SUSTAINABLE HOUSING RETROFIT DEVELOPMENT USING WHOLELIFE COSTING

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Abstract: Making existing buildings more sustainable involves a significant level of investment which more often than none, requires the consideration of a long-term view in terms of returns. Several options exist and whilst technology continues to improve the ability to conceptualise, design and implement these purported solutions, property owners and registered social landlords still require a means of assessing the cost implications from a whole life cycle point of view. Such solutions usually comprise of a combination of measures which seek to address: energy efficiency improvements, the use of environmentally friendly materials and procedures in addition to the retrofitting of components that can aid the principal objectives of energy performance, low carbon emissions and overall sustainability.

The 'Eco-terrace' project's objective was to radically improve the energy performance of existing UK Victorian terrace properties and provide environmentally friendly, well designed, modern, desirable and energy efficient homes using principles that could be repeated on other properties of a similar nature. Six pre-1919 terraced properties in Chesterton, Newcastle under Lyme were radically re-modeled and refurbished to provide contemporary living accommodation to a very high energy efficient standard. The project achieved an 'Excellent' standard under the BRE 'Eco-homes' assessment, equivalent to UK Code for Sustainable Homes Level 4/5. Generally, the six properties, which are of differing size and layout, adhered to the following core principles: retention of the front elevation facades to preserve the appearance of the street scene; removal of the rear elevation 'out-rigger' extensions and relocation of the kitchen to the centre of the house and bathroom to the first floor; providing integrated 'sun-space' extensions, angled to make best use of the sun's energy; as a result of removing the rear out-rigger extensions, create a larger and more usable rear garden and where access permits, provision of off-street parking; the use of glazed walls and doors to deliver natural light throughout the accommodation; focus on insulating the existing building fabric and ensuring a high degree of air tightness with an energy efficient ventilation strategy; and the avoidance short-lived technologies that may prove to be obsolete before the long-term benefit is realised.

All of the six properties had data loggers and individual circuit meters providing data on energy consumption, together with an occupant survey, capturing the qualitative data on what it is like to live in the properties.

A wholelife costing study was commissioned by the projects managers in order to assess the rationale for the measures undertaken. Two of the six properties which had already been occupied provided the data for the wholelife costing assessment. Four options of assessment were defined as: do-nothing; carry out minimal upgrade; Eco Terrace design; and Code 4 Sustainable Homes design. A sensitivity analysis was thus conducted and this was aimed at demonstrating the effect of variability of energy costs on the various options considered. A financial model was subsequently created for each option and each model was populated with the project's capital/maintenance/energy costs. Net Present Value (NPV) results were also computed in addition to carrying out a sensitivity analysis for energy variations over the life of the property.

With respect to the four options analysed, the Ecoterrace option had the most reasonable initial capital and maximum NPV (Lifecycle) costs. However, operating costs are at about the same level when comparing the Ecoterrace and Code 4 Sustainable Homes options. Nonetheless, the Ecoterrace option still demonstrated the best NPV (Lifecycle) costs when compared to the other options. The study therefore provided a platform for a justification assessment which can be enhanced with additional data acquisition and the consideration of other technologies or options via further research.

Keywords: Costing, Housing, Refurbishment, Sustainability, Wholelife

INTRODUCTION

The United Kingdom (UK) (like most countries of Europe with aging stock) is witnessing a huge increase in major alteration and refurbishment works in recent times. This is due partly to the need to adapt buildings and other structures to the ever evolving user requirements and partly to the need to upgrade building performance [2]. The scales of the projects vary substantially depending on the client requirements. At the domestic level, a substantial amount of such works entail permitted extensions, loft conversions, basement constructions and more recently work involving retrofitting of old stock to make them more energy efficient [4]. At the non-domestic level, alteration and refurbishment projects would normally entail a significant amount of demolition, extension and refurbishment activity. In some rare cases, and especially on the older stock, such works involve complete demolition and new build. Whichever way, however, evidence suggests that this trend is likely to continue in the foreseeable future as the industry continues to address the requirements of sustainable development [5].

Making existing buildings more sustainable involves a significant level of investment which more often than none, requires the consideration of a long-term view in terms of returns [3]. Several options exist and whilst technology continues to improve the ability to conceptualise, design and implement these purported solutions, property owners and registered social landlords still require a means of assessing the cost implications from a whole life cycle point of view [1]. Such solutions usually comprise of a combination of measures which seek to address: energy efficiency improvements, the use of environmentally friendly materials and procedures in addition to the retrofitting of components that can aid the principal objectives of energy performance, low carbon emissions and overall sustainability

BACKGROUND TO THE STUDY

The 'Eco-terrace' project's objective was to radically improve the energy performance of existing Victorian terrace properties and provide environmentally friendly, well designed, modern, desirable and energy efficient homes using principles that could be repeated on other properties of a similar nature.

Six pre-1919 terraced properties in Chesterton, Newcastle under Lyme were radically remodelled and refurbished to provide contemporary living accommodation to a very high energy efficient standard. The project achieved an 'Excellent' standard under the BRE 'Eco-homes' assessment, equivalent to Code for Sustainable Homes Level 4/5.

In brief, the six properties, which are of differing size and layout, adhered to the following core principles: (a) Retain the front elevation facades to preserve the appearance of the street scene; (b) Remove the rear elevation 'out-rigger' extension and relocate the kitchen to the centre of the house and bathroom to the first floor; (c) Provide integrated 'sun-space' extensions, angled to make best use of the sun's energy; (d) As a result of removing the rear out-rigger extensions, create a larger and more usable rear garden and where access permits, provide off-street parking (e) Use glazed walls and doors to deliver natural light throughout the accommodation; (f) Focus on insulating the existing building fabric and ensure a high degree of air tightness with an energy efficient ventilation strategy; (g) Avoid short-lived technologies that may prove to be obsolete before the long-term benefit is realised.

All of the six properties had data loggers and individual circuit meters providing data on energy consumption, together with an occupant survey, capturing the qualitative data on what it is like to live in the properties.

As at the time of compiling this report, only two of the six properties were occupied and these are the properties that provided the data for this study.

AIM AND OBJECTIVES AND SCOPE OF STUDY

The objective of this study was to analyse and calculate the whole life costs of the two identified eco-terraces based on a type model. In this context, therefore, whole life costs consist of: (a) Capital costs of the refurbishment project; (b) Maintenance costs associated with keeping the accommodation up to a reasonable state of repair; (c) Energy costs associated with running the accommodation to a habitable standard.

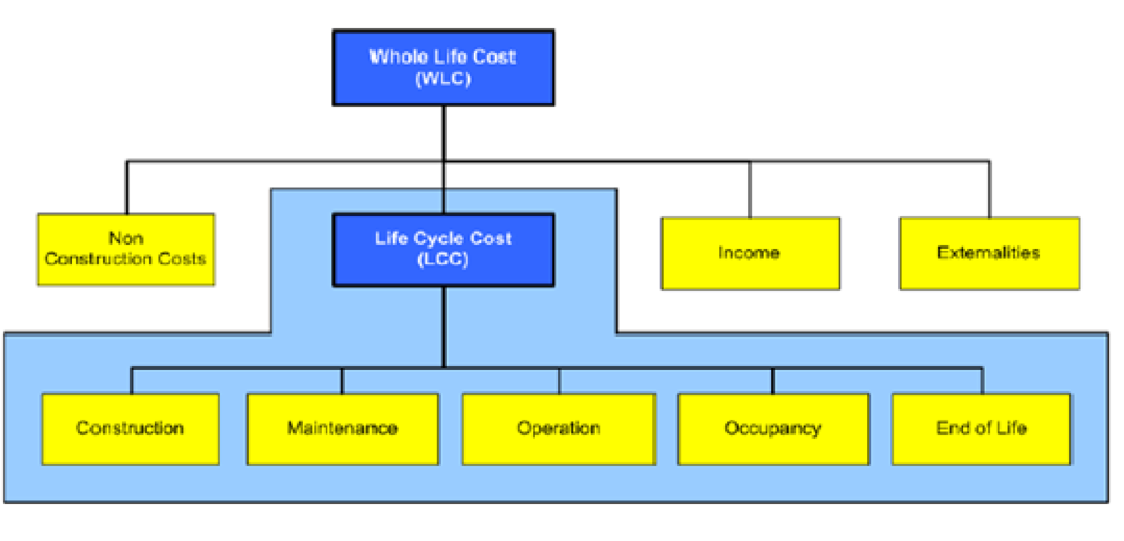

Figure 1: Whole Life Cycle Costing and LCC Elements (Source: BS EN 15686-5:2008)

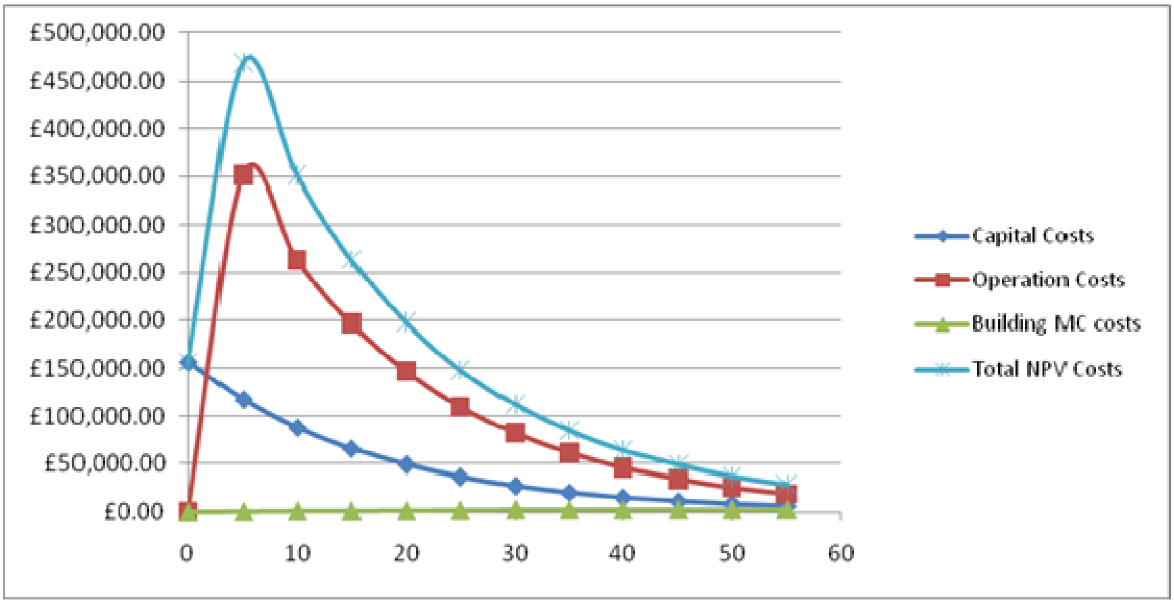

Figure 2: NPV Calculations for the Do-Nothing Option

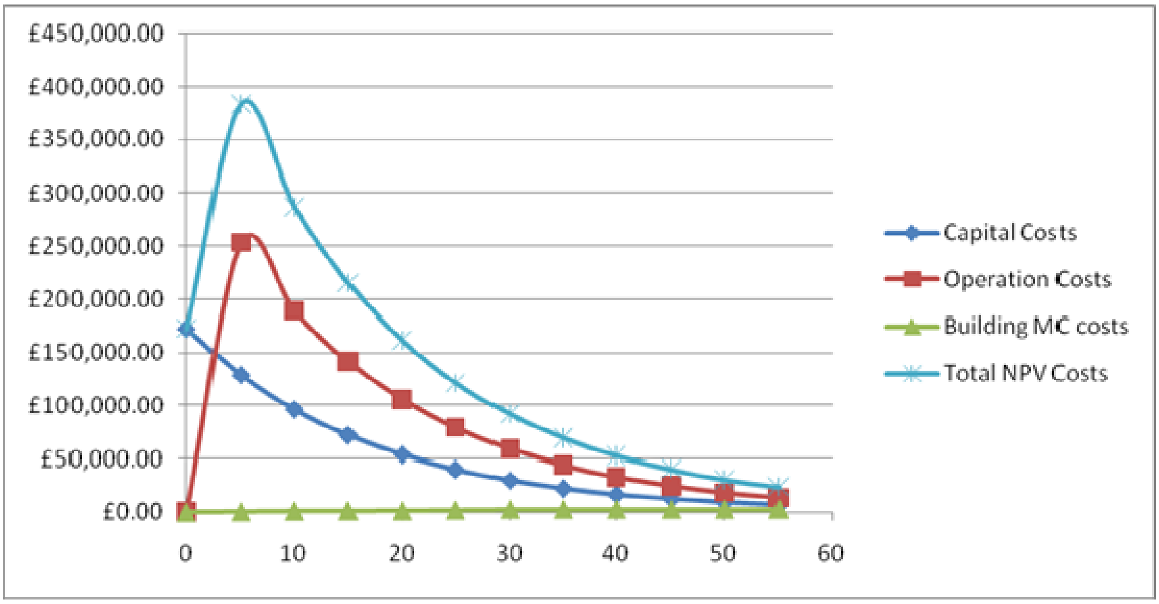

Figure 3: NPV Calculations for the Minimal Upgrade Option

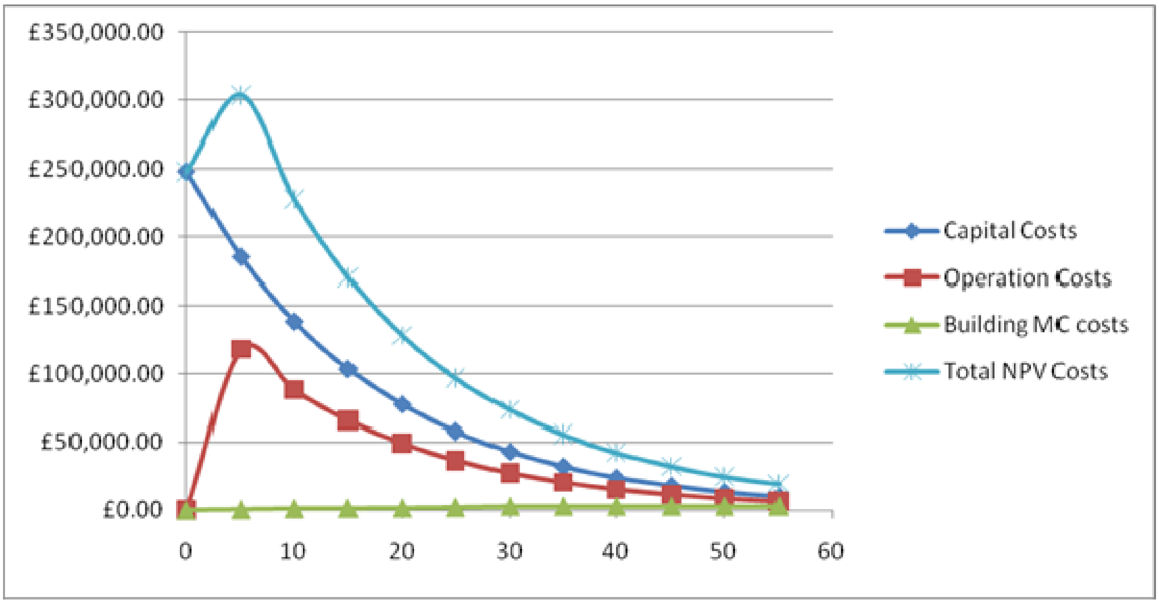

Figure 4: NPV Calculations for the Code for Sustainable 4 Option

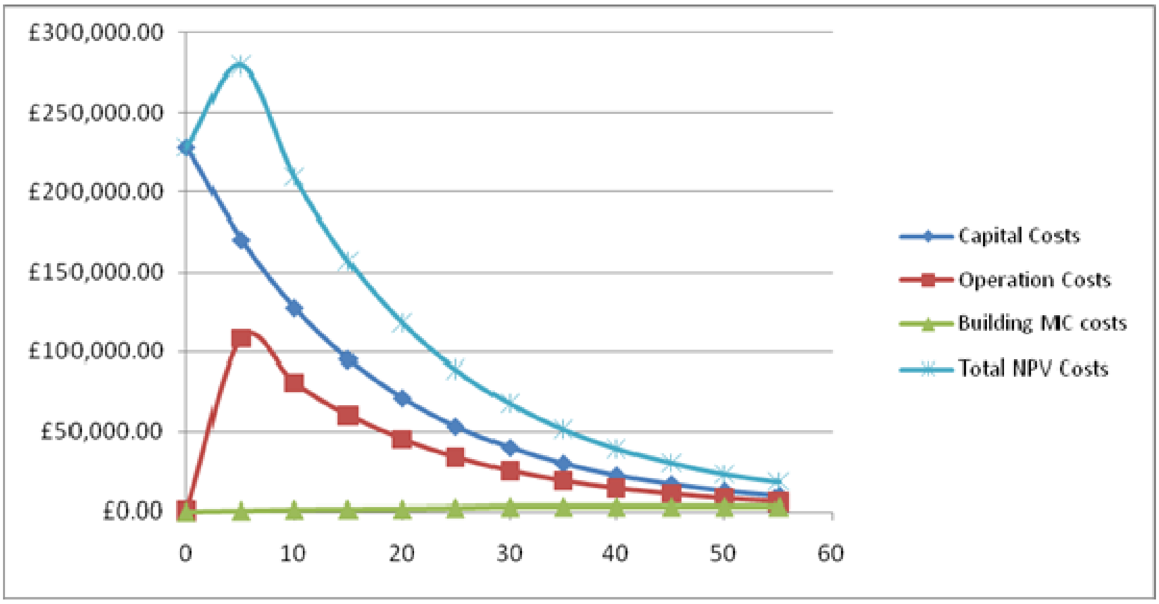

Figure 5: NPV Calculations for the Ecoterrace Option

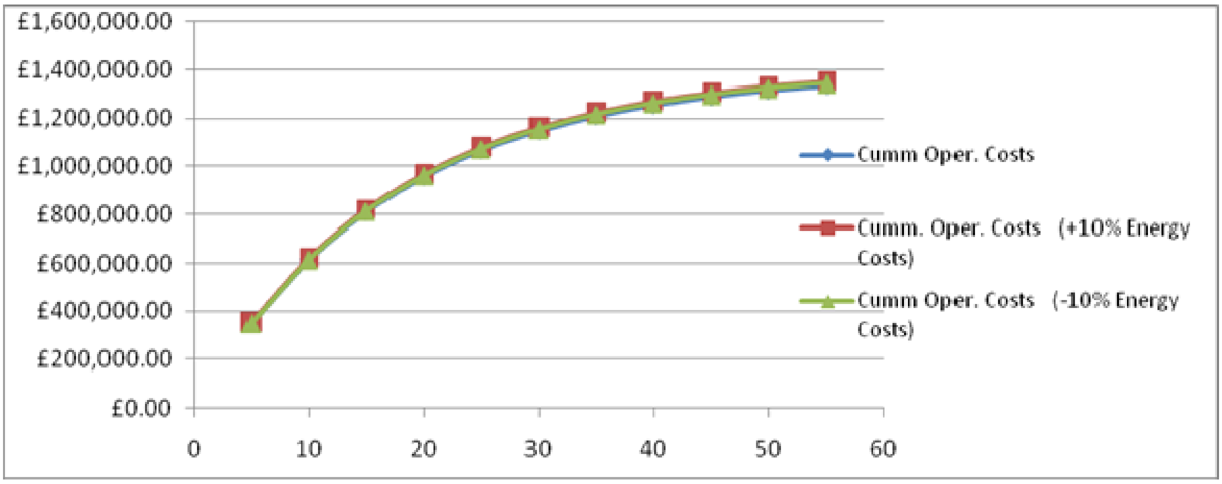

Figure 6: Senstivity Analysis Results for the Do-Nothing Option

Based on the above, whole life costs of three alternative options are calculated for comparison: (a) Do nothing (control) – simply maintain the existing accommodation to its current standard, with associated energy costs; (b) Demolish and re-build to Code for Sustainable Homes Level 4; (c) Retain the layout of the existing building; carry out minimal upgrades to the property that would be expected by the majority of owner-occupiers and landlords.

The three alternative options were also compared with the whole life cost for the Ecoterrace option.

Therefore, this study seeks to achieve the following: (a) Creating the financial model and populating it with the project's capital/maintenance/energy costs (b) Calculating the results with conclusions on the capital cost of carrying out the work initially, the cost of maintaining, repairing and replacing the various work items and the cost of the energy consumption over the life of the property; and (c) Providing recommendations as to which aspect of the project returns best value from which a more focused and beneficial scope of works can be derived for similar retrofit projects.

Due to the constraints associated with data and available resources, the scope of the study is limited to: (a) Refurbishment costs excluding site specific costs such as remedial works associated with the property due to structural defects and external works due to the variances in plot sizes; (b) Life cycle costs of property maintenance as defined by BS EN 15686-5:2008; (c) Energy costs associated with running the homes with assumptions concerning energy cost fluctuations over the specified life of the properties; (d) The project includes a sensitivity analysis for variances in energy costs; (e) The three alternatives will utilise indicative costs derived from published Building Cost Information Service (BCIS) and Building Maintenance Information (BMI) data; (f) The whole life cost will be expressed as Net Present Value (NPV) with an agreed discount rate.

This study will, however, not calculate or compare carbon emissions associated with the embodied energy of materials used in the original construction or refurbishment/re-build options.

Development of the Financial Model

Four financial models were developed using the same template whilst, however, accounting for the data input requirements of BS EN 15686-5:2008 [1]. The code requires that Lifecycle Costs (LCC) treated as part of the Whole Life Cost as shown in Figure 1. However, for the purposes of this study, other aspects of Whole Life Cost such as: Externalities, Non-construction costs and Income are not considered. In effect, going by the categorisation given in Figure 3.1, the Whole Life Cost is the same as the Lifecycle cost. The Simulation was carried out on a Spreadsheet Programme for each of the options and using the same assumptions for discount rate. Each of the Input and Output sheets are labeled as appropriate Worksheets within the Spreadsheet. The results are subsequently obtained are presented and discussed.

The sensitivity analyses conducted as part of this study was aimed at demonstrating the effect of variability of energy costs on each option. According to BS EN 15686-5:2008, sensitivity analyses can be undertaken to examine how variations across a (plausible) range of uncertainties can affect the relative merits of the options being considered and compared. These ranges should be probable, within the limits of what is anticipated and fit within the client's brief. These analyses can help to identify which input data have the most impact on the LCC result and how robust the final decision is. Some key assumptions can have substantial effects on the uncertainties include the following and as such they have been carefully considered in this study. They are: (a) discount rates – we have assumed a rate of 6% for the analysis but this can be modified in the spreadsheet in order to demonstrate its effect. (b) the period of analysis – a period of 60 years has been assumed for these analyses. (c) incomplete or unreliable service life or maintenance, repair and replacement cycles or cost data based on the assumptions made on anticipated manpower demand over the life cycle.

The results of the sensitivity analysis can be an important guide to assessing what additional information is worthwhile collecting and what significant assumptions are most necessary to make. It can also be used to consider how flexible or variable requirements can be during the period of analysis or the life cycle.

DISCUSSION OF RESULTS

Commencing with the Do-Nothing Option, the simulation results indicated an initial capital cost of £150,000 and maximum NPV of £475,000 (see figure 4.1). The high NPV is due to the high operational costs as envisaged for this option. It infers that whilst initial investment may be attractive, the longer-term NPVs indicate that this option could be more expensive option.

The Minimal Upgrade option, on the other hand, has a reduced operational cost regime, attributable to the energy savings achievable. Albeit, initial construction costs unlike the Do-nothing option are higher coming out at £175,000; whilst the maximum NPV is circa £375,000 (See Fig. 3).

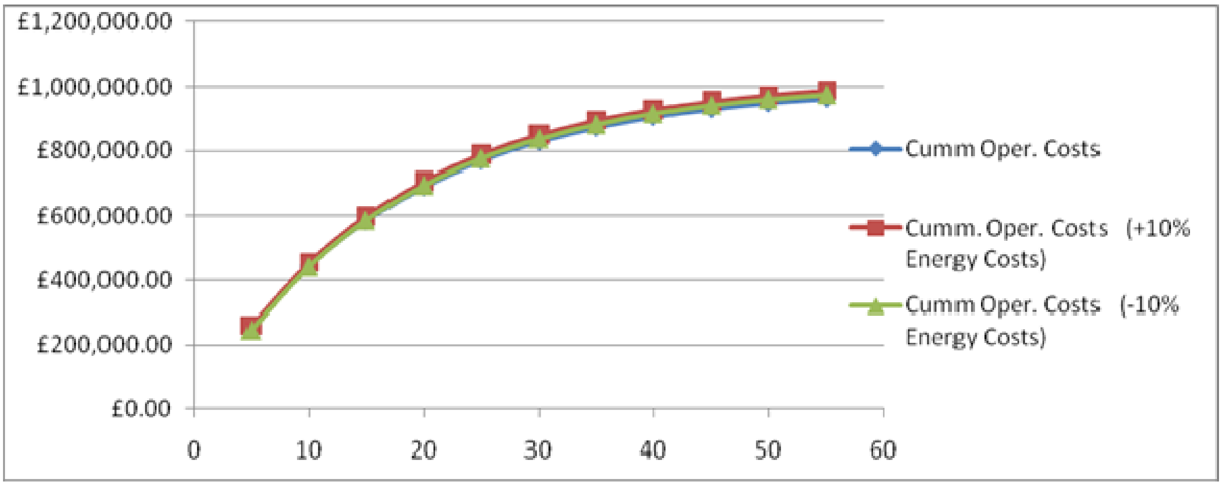

Figure 7: Senstivity Analysis Results for the Minimal Upgrade Option

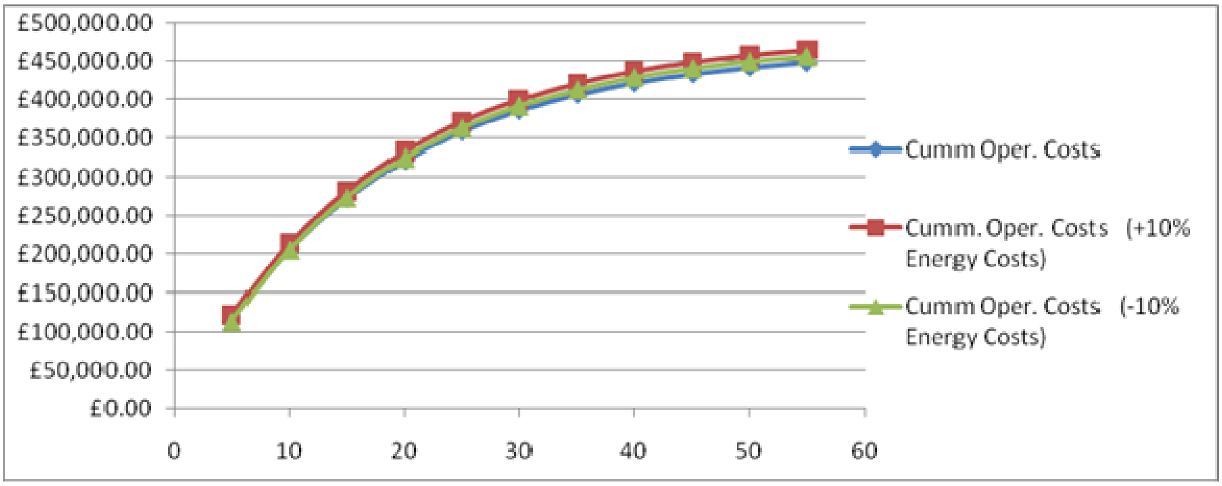

Figure 8: Sensitivity Analysis Results for the Code 4 Sustainable Homes Option

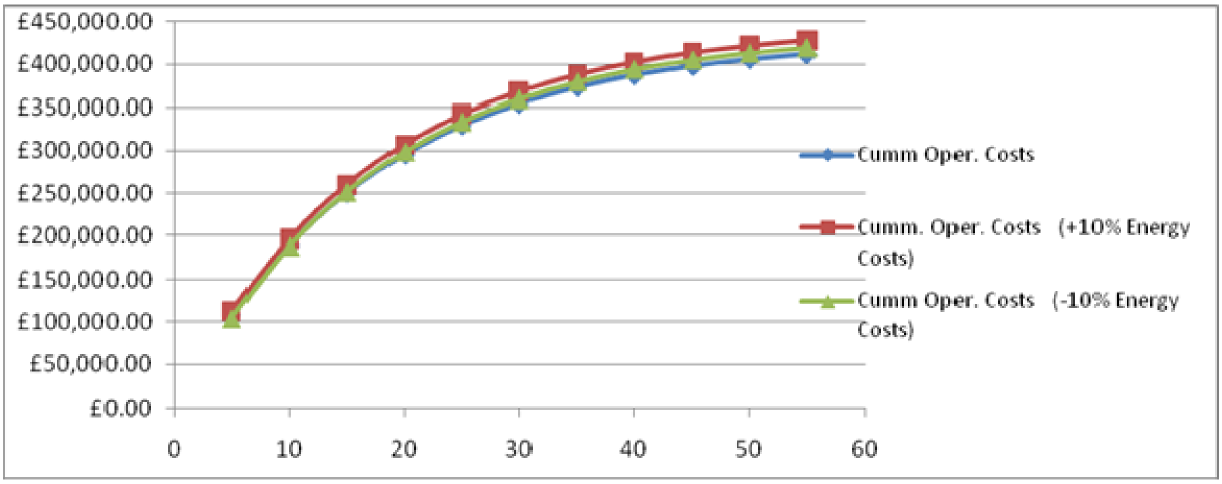

Figure 9: Sensitivity Analysis Results for the Ecoterrace Option

For the Code 4 Sustainable Homes Option (figure 4), the unique observation is the closeness of the initial capital cost and the maximum NPV – which are £250,000 and £300,000 respectively. Operating costs are lower than the costs applicable to the other two previous options, however.

With respect to the Ecoterrace Option (figure 5), the initial capital cost and the maximum NPV are £225,000 and £275,000 respectively. Operating costs are at about the same level when comparing the Ecoterrace and Code 4 Sustainable Homes options. However, the Ecoterrace option still demonstrates the best NPV when compared to the other options discussed hitherto.

Considering the above results, the Ecoterrace Option appeared to be the option that returns the most value for money based on the initial capital costs and the NPV.

Nevertheless, a sensitivity analysis which sought to explore the effect of energy variations on the cumulative lifecycle operating cost profiles. Hence, the sensitivity analyses were still conducted on the four options. Figs. 6 to 9 show the generated graphs – the graphs consider the effect of 10% increase or decrease in energy costs. Observing the graphs, it appears that this degree of variability will have little or no effect on the operating costs of the Do-Nothing and the Minimal upgrade options (Figs. 6 and 7).

However, with regards to the Code 4 Sustainable Homes and Ecoterrace options (Figs. 8 and 9), these changes impact on the cumulative costs substantially with the Ecoterrace model showing the most sensitive response. In this model, a 10% increase in energy costs over the life of the property would increase the estimated operating cost after the first 15 years. In all cases, however, a reduction of up to 10% in energy costs will have very little or no impact on the lifecycle operational costs

CONCLUSION AND RECOMMENDATIONS

This study set out to analyse and calculate the whole life costs of the two identified eco-terraces -from which data was collated and analysed in a typically designed Lifecycle costing Spreadsheet model. In this context, therefore, whole life costs consisted of: capital costs of the refurbishment project; maintenance costs associated with keeping the accommodation up to a reasonable state of repair; and energy costs associated with running the accommodation to a habitable standard. To achieve these objectives, whole life costs of three alternative options (in addition to the Ecoterrace option) were calculated for comparison. These were the: Do nothing; Code for Sustainable Homes Level 4; the Minimal Upgrade option and the Ecoterrace option.

The financial model was thus created for each option and each model was populated with the project's capital/maintenance/energy costs. NPV results were computed in addition to carrying out a sensitivity analysis for energy variations over the life of the property.

With respect to the four options analysed, the Ecoterrace option had the most reasonable initial capital and maximum NPV (Lifecycle) costs. However, operating costs are at about the same level when comparing the Ecoterrace and Code 4 Sustainable Homes options. Nonetheless, the Ecoterrace option still demonstrates the best NPV (Lifecycle) costs when compared to the other options. Also, although a 10% increase in energy costs over the life of the property would increase the estimated Lifecycle operating costs after the first 15 years (based on the sensitivity analysis). These results generally indicate that although the Ecoterrace option has some element of initial capital costs, the overall lifecycle costs associated with it indicates best value. Keeping the initial capital costs to the barest minimum will also further maximise this value and yield a more focused and beneficial scope of works which indeed can be derived for similar retrofit projects.

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