional building to be higher than that of a green buildings*".

As the bottom line lies in the internal construction, the RC of finishes and fittings cannot be predicted. Apart from that sustainable features such as PV

panels, solar tubes, eco roof LED lights and storm water recycling equipment play a significant role in green Buildings and their RCs are higher compared to those of conventional buildings. With regard to water consumption, the cost is less in green buildings whereas the RC remains same for both types of buildings in respect of fuel consumption. In considering the indirect cost component of RC, respondents argued that the cost of staff facilities is high in green buildings as it is the educated people who are involved in running them. Under the planning and inception cost one respondent has highlighted that, "*there is a little difference because in green buildings we have to provide an energy simulation plan and with that we have to submit additional documentation making the cost high*". On the other hand, the majority of the respondents have stated that the RC of the building management system can vary because of the building services. Hence the analysis has revealed the possibility of having a realistic platform on which the RC components of the green and conventional buildings could be discussed thoroughly in terms of their direct and indirect costs.

8.2. DATA ANALYSIS – DOCUMENT REVIEW

For the analysis done under the document review, all data related to the cost components of the running period were collected from documents prepared in 2013. Table 5 gives the RC details of labour, material and equipment (including cleaning, maintenance repairing) of different buildings.

Table 5, RC data of each Cases

Cost components	Case A1	Case A2	Case B1	Case B2
DIRECT COST				
Main structure	21,299.00	12,835.00	300,000.00	280,000.00
Internal construction	8,520.00	7,333.00	162,000.00	160,000.00
Finishes and fittings	42,600.00	11,920.00	600,000.00	260,000.00
Plumbing and sanitary fittings	63,899.00	18,339.00	900,000.00	400,000.00
Mechanical services, heating and ventilating	266,400.00	324,922.00	1,500,000.00	340,000.00
Electrical services	19,170.00	9,252.00	270,000.00	195,000.00
External works	480,000.00	153,600.00	960,000.00	668,000.00
Internal and external decoration	17,040.00	16,506.00	540,000.00	360,000.00
Sustainable features	506,940.00	917.00	2,784,600.00	20,000.00
Energy consumption	1,939,788.00	9,739,600.00	4,302,800.00	19,134,461.00
others	78,000.00	18,000.00	145,000.00	25,000.00
Total cost	**3,443,656.00**	**10,313,224.00**	**12,464,400.00**	**21,842,461.00**
INDIRECT COST				
Administration	6,010,000.00	3,605,000.00	10,825,000.00	7,220,000.00
BMS	-	-	1,800,000.00	900,000.00
Other outsource	3,060,000.00	3,294,666.00	410,000.00	525,000.00
Documentation	200,000.00	100,000.00	350,000.00	200,000.00
Total cost	**9,270,000.00**	**6,999,666.00**	**13,385,000.00**	**8,845,000.00**

The main RC varies for only two cost components in the four cases. The RC of the roof covering of Case A1 (green building) is 55% higher than that of Case A2. Similarly, Case B1 has a 31% higher cost than Case B2. Case A uses storm water recycling equipment for purifying the water. Similarly, the RC for gutters and rain water pipes is higher in green buildings. Thus, in the main structure, the RC is more in green buildings than in conventional buildings. In respect of ceiling, wall and floor finishes , the RCs are high for green buildings and Case A1 has nearly a 73% higher cost than Case A2. Similarly in Case B1 it is 68% higher than in Case B2. Even though the gross floor area matters for some extent, the cost is not saved here during the running period of green buildings.

Ultimately in each case, green buildings are not capable of saving the RC component during the running period. In contrary to this in the analysis of the direct cost components of energy consumption related to fuel, electricity and water it is found that nearly 78% of the RC of green buildings is saved compared to that of conventional buildings and in Case A1 this is 66% and in Case B1 it is 42%. On the other hand, the indirect cost of RC is 24% higher in Case A1 than in Case A2. Similarly, in Case B, the RC of green buildings is 33% higher than in conventional buildings. Thus, in green buildings there is no saving from the RCs of indirect cost components. Eventually there is no saving of direct and indirect cost components and therefore the total RC in green buildings is less than in conventional buildings as shown in Table 6.

Table 6, Total Running Cost (RC)

Cost Components	Case A		Case B	
	Case A1	Case A2	Case B1	Case B2
Direct cost	3,443,656.00	10,313,224.00	12,464,400.00	21,842,461.00
Indirect cost	9,270,000.00	6,999,666.00	13,385,000.00	8,845,000.00
Total cost	12,713,656.00	17,312,890.00	25,849,400.00	30,687,461.00

Table 6 clearly depicts the total RC including both direct and indirect RC components of selected cases during a one year running period. The findings elaborated that in the green buildings of Case A, there is a 26% saving of RC of a conventional building during a one year running period. Similarly, in Case B1 there is a total saving of 15% from that of Case B2. Noticeably, the RC savings comes from direct cost components whereas indirect cost components add costs to green buildings.

According to the table the indirect RC is 24% higher in case A1 than case A2. Similarly, in Case B1, the RC of green building is 33% higher than conventional building. Thus, there is no running cost saving during the

running period when the indirect cost is considered. In green buildings, there is a saving of nearly 66% in the direct cost components of Section A buildings whereas for Section B buildings the cost saving is only 42%. However, RC of indirect cost components in green buildings is higher than those of conventional buildings. i.e. it is nearly 24% in Section A buildings and 33% in Section B buildings. Thus, the saving in costs is higher than the addition of costs during the running period of green buildings and this saving is only related to energy consumption.

Further, it has been automatically stressed that the cost savings are only from the energy consumption charges during the life cycle and ultimately the results highlighted that, in green buildings the saving of RC is a considerable benefits for the building owner.

5. Conclusions

Green buildings provide environmental, economic and social benefits as they are designed for a healthier environment to live in and work while reducing any negative impacts on the environment. However, the lack of knowledge on the cost of green building is a significant barrier in its implementation. In Sri Lanka, the lack of knowledge and projects based on green concept have already made the authorities to investigate the RC components and its savings. Under the savings of the RC, the contribution of the direct and indirect cost components is significant. When it is compared between the green and conventional buildings, the overall RC saving in the green buildings is heavily determined by the energy saving mechanism, while all the other maintenance and operational activities add cost to green buildings.

Although green buildings use more sustainable features to reduce energy cost during their running periods, in respect of maintenance there is an additional cost identified as expertise are involved during the running period in supervising labour and maintaining documentation. This indicates the necessity for an in depth analysis in generalizing the different situations when investigating the RC. Ultimately a thorough understanding of the RC leads to effective maintenance and operation of the buildings during their running periods, securing a long-term return on investment in the green building construction industry in Sri Lanka.

References

Ali, H. and Al Nsairat, S. 2009. Developing a green building assessment tool for developing countries – Case of Jordan. *Building and Environment*, 44(5), pp. 1053-1064.

Al-Khatam, J. A. 2003. *Buildings Maintenance Cost*. Saudi Arabia: King Fahd University of Petroleum and Minerals.

Aye, L., Bamford, N., Charters, B. and Robinson, J. 2000. Environmentally sustainable development: a life-cycle costing approach for a commercial office building in Melbourne, Australia. *Construction Management and Economics,* 18(8), pp. 927-934.

Barnes, L. L. 2012. Green buildings as sustainability education tools. *Library Hi Tech, 30*(3), 397-407. doi:10.1108/07378831211266546

Berardi, U. 2013. Clarifying the new interpretations of the concept of sustainable building. *Sustainable Cities and Society, 8*, 72-78. doi:10.1016/j.scs.2013.01.008

Brown, M. P. and Robertson, L. G. 1990. *Comparative office building maintenance costs.* Singapore, Longman Singapore Publishers (Pte)Ltd., pp. 67-73.

El-Haram, A. M., & Horner, W. M. 2002. Factors affecting housing maintenance. *Journal of Quality Maintenance, 8*(2), 115-123. doi:10.1108/135525102104300008

Fernando, W. 2012. *Benefits of adopting green concept for construction of buildings in Sri Lanka,* Sri Lanka: University of Moratuwa.

Forster, . M. A. and Kayan, B. 2009. Maintenance for historic buildings: a current perspective. *Structural Survey,* 27(3), pp. 210-229.

Fowler, M. K., & Rauch, M. E. 2008. *Assessing Green Building Performance: A Post Occupancy Evaluation of 12 GSA Buildings.* Washington: Pacific Northwest National Laboratory.

Gottfried, D. A. 1996. The Economics of Green Buildings. In D. A. Gottfried, *Sustainable Building Technical Manual, Green Building Design, Construction, and Operations* (pp. I.3-13). United States: Public Technology Inc., US Green Building Council.

Green Building Council Sri Lanka, 2011. *Green sl® rating system for built environment.* Sri Lanka: Green Building Council Sri Lanka.

International Telecommunication Union, 2012. *Sustainable buildings,* s.l.: ITU.

Jayantha, . M. W. & Man, S. W. 2013. Effect of green labelling on residential property price: case study in Hong Kong. *Journal of Facilities Management,* 11(1), pp. 31-51.

Jayalath, S. M. 2010, July 30. Build green to ensure sustainability. *Sri Lanka Energy Managers Association - Annual Sessions,* p. 32.

Kats, G. 2003. *Green building costs and financial benefits. Renewable energy trust.,* New England,: Westborough.

Kats, G. H. 2003. *Green building costs and financial benefits,* USA: Massachusetts Technology Collaborative.

Kubba, S. 2012. *Hand book of Green Building Design and Construction LEEDS BREEAM and GREEN GLOBES.* USA: Elsevier Inc. doi:10.1016/B978-1-85617-676-7.00014-2

Levitt, J., 2009. *The hand boof of maintenance management.* 2 ed. New York: Industrial Press Inc.

Local governments in Alameda County, 2009. *A guide to green maintenance and operations.* Oakland: StopWaste.Org.

Maintenance Practice Committee, 1975. *Maintenance Management,* Beikshire: The insitute of Building.

Marszal, . J. A. & Heiselberg, P. 2011. LCC analysis of a multi-storey residential net zero energy building in Denmark. *Energy,* Volume 36, pp. 5600-5609.

Ortiz, O., Castells, F., & Sonnemann, G. 2009. Sustainability in the construction industry: a review of recent developments based on LCA. *Construction and Building Materials, 23*, 28-39. doi:10.1016/j.conbuildmat.2007.11.012

Pelzeter, A., 2007. Building optimisation with LCCs – the influence of calculation methods. *Journal of Facilities Management,* 5(2), pp. 115-128.

Ryghaug, M., & Sørensen, H. K. 2009. How energy efficiency fails in the building industry. *Energy Policy,* 37, 984-991. doi:10.1016/j.enpol.2008.11.001

SGS Economics and Planning Pty.Ltd, 2008. Building green: financial costs and benefits. *Urbecon Bulletin,* pp. 1-7.

Tatari, O., & Kucukvar, M. 2011. Cost premium prediction of certified green buildings: a neural network approach. *Building and Environment, 46*, 1081-1086. doi:10.1016/j.buildenv.2010.11.009

Wang, W., Zmeureanu, R. & Rivard, H. 2005. Applying multi-objective genetic algorithmsin green building design optimization. *Building and Environment,* 40, pp. 1512-1525.

Wilhelm, D. M. 2005. *Green Building Specifics: Costs, Benefits and Case Studies.* United States: U.S Green Building Council.

Wu, S. 2010. Research opportunities in maintenance of office building services systems. Journal of Quality in Maintenance Engineering, 16(1), 23-33. doi:10.1108/13552511011030309