Whole Life Costing of Sustainable Design

K. Hunter, J. Kelly and G. Trufil

School of the Built and Natural Environment, Glasgow Caledonian University, Sustainability Centre Glasgow, Drummond House, 1 Hill Street, Glasgow, G3 6RN

Email: khu@gcal.ac.uk

Abstract: Sustainability is a large subject and one which is currently attracting considerable funding. However, attention is primarily being directed towards the macro economic issues of sustainable urban environments, sustainable power and sustainable infrastructure. The principles of whole life costing are well described; however, a standard method approach to whole life costing of sustainable design is not available. Whilst there are a number of publications which deal with sustainability at a global impact level, few deal with sustainability at a project level and none set a whole life cost methodology suitable for use by surveyors in option appraisal for representing costs and benefits associated with sustainability. It is clear that the majority of surveyors are grappling with the problem of a lack of tools to facilitate the production of management data in a standard form conducive for the client to make an informed cost - benefit decision.

This project is funded by the Royal Institution of Chartered Surveyors (RICS) Education Trust and builds on previous research into Whole Life Cost models and sustainability to produce a workable project based tool for surveyors focused on the key elements of insulation, controlled ventilation, micro and biomass heating and electricity generation. A standard approach to the whole life costing of sustainable design is required which is the intention of this research. This research will evolve a methodology for a judgement to be made on the basis of the full knowledge of the characteristics of the system proposed and its associated whole life costs. This paper will focus on phase one of three phases proposed which involves identifying the issues impacting sustainability. This will be done through an in depth review of sustainability literature to uncover the issues within sustainable design. The paper will conclude with the production of; a checklist of factors which impact whole life costing, and those elements of the whole life costing calculation.

Keywords: Issues, Surveyors, Sustainable Design Sustainability, Whole Life Costing

1. An Introduction to the Project

This research project is funded by the Royal Institution of Chartered Surveyors (RICS) Education Trust and aims to produce a workable project based tool for surveyors focused on the key elements of insulation, controlled ventilation, micro and biomass heating and electricity generation. This project builds on the work of a previous research project funded by the Society of Construction Quantity Surveyors (SCQS) to construct a user friendly document on whole life costing and design a software input tool for surveyors to use when calculating whole life costs. This particular project focuses on the sustainability issues to identify the barriers preventing more sustainable practices being adopted. The output of the project will be a whole life costing model containing the elements of sustainable design to promote more sustainable practices in the construction industry.

2. A Background on Sustainable Construction

Sustainable development relies on long term planning. Schmid (2003) states that; 'the future of sustainable construction has its roots in past and present actions and the future depends on our (ethical) awareness concerning the consequences of our acts and deeds.' Van Bueren and Priemus (2002) state that sustainable construction is; 'the design, development, construction, and management of real estate such that the negative environmental effects of the construction, restructuring, and management of the built environment are reduced as far as possible.'

The construction industry addresses the three dimensions of sustainability; environmental, social and economic, in different ways (Adetunji *et al*., 2003). Environmental factors in construction encompass the use of natural resources, waste minimisation, and energy and water efficiency to prevent a harmful effect on the environment. Social aspects include taking the stakeholders into account which include employees, suppliers and the community, and economic factors include the construction industry's contribution to economic growth and employment.

There are a number of drivers for change in sustainable construction outlined by Adetunji *et al* (2003), these are; government policy and regulations, business pressures, stakeholder expectations, increased realisation of the importance of the construction image, branding and reputation, and new client procurement policies. Adetunji *et al* (2003) cite Kibert (1994) who outlines what is involved in sustainable construction, this includes; whole life costing, procurement, site planning, material selection and use, recycling, and waste and energy minimisation. From this, it is evident that sustainability is a huge field incorporating different dimensions and areas within sustainable construction; this paper focuses on the whole life costing aspect of sustainable construction.

3. Whole Life Costing Defined

In recent years whole life costing has become best practice in construction procurement (Whole Life Cost Forum). Kirkham *et al.* (2004) highlights that Rethinking Construction, Best Value and procurement routes such as Public Private Partnerships and the Private Finance Initiative have lead to clients and designers putting more emphasis on the consideration of whole life costs. OGC Procurement Guide 07: Whole-life costing and cost management state that; 'value for money is the optimum combination of whole-life cost and quality to meet the user's requirement.' Whole life costing is defined as; 'a technique for examining and determining all the costs – in money terms – direct and indirect, of designing, building and facility management (operating, maintenance, support and replacement) of a building throughout its entire service life including the disposal cost' (El-Haram *et al*., 2002). OGC Procurement Guide 07 defines the whole-life costs of a facility as; 'the costs of acquiring it (including consultancy, design and construction costs, and equipment), the costs of operating it and the costs of maintaining it over its whole life through to its disposal – that is, the total ownership costs.' Total Asset Management (New South Wales Treasury, 2000), an Australian government document, use the term life cycle costing (LCC) and define the LCC of an asset as; 'the total cost throughout its life including planning, design, acquisition and support costs and any other costs directly attributable to owning or using the asset.' It should be noted that whole life costing, life cycle costing and through life costing are terms used interchangeably, however to prevent confusion, this paper uses the term whole life costing.

4. Whole Life Costing and Sustainability

Sorrell (2003) states that; 'the energy efficiency of new buildings is critical to a sustainable future.' It is highlighted that new construction can take advantage of energy efficient technology if the right choices are made on building form, fabric, orientation and building services. In terms of building services; heating, ventilation, air conditioning and lighting are where most consideration should be given to prevent problems (Sorrell, 2003). However, Sorrell highlights that building services tend to come last in the sequence of design work and therefore, usually result in being compromised to fit with the design as opposed to optimising their integration into the building to ensure energy efficiency. In addition to this, it is also suggested that for this reason building services are at risk from budget cuts and time pressures resulting in the rejection of sustainable energy features. This paper seeks to explore the issues related to sustainable design.

5. The Research Methodology

This research project has adopted an extensive research methodology consisting of three primary phases. However, this paper will focus on phase one of the three phases proposed which involves identifying the issues impacting sustainability.

Phase one consists of two strands of which strand A is the focus for this paper. Strand A includes a detailed examination of the sustainability literature to uncover the issues which impact sustainability generally. Strand B will involve the review of methods and models contained in whole life costing literature and will investigate option appraisal methodologies. Strand B will be touched on with regards to a previous project conducted on behalf of the Society of Construction Quantity Surveyors (SCQS) to develop a user friendly whole life costing tool for use by surveyors (Hunter *et al*., 2005).

Phase two will involve the construction of a whole life costing model which will include the issues impacting sustainable design. The model will be subject to robust testing and simulation exercises and will also be demonstrated at seminars involving designers and surveyors. The model will be refined in light of testing and any recommendations made for improvements. Phase three will involve the launch of the sustainability whole life costing model, the accompanying document / user guide for use of the model, and the final report describing the research methods process and the methodology for the use of the model.

6. Whole Life Cost Models

A previous research project conducted by the research team on behalf of the SCQS involved the development of a framework document on whole life costing to replace the dated Life Cycle Cost Planning publication (Smith, 1984) and an accompanying IT-based whole life costing model for use by surveyors. Prior to the development of this model, a review of whole life cost models was conducted to identify what tools were currently available on the market. A key finding of this was that there were not many user friendly models available that were capable of providing the type of system that the SCQS were looking for. Most systems adopted a 'black box' approach meaning that the user was unable to see what was going on behind the input of cost information. One of the key requirements for the model developed for the SCQS was that it be user friendly. Therefore, the tool was designed with this in mind using a 'clear box' approach in preference to a black box which prompted the user to input the information into a series of input boxes allowing them to see the information being built up in the whole life cycle costing spreadsheet as cost information was input.

The SCQS research project involved an investigation of ongoing research and tools available in the industry on whole life costing models. This included research undertaken by Dundee University funded by the EPSRC to develop a generic framework for the collection of whole life cost data for the building industry, the Whole Life Cost Forum (WLCF launched November 1999, (http://www.wlcf.org.uk), a national initiative on whole life cost, a whole life cost tool developed by the Building Research Establishment (BRE) (http://projects.bre.co.uk/wlccomparator), and EuroLifeForm (http://www.eurolifeform.com), a probabilistic approach for predicting life cycle costs.

Dundee University – This project was funded by the EPSRC to develop a generic approach to minimising whole life costs in the construction industry (El-Haram *et al*., 2002). The objectives of the project were to design a comprehensive, consistent and flexible framework for collecting whole life data; to write the specification for a construction industry maintenance management operating system and develop demonstration software; and, to quantify the benefits of implementation at the design stage of construction projects.

Whole Life Cost Forum – The WLCF claims to have been set up as the first construction industry initiative to promote the use of whole-life costs. It was launched in November 1999 with the aim of developing an online comparator tool to remove errors and prevent the reliance on spreadsheets. One of the main objectives was to advance the use of whole life costing along the entire length of the supply chain. The tool allows whole-life costs to be compared on a like-for-like basis and works on the basis that the supplier is the best source for information on whole life costs of their own products. There is also a system that provides benchmarks contained in a central database to allow for comparisons across similar projects. This tool is available on the web for those who want to set up their own project and can also be used to select suppliers and their products. The WLCF Online Comparator Tool can be found at www.wlcf.org.uk. Information is provided on whole-life costs, training materials and the organisation itself.

Building Research Establishment – WLCcomparator (http://projects.bre.co.uk/wlccomparator) is a tool developed by BRE to calculate the whole life cost of building elements and components. It reduces the amount of time normally spent working on whole life cost calculations by minimising the effort required. The tool highlights how higher capital costs at the outset can be more effective over the long term with regard to lower maintenance and operating costs.

EuroLifeForm (ELF) – This is a three-year European RTD project with 14 partners from eight countries, partly funded by the European Union under the Competitive and Sustainable Growth (GROWTH) specific programme. EuroLifeForm (http://www.eurolifeform.com) is a probabilistic approach for predicting life cycle costs and performance of buildings and civil infrastructure. The project aims to develop a design methodology and supporting data, using a probabilistic approach. It addresses technological and cost issues and considers environmental impact and other factors. The final deliverable will be a generic model for Life Cycle Costing and Performance (LCCP), in a software format. This will be applicable to the design of buildings and other facilities to optimise the whole life costs and to optimise interventions through maintenance and repair (Kirkham *et al*., 2004).

Other whole life costing methodologies are also available such as BRE's Ecopoints method which identifies the environmental impacts across the life cycle of construction materials or components from extraction to disposal. The Ecopoint system assigns weights for construction materials across thirteen categories which include climate change, atmospheric and water pollution, and raw materials consumption. The higher the Ecopoint score the higher the environmental impact (Edwards *et al*., 2000).

Since the SCQS project, other whole life costing (WLC) tools have emerged such as BRE's Whole Life Value (WLV) Framework which is a web-based tool that addresses sustainability in the built environment; http://www.wlv.org.uk. The framework allows the user to access a range of resources within a database which include guidance notes, information papers, and tools to assist in identifying and achieving higher levels of sustainability in projects (Waterman and Bourke, 2004).

Other tools also exist such as ENVEST which is also developed by BRE (http://envestv2.bre.co.uk/). This is a software tool that makes it easier to design buildings to ensure low environmental impacts and takes whole life costs into consideration. ENVEST works by identifying the elements of the building that have the most environmental impact and influence on whole life costs after this information has been input by user. It shows the effects of selecting different materials and predicts the environmental and cost impact for heating, cooling and operation a building. This information can then be demonstrated to clients and an environmental report can be generated.

Sorrell (2003) suggests that standardised methodologies for assessing whole life costs and a method for analysing the energy efficiency of design options is what is required to ensure more sustainable design. This research project aims to address this by considering those tools and methodologies already available and by identifying all the issues preventing the adoption of sustainable practices.

7. Issues Impacting Sustainability

Despite sustainable design and the adoption of sustainable practices being of benefit to the environment, the industry, and the end user, the literature review resulted in a number of issues and barriers impacting its adoption. These range from public policy to issues with the construction supply chain and fragmentation of the industry. Sorrell (2003) states that; 'barriers to energy efficiency in the construction sector are pervasive and multifaceted.' Van Bueren and Priemus (2002) state that decisions on sustainable practice are impacted by various societal and policy sectors as well as the building sector. This is supported by Sorrell (2003) who highlights that changing energy policy is not enough as the basic organisation of the industry and the relationship between the team are what needs to be right to ensure energy efficient design.

Impacts and barriers have been identified in a study conducted by Schmid (2003) who spoke to experts in the field of sustainable building in namely the UK, USA, Italy and Indonesia. The five main impacts identified were; (1) government policy, (2) market, supply chains and economies, (3) technological possibilities, (4) users, and (5) designers. The five top barriers were: (1) economies, supply chain and market, (2) users, clients and consumers, (3) designers, planners and architects, (4) government policy, and (5) other obstacles.

Bartlett and Howard (2000) suggest that there is a misconception in the construction industry that energy efficient and environmentally friendly buildings cost 5 - 15% more to build. They outline one of the reasons for this being that examples of environmentally friendly buildings are used in the press that are usually 'futuristic' buildings that do cost more to build and therefore the wrong conclusions are drawn that green buildings are more expensive and complex to build. This is supported by Sorrell (2003) who highlights that there may be a bias against energy efficient buildings as they tend to involve more design work and therefore a timelier design process despite the possible result of lower capital and operating costs. It is stated that; 'at all stages of the construction process, it can take longer to design, assess and implement novel and unfamiliar features than to use tried and trusted solutions.' In addition to this, it is insinuated that contractors may modify previous bids due to time constraints resulting in inappropriate specifications not fully addressing the client's requirements.

Bartlett and Howard outline that construction professionals as well as funders and insurers have no long term interests in the building as there is little environmental interest or financial incentive to do so. However, the introduction of the Private Finance Initiative (PFI) as a procurement route in public sector projects has meant that construction professionals now have a stake in the lifetime performance of public buildings which should impact on whole life costs.

Sorrell (2003) suggests that the organisation of the construction industry is the key barrier to the adoption of sustainable practices. This includes the linear design process, the reliance on cost-based competitive tendering and the incentives placed upon different actors. Sorrell outlines the consequences of the these barriers which are; oversizing of equipment, reduced quality, neglect of whole life costs and a lack of integrated design.

The contractual culture of the industry is another barrier. Designers are liable and if their design does not meet specification then they may get sued. This can lead to over-design and oversized equipment such as that of a heating or an air conditioning system which may be too big in relation to the load resulting in reduced energy efficiency (Sorrell, 2003). Sorrell cites Brittain (1997) who estimates that 15% or more of UK HVAC energy consumption is due to the oversizing of equipment. However, engineers are not penalised for oversizing or rewarded for specifying equipment of optimum size, therefore there is no incentive to do so.

Adetunji *et al* (2003) outlines the barriers to sustainable construction which involve the characteristics of construction industry; teams forming for short periods, divisions between the trades, diversity of stakeholders, fragmentation, rigid specifications, client unwillingness, and the conservative culture of the industry. Funding and speed of construction are other barriers preventing the adoption of sustainable practices. Their impact may be due to funds having to be spent within a specific timeframe preventing time for the design of sustainable features.

Sorrell (2003) suggests that capital constraints are a primary reason for the lack of energy efficient measures being taken. Also mentioned is time in terms of spending the time getting the right people together to discuss ideas and be creative. In a study conducted by Sorrell it was discovered that there was the perception that innovative practices took longer and usually resulted in the unexpected to be dealt with therefore, resulting in the design team going for the safest option.

Commissioning is another area where not enough time is spent to ensure an energy efficient building. This includes the commissioning of the services and the time spent training the staff in the operation of the building. Again, communication is key (Sorrell, 2003). User discipline of the building is also outlined by Van Bueren and Priemus (2002) who suggest that the adoption of sustainable features requires the user to change their behaviour to optimise the use of the facility.

A barrier that Van Bueren and Priemus (2002) outline is that people involved in location development do not take advantage of the opportunities for environmental practices by paying due regard to the infrastructure for transport, water, energy and waste which can impact the building efficiency at a later stage.

Whole life costs, the focus of this research project in the area of sustainability, are a key area for consideration. However, only the client will have an incentive to maximise whole life costs as this is of no concern to the contractors and consultants as they do not have a long term interest in the facility and therefore will opt for the most practical solutions in the short term. However, this is not the case for contracts that involve the design-build-operate-transfer route which results in the contractor being responsible for the operation of the facility as well as its construction.

8. Moving Towards Sustainable Practices

An integrated design team and good communication is required to ensure energy efficient measures are employed (Sorrell, 2003). Currently the industry is fragmented, there is a lot of subcontracting and a new team is formed for each project. In addition to this, clients have to request green buildings and have an understanding of sustainable issues (Sorrell, 2003; Abidin and Pasquire, 2005).

It is evident that due to the fragmented nature of the construction industry there needs to be somebody driving energy efficiency for it to be considered. This is supported by Sorrell (2003) and Van Bueren and Priemus (2002) who emphasize that there should be better communication, coordination and interaction between the design team. They suggest that only one or a few players should be responsible for coordinating sustainable construction to address the fragmented nature of the industry and state that; 'sustainable construction measures need the support of multiple actors at various places and times in the decision making process to become effective.' This was also the case highlighted by Bartlett and Howard (2000) who suggest that green buildings require a knowledgeable consultant being involved at each stage of the design process. Van Bueren and Priemus (2002) outline that there are conflicting goals between departments that manage the construction process.

Sorrell (2003) suggests various measure to improve sustainable practices, these are:

- Making developers more accountable for the performance of buildings in use
- Widespread adoption of whole life costing
- Development of integrated design
- Adoption of post-occupancy evaluation
- Client education
- Comparison of building performance against standardised benchmarks

Bartlett and Howard (2000); Sorrell (2003) and Abidin and Pasquire (2005) specifically mention 'value management' as a means to address sustainability. It is suggested that sustainable practices are integrated into the design in the early stages and then 'proactively value managed' (Bartlett and Howard, 2000). Value management focuses on eliminating waste and examining the whole life costs of the facility to ensure the best value option is selected based on the values important to the client. Van Bueren and Priemus (2002) emphasize the improvement of communication between players which is evidently something that value management could address.

Edwards *et al* (2000) outlines the role each of the key players in the construction industry should play towards improving sustainability. For instance, the client should be asking the contractor for WLC information, considering how to reduce environmental impacts over the life of the building and could be keeping facilities management records to inform WLC on future projects. The design team requires the knowledge to provide environmental information about the design and communicate with sub-contractors on the materials that are to be used. Materials suppliers need to be able to provide information on WLC, durability and maintenance data about their products. Bartlett and Howard (2000) support this by suggesting that construction professionals should know more about whole life costs to be able to inform their clients to make decisions based on sustainability aspects. They also highlight that manufacturers / materials suppliers have a huge influence on the supply chain in terms of being able to demonstrate the whole life costs of their products to decision makers.

9. Sustainable Practices

Schmid (2003) suggests that the industry review the way that it builds to encourage more sustainable construction. A review of fifteen case studies on sustainable refurbishment by Sustainable Homes (www.sustainablehomes.co.uk) resulted in many good practice ideas which have been collated and are tabulated in Table 1.

Table 1 – Sustainable Design Elements

Sustainable Design Element	Good Practice Idea
Insulation	• Installation of a wind skin • Dry-lined brick external walls • Cavity insulation / external insulation (board and rendered) • Loft insulation • Insulation of hot water cylinders and water pipes
Sustainable materials	• Sustainably sourced timber windows • Use of natural or recycled materials • Locally sourced products
Sustainable heating	• Solar water heating panels • Photovoltaic panels • Central heating / gas condensing boilers • Thermostatic radiator valves
Managing waste	• Organic waste disposal units • Dedicated space for storing segregated domestic waste (encourages household to recycle) • Waste separation bins and chutes
Re-using and reclaiming	• Re-using window frames, kitchen units, internal joinery and carpentry items • Reclaiming and reusing bricks and using crushed concrete infill
Other	• Low energy light bulbs • Double glazed low-emissivity glass • Grey-water recycling system / rainwater harvesting system • Installation of water butts • Underground water storage tanks • Water based paints and stains • Passive ventilation • Low-flush toilets / dual flush WCs, spray taps and low-flow showers • Time monitoring switches on bathroom water supply • Draught-proofing • Wind powered street light • Roof wind turbine

This research study explores the key elements of insulation, controlled ventilation, micro and biomass heating and electricity generation to produce a workable based project tool for surveyors. It is clear that there are many issues and obstacles to be overcome with regards to these areas from the literature and examples given. For instance, insulation is an area where huge cost savings over the life of the building could be made. Insulation provides thermal resistance in a buildings structure to prevent unnecessary heat loss. However, there are a number of considerations that have to be taken to prevent the following from occurring; air leakage, dampness, poor detailing and application, and poor quality of the product. In addition, there can also be various health and environmental problems with many types of insulation (http://naturalbuildingproductscouk). Therefore, it is important to counteract these factors and select sustainable insulation that considers the whole life costs and is better value for the end user.

Biomass heating is now becoming an area of interest particularly where the Carbon Trust are concerned. Biomass involves using material drawn from a number of sources, such as; wood, straw, crops, and animal wastes to generate heat and electricity. The Carbon Trust has launched a £5 million project to commercially develop biomass heat in the UK. The project aims to reduce the costs of biomass, reduce supply chain risks, and raise awareness. Currently there are a number of barriers that require to be overcome for the adoption of biomass to be successful, these are; high costs, an immature supply chain infrastructure and a lack of awareness of the benefits of biomass (http://carbontrust.co.uk). However, biomass has the potential to deliver carbon savings of up to 5.6MtC per annum and therefore, is an area certainly worthy of development to meet the UK's carbon targets.

10. Summary and Conclusion

It is evident that sustainability in general is a huge field incorporating different dimensions and within that there are different areas to consider with regards to sustainable construction. This paper has focused on the issues concerning whole life costing in sustainable construction with a view to improving the adoption of sustainable practices which will be dealt with through the production of a whole life costing tool incorporating sustainable aspects and issues to consider to be developed at a later stage in the research programme.

This paper has formed the first stage of the research study by clearly identifying the barriers preventing the adoption of sustainable practices in the construction industry and has reviewed the various ways in which these obstacles could be overcome. This information will be incorporated in the proposed sustainable whole life costing tool to prompt the user to consider these issues and to inform the client when reviewing the whole life costs of a facility.

A definition of whole life costing and the various tools and methodologies available have been reviewed. As well as this, a background on sustainable construction and how this links with whole life costing has been provided. The barriers to the adoption of sustainable practices in the construction industry have been identified and this will be used to inform the next stage of the research which will involve interviewing those designers involved in sustainable building projects to uncover the issues within sustainable design.

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