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Stage 2: Life Cycle Assessment and Life Cycle Cost Analysis

Phase II, Helix, Amesbury

CHBS-AV-21031-5

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Document Control

Project Name	Phase 2, Helix, Amesbury
Client	RO Real Estate
Project No.	21027
Report	Stage 2: Life Cycle Assessment and Life Cycle Cost Analysis
Software	eTool

Quality Assurance

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Issue Record

Revision	Revised	Checked	Date	Comments
*	-	-	26/05/23	-

Abhinaya Vittal has completed Life Cycle Assessment Training and Examination with eTool and achieved her certificate of competence May 24th,2022.

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Executive Summary

The purpose of this analysis is to present life cycle costs (LCC) and environmental impacts (LCA – Life Cycle Assessment) for a period of 60 years for the proposed project Helix Phase 2 Trade Park in Amesbury.

The main objective of the study is to develop informed choices between alternative design options that demonstrate optimum value. The initial analysis consists of estimating the design specifications and understanding how different design options can influence both the capital cost, overall life cycle costs and environmental impacts.

The Life Cycle Cost (LCC) analysis conducted in accordance with ISO 15686-5:2017 (Buildings & constructed assets – Service life planning – Part 5: Life cycle costing) and implemented according to the PD-156865 (Standardized Method of Life Cycle Costing for Construction Procurement). The Life Cycle Assessment (LCA) of environmental impacts is conducted in accordance with BRE EN15804. The LCC analysis has been developed to align with the BREEAM V6 MAT01 options appraisal in order to give a full picture of life cycle design at RIBA Stage 2.

The LCC has shown that construction costs represent the largest proportion of the life cycle cost impacts. Figure 1 demonstrates the breakdown to different cost types over the life cycle of the base design. The elemental study demonstrates that: replacing composite metal panels for built-up cladding and use of recycled aggregate sub-base in hard landscaping would both have life cycle environmental benefits and be win-win in terms of life cycle costs. Both of these options are expected to be chosen to be taken forward in the development.

As the design process evolves, this study may be updated.

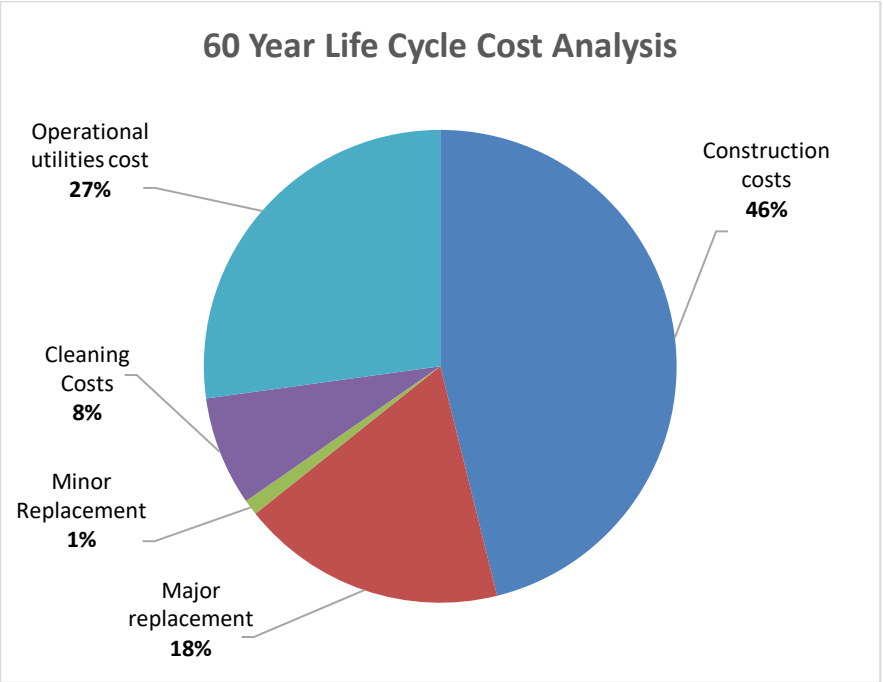


Figure 1: Baseline Life Cycle Cost Summary 60 Year (NPV)

Introduction

Life Cycle Design Purpose

CHB Sustainability have prepared this Life Cycle Design Analysis to understand the cost and environmental impacts of the proposed Trade Park industrial development, and to present opportunities for reducing the impacts from a life cycle perspective. This Stage 2 analysis presents key construction cost hotspots alongside the cost benefit of design options currently under consideration for future design iterations.

The objectives of the LCD analysis are to:

- determine the total Life Cycle Cost (LCC) (including construction costs, operation and maintenance costs) of the project.
- establish the importance of the building components that have a major impact within the total cost (due to capital expense, major replacements or energy/water consumption costs).
- analyse the total life expectancy of the major building systems and components.
- support design decisions and put forward recommendations for alternative design options for major building systems and components.
- determine the total Life Cycle Assessment (LCA) environmental impact of construction materials in terms of BRE EN15804.
- provide evidence for compliance with BREEAM criteria for Man02 Elemental LCC (Component Level LCC to be completed during stage 4).
- and provide evidence for compliance with BREEAM criteria Mat01 LCC and LCA Alignment.

Life Cycle Design Scope

The modelling has been completed in line with ISO 15686-5 and reporting follows BS EN 16627. The scope of the LCC modelling is shown in Figure 2, all major cost items over the life of the project are considered excluding the following:

- Non-construction costs (such as land acquisition etc.)
- Income (such as rental income etc.)
- Externalities (such as environmental damage not remediated etc.)

The LCC approach is recognised as the most appropriate method of determining the total costs of ownership and assessing project alternatives. It enables improvements to be identified, compared and prioritised.

The Life Cycle Assessment system boundary is in accordance with ISO 14044 as shown in figure 3.

Period of Analysis

This covers the entire period of estimated life expectancy for the most important components and systems to help to highlight the frequency and impact of major replacement costs. LCC analysis has been completed for 0 – 60 years (including 20 and 30 year totals).

Additionally, a 15 year "Service Life" model was prepared to offer an insight of the costs related to the first years of occupancy.

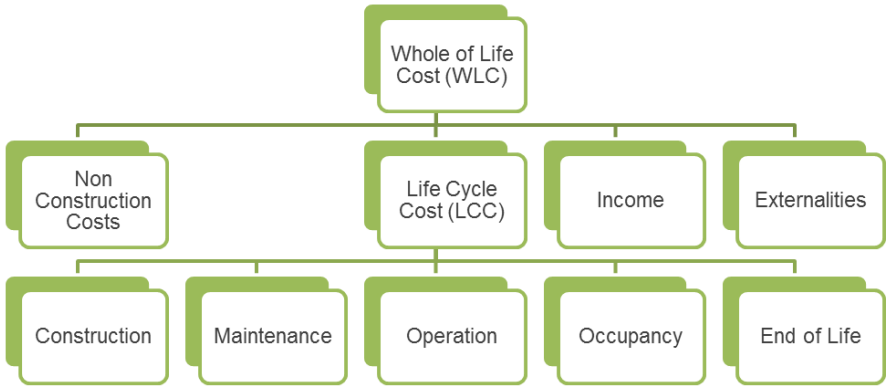


Figure 2: Whole of Life Costing and Life Cycle Costing Scopes. Adapted from ISO 15686-5 (2008)

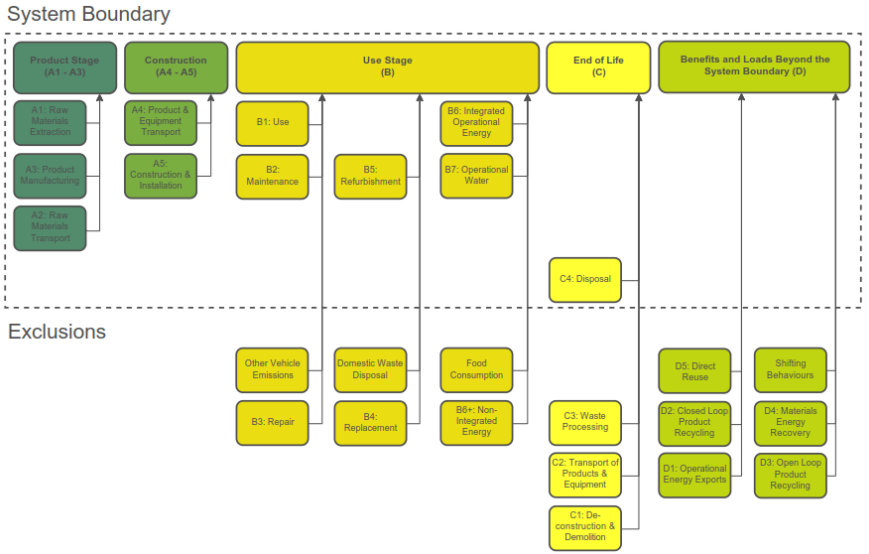


Figure 3: Stages of Life Cycle Assessment and System Boundary. Adapted from ISO 14044 (2006)

BREEAM V6

2 credits are available for demonstrating:

1. An elemental life cycle cost (LCC) analysis has been carried out, at Process Stage 2 (equivalent to Concept Design - RIBA Stage 2) together with any design option appraisals in line with 'Standardized method of life cycle costing for construction procurement' PD 156865:2008.

2. The LCC analysis shows:
    a. An outline LCC plan for the project based on the building's basic structure and envelope, appraising a range of options and based on multiple cash flow scenarios e.g. 20, 30, 60 years;
    b. The fabric and servicing strategy for the project outlining services component and fit-out options (if applicable) over a 15 year period, in the form of an 'elemental LCC Plan'.

BREEAM V6 Mat01 compares EN15804 "Ecopoint" LCA environmental impact metrics with benchmark figures and encourages an 'options appraisal' to give the design team feedback on alternative options for superstructure, substructure and hard landscaping, and building services (if applicable). The Mat01 benchmark comparison and options appraisal may be carried out at both concept (RIBA Stage 2) and technical design (Stage 4). An innovation credit is available where the Mat01 options appraisals align with the Elemental and Component LCC analysis at both Stages 2 & 4.

Project Description

The Trade Park development consists of 4 industrial units. The proposed industrial units are speculative shell & core class B2/B8 warehouse units, fitted-out core and mezzanine office. The total net lettable internal area of the development is 12,851 m^2, inclusive of 1,311 m^2 office mezzanine.

The development includes access road, car park and manoeuvring areas.

The assessment includes all the life cycle costs incurred to provide the primary function of the structure from construction, maintenance, operation, and final demolition.

Process

Following production of the baseline LCC/LCA model, discussions will be held to communicate the LCC/LCA impacts of the building and to identify opportunities for improvement. Options have then been modelled with varying life expectancies. The results of which are presented in this report.

The model may be updated when further detailed design information becomes available during Stage 4.

Life Cycle Design Model

eToolLCD software was used to model the development and perform the Life Cycle analysis. Modelling of the project begins with defining key parameters such as life span, functional size, and use characteristics (e.g. hours of use). Next an analysis of available design documentation (e.g. architectural, mechanical, and electrical drawings, schedules, and specifications). This information provides an initial material quantity take-off which is combined with standardised and referenced eToolLCD templates. These templates include additional data relating to a specific use of a given material quantity such as:

- Construction equipment use
- Construction labour requirements
- Estimated product service life (which in turn determines the maintenance and replacement years)
- Other auxiliary data (e.g. timber formwork estimates per unit of concrete)

This eToolLCD model is then ready for interpretation of results. The eToolLCD software provides a breakdown of the project's impacts into separate categories which aids interpretation.

The study has been completed at RIBA stage 2 and therefore a number of assumptions have been made in terms of the construction and servicing make-up. A relative high level of detail was made available in the Stage 2 design information, so assumptions made are unlikely to make a significant impact on the conclusions made. The study may be further updated at Stage 4 when more detailed information is available. The key construction specifications were taken from the Kier Property Trade City and Logistics City Specifications.

A life cycle design study carries inherent assumptions both in terms of the initial build and how the building will develop over its life cycle. The actual capital costs for the various construction elements can vary significantly depending on project specifics, suppliers and unknowns. The assumptions have been reduced as far as practically possible and appropriate references have been consulted for each data entry.

Table 1 presents an analysis of the confidence levels with respect to each stage of the life cycle cost analysis due to the underlying assumptions.

For indicating / estimating costs:

- Industry benchmarks (In house knowledge cross-referenced with SPONS, Construction rates and other sources)
- Bids from different manufacturers / contractors
- In house knowledge

For estimating life expectancy period:

- BRE IMPACT data defaults
- Design team experience
- Manufacturer's information
- Typical Life Expectancy of Building Components - BCIS, RICS

For technical data / materials properties:

- Information provided by the design team
- Technical sheets of the products / manufacturer's information / studies

LCC Fluctuation rates:

- The real discount rate used in the calculations was set to 3.5% in line with government guidelines with effects of general inflation removed (HM Treasury Greenbook)
- Energy price escalation 2% (Industry average)
- Water price escalation 2% (Industry average)

The LCC can be consolidated and scaled to closely match any cost plan information that may be available.

If the value of the options presented are particularly sensitive to capital costs, quotes should be sought and fed back into the LCC model.

Life Cycle Module	LCC Element	Confidence	Comments and Reasons for Fluctuation
Construction	Capital Costs (Materials)	Medium	Based on industry standard costs and design documentation
	Capital Costs (Installation Labour and Equipment)	Medium	
	Capital Costs (Transportation of Materials, Equipment and Labour)	Low	
Maintenance	Maintenance Costs (Materials and equipment replacement)	Low – Medium	Large uncertainty due to inaccuracies in future churn rates of materials and equipment (may not be dictated by service life but building owner's needs).
	Maintenance Costs (Labour and Equipment)	Low – Medium	Large uncertainty dependant on region, contracts, expectations, building use and management.
	Maintenance Costs (Transportation of Materials, Equipment and Labour)	Low	Large range of variables that may affect transportation costs in the future.
Operation/ Maintenance	Operational Energy/Water Costs	Low – Medium	Energy figures are based on SBEM Energy Modelling from similar developments. Possible uncertainty in future energy tariff structures. Assumption needed to be made regarding the occupancy profiles of the buildings.
	Building Management / Occupant behaviour	Low	Large fluctuations dependant on region, number of facilities being managed and contracts.
	Cleaning Costs	Low	Large fluctuations dependant on region, contracts, expectations, building use and management.
End of Life	Residual Value	Very Low	It is assumed the only residual value is in revenue from recyclable materials etc (likely zero net revenue after demolition costs). If the building was sold the residual value may be very different.

Table 1: Life cycle module confidence levels

Results and Options Appraisal

Meeting minutes and discussions with the design team have been used to inform potential design options for consideration. The results presented in this report shall be used to inform further discussions with key members of the design team to discuss the impact of different design options and how they influence the life cycle performance of the building both in terms of cost and environmental performance. Results for the baseline specification are summarised in Figure 4, the detailed capital costs based on a 15-year service life are provided in Appendix A and full year on year costs over 60-year period in Appendix B.

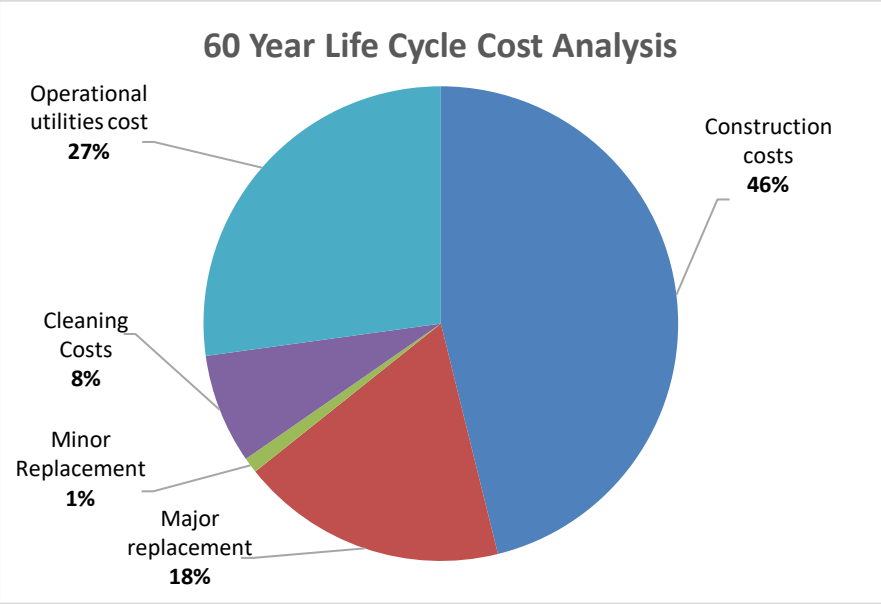


Figure 4: Baseline Life Cycle Cost Summary 60 Year (NPV)

Top 5 key contributors to the life-time materials cost are:

1. Concrete
2. Structural steel
3. Metal cladding panels
4. Office carpets (high recurring replacement costs)
5. Steel reinforcement

In terms of environmental impacts, the top contributors are:

1. Structural steel-work
2. Metal cladding panels
3. Steel reinforcement
4. Concrete
5. Insulation

The top three key contributors to the life-time operational costs are:

1. Equipment energy-use
2. Lighting
3. HVAC

It may be observed that there are significant cross-overs between where the main cost and environmental impacts lie due to both quantities of materials and other factors such as transport, where a high bulk or mass material will incur significant cost and environmental impact.

The following options (in alignment with BREEAM Mat01 reporting tool options) have been compared against this baseline in terms of cost and environmental impact:

Superstructure Option 1
Replace aluminium window frames for aluminium/timber composite

Superstructure Option 2
Replace composite metal panels for built-up cladding (mineral wool insulation replaces PIR)

Superstructure Option 3
Replace composite metal wall panels for closed panel timber system with mineral wool insulation & larch cladding

Substructure Option 1
Zero GWP/ODP Blowing agent extruded polystyrene under slab insulation

Substructure Option 2
30% pulverised fly-ash blend to foundation concrete

Hard Landscaping Option 1
Recycled aggregate sub-base for external hard landscaping

Hard Landscaping Option 2
Open concrete permeable paving for car parking & paths rather than standard concrete paving

Figure 5 shows the life cycle design results for the options stated above in terms of both cost and environmental impact.

From analysis of figure 5 it can be shown that:

- The biggest potential for environmental benefits is replacing composite metal panels for built up cladding with significant cost savings.
- Use of recycled aggregate sub-base for external hard landscaping shows the next biggest potential for environmental benefits with small cost savings.
- Specifying an under-slab insulation that is manufactured using a zero GWP/ODP blowing agent may have no adverse effects on costs and shows a slight potential for environmental impact.
- An aluminium-timber composite window shows no significant increase costs and shows significant potential for environmental impact.
- Although an alternative wall construction utilising timber instead of metal would show significant environmental benefit, it also shows a significant cost increase.
- Specifying an open concrete slab permeable paving system has a negligible impact in terms of LCC/LCA.
- Replacing concrete with 30% pulverised fly ash (PFA) in the foundations also show negligible impacts in terms of LCA/LCC.

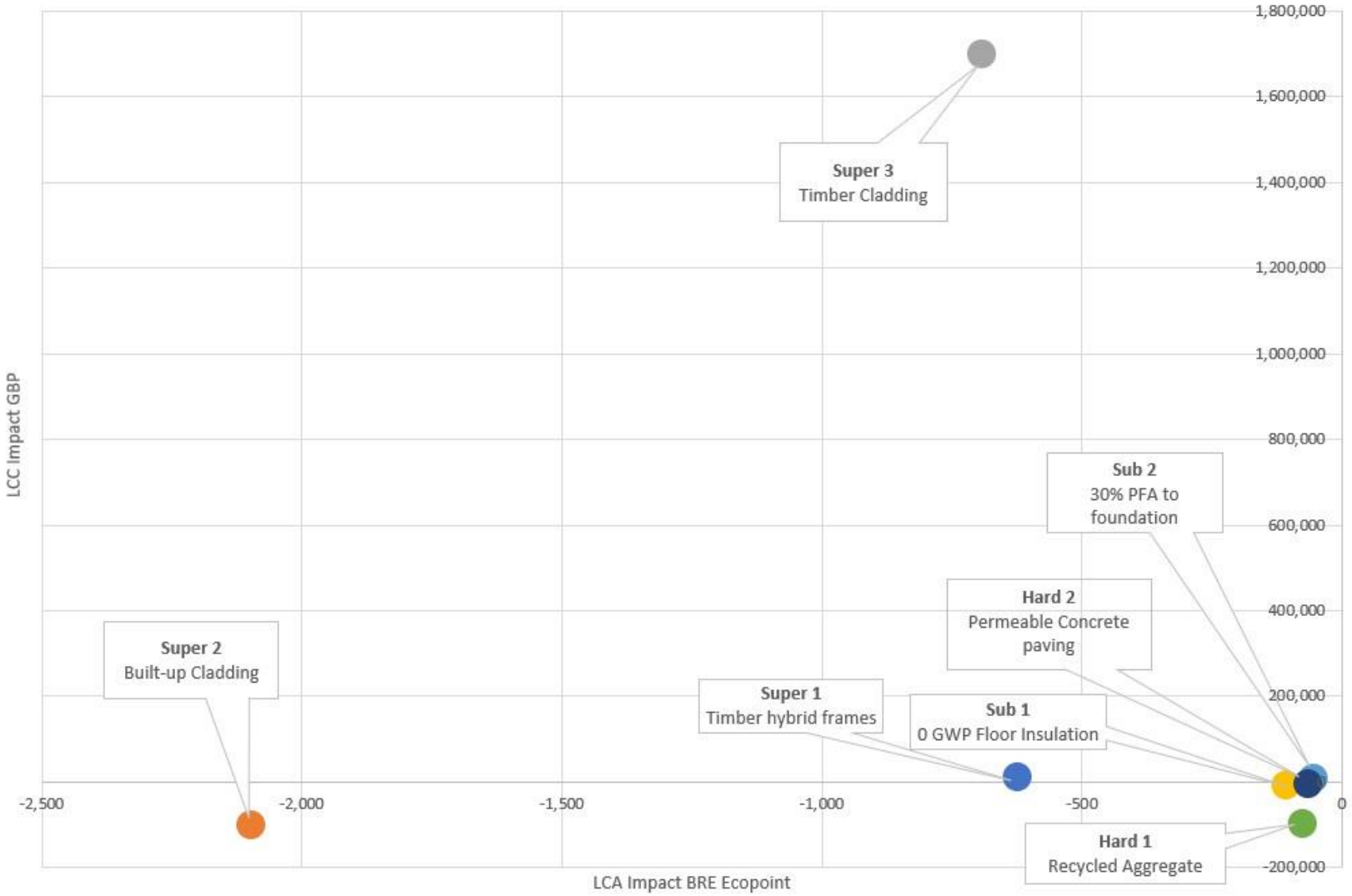


Figure 5: Plot of LCC against LCA results for each option

On this basis the following options would be recommended for implementation based on life cycle cost and environmental assessment:

Superstructure Option 2
Replace composite metal panels for built-up cladding (mineral wool insulation replaces PIR)

Hard Landscaping Option 1
Recycled aggregate sub-base for external hard landscaping

Assuming that the options above are implemented within the design, Table 2 shows a summary of results by major life cycle phases compared to the Base Design.

These results are provided in tabular format with additional detail of 60-year design life following the guidance of the British Standard "Standardised Method of Life Cycle for Construction Procurement".

	Base Case	Improved
1 Construction		
1.1 Construction works costs	6,537,757	6,451,936
1.2 Other construction related costs		
2 Maintenance		
2.1 Major replacement costs	2,573,092	2,466,583
2.2 Subsequent refurbishment and adaptation costs		
2.3 Redecorations		
2.4 Minor replacement, repairs and maintenance costs	150,531	150,531
2.5 Unscheduled replacement, repairs and maintenance costs		
2.6 Grounds maintenance		
2.7 Client definable costs		
3 Operation		
3.1 Cleaning costs	1,059,495	1,059,495
3.2 Utilities costs		
3.2.1 Fuel & Electricity	3,851,291	3,851,291
3.2.2 Water and drainage	104	104
5 End of life		
5.1 Disposal inspections		
5.2 Demolition	1,940,013	1,957,966
5.3 Reinstatement to meet contractual requirements		
Total	16,112,284	15,937,907
Net Saving		174,377

Table 2: LCC Options Appraisal Summary Results Table (£)

Figure 6 below shows the overall life cycle cost summary for both base case and the improved case. From the figure, it is evident that the largest contributor to the life cycle costs of the base design is the construction costs, followed by operational and maintenance.

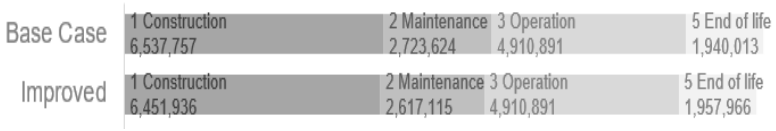


Figure 6: Base case and improved case life cycle cost summary

CHB Sustainability remain open to modelling alternative options throughout the design to understand their Life Cycle implications. Detailed component level analysis on these may be provided in Stage 4 on request.

Conclusions

The LCD analysis shows that construction costs are the most significant. Key contributors making up the construction impacts are concrete, structural steel, metal cladding panels, carpets and steel reinforcement.

The carpet impacts are high mainly due to replacement costs, therefore a robust product with a long service life is likely to reduce life cycle costs. Sourcing equipment with extended warranties and durability can provide substantial life cycle savings.

The main costs are for construction rather than replacement, however a robust product with a long service life is likely to reduce life cycle costs and reoccurring environmental impacts. Sourcing equipment and materials with extended warranties and durability can provide substantial life cycle savings.

The LCC analysis shows that the biggest utilities costs shall be due to equipment, followed by HVAC and lighting. Energy efficient building design and services may reduce operational utilities costs throughout the building life cycle, although it is inherently difficult to influence equipment energy usage at the design stage.

The highest construction costs are for the superstructure, therefore careful procurement and sourcing of high bulk/mass items from a local source to reduce transport may reduce these costs.

The LCC impact of the LCA appraisal options considered for BREEAM Mat01 have been assessed. It was found that choosing built-up cladding over composite and using recycled aggregates for external landscaping both have benefits in terms of cost and environmental impact.

References

Design documentation – construction drawings and specifications as at April 2023

BRE Group. (2013). *BRE Global Product Category Rules for Type III environmental product declaration of construction products to EN 15804:2012+A1: 2013 .* Watford: BRE Group.

CEN European Committee for Standardization. (2012). *EN 15804:2012+A1:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.* Brussels: CEN.

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ISO International Organization for Standardization. (2017). *ISO 15686-5:2017(en) Buildings and constructed assets - Service life planning - Part 5: Life cycle costing.* Geneva: ISO.

NBS. (2015). *BS EN 16627:2015 Sustainability of construction works - assessment of economic performance of buildings - calculation methods.* London: BSI.

Appendix A: 15 Year Services Life

Row Labels	01 Substructure	02 Superstructure	05 Services equipment	07 Work to Existing Building	Grand Total
1					
(TS) Whole building office tenant fit-out Cat A	0	0	0	22,659	22,659
_Minor Items	0	0	2,405	0	2,405
2					
(TS) Whole building office tenant fit-out Cat A	0	0	0	22,419	22,419
_Minor Items	0	0	2,393	0	2,393
3					
(TS) Whole building office tenant fit-out Cat A	0	0	0	22,181	22,181
_Minor Items	0	0	2,354	0	2,354
4					
(TS) Whole building office tenant fit-out Cat A	0	0	0	21,946	21,946
_Minor Items	0	0	2,342	0	2,342
5					
(TS) Whole building office tenant fit-out Cat A	0	0	72	21,713	21,785
_Minor Items	0	1,602	4,179	0	5,782
6					
(TS) Whole building office tenant fit-out Cat A	0	0	0	21,483	21,483
_Minor Items	0	0	2,293	0	2,293
7					

(TS) Whole building office tenant fit-out Cat A	0	0	22	21,255	21,277
_Minor Items	0	0	2,235	0	2,235
8					
(TS) Whole building office tenant fit-out Cat A	0	0	0	21,030	21,030
_Minor Items	0	0	2,244	0	2,244
9					
(TS) Whole building office tenant fit-out Cat A	0	0	0	20,807	20,807
_Minor Items	0	0	2,209	0	2,209
10					
(TS) Whole building office tenant fit-out Cat A	0	0	68	20,587	20,655
_Minor Items	0	1,519	3,975	0	5,494
11					
(TS) Whole building office tenant fit-out Cat A	0	0	0	20,368	20,368
_Minor Items	0	0	2,162	0	2,162
12					
(TS) Whole building office tenant fit-out Cat A	0	0	0	20,152	20,152
_Minor Items	0	0	2,151	0	2,151
13					
(TS) Whole building office tenant fit-out Cat A	0	0	0	19,939	19,939
_Minor Items	0	0	2,116	0	2,116
14					
(TS) Whole building office tenant fit-out Cat A	0	0	20	19,727	19,747
_Minor Items	0	0	2,085	0	2,085
15					
(TS) Whole building office tenant fit-out Cat A	0	0	64	19,518	19,583
_Minor Items	0	1,440	2,666	0	4,106
Services lift elevator car	0	0	1,091	0	1,091
WC, Commercial Cubicle	0	0	145	0	145
Grand Total	0	4,562	39,291	315,785	359,638

Appendix B: 0 – 60 Years LCC

Row Labels	0	5	10	15	20	25	30	35	40	45	50	55	60	Grand Total
⊞1.0 Construction Costs	6,537,757	0	0	0	0	0	0	0	0	0	0	0	0	6,537,757
⊟2.0 Maintenance Costs														
(TS) Whole building office tenant fit-out Cat A	0	7,532	156,165	145,082	6,419	199,518	140,834	116,105	9,281	107,547	149,761	4,421	88,406	1,131,070
_Minor Items	0	13,561	14,476	13,373	13,011	17,027	16,243	12,300	11,161	11,049	13,640	7,959	6,732	150,531
Door internal solid core laminate (BRE)	0	0	0	22,058	0	0	18,800	0	0	16,022	0	0	0	56,880
Door steel door and steel frame insulated core	0	0	0	0	3,825	0	0	0	3,091	0	0	0	0	6,916
Door steel roller door (garage etc) (m2)	0	0	0	2,795	54,307	0	2,382	0	43,883	2,030	0	0	0	105,397
External Roof System composite metal cladding (Copy)	0	0	0	0	0	0	194,390	0	0	0	0	0	0	194,390
External Wall System composite metal cladding	0	0	0	0	0	0	152,952	0	0	0	0	0	0	152,952
Internal wall system - finished plbrdx2, steel stud, 50mm rockwool and 80mm rigid insulation board	0	11,298	10,712	10,156	9,629	9,130	8,656	8,207	7,781	7,377	8,582	6,631	0	98,161
Landscaping concrete paving on aggregate sub-base	0	0	0	0	0	0	106,509	0	0	0	0	0	0	106,509
Landscaping Road/Paving - Asphalt 80mm on 200mm aggregate base	0	0	0	0	1,932	54,283	0	71,694	1,561	0	41,587	0	0	171,057
Roof covering grp glass reinforced plastic 23mm	0	0	0	0	0	0	0	8,982	0	0	0	0	0	8,982
Services lift elevator car	0	0	0	6,820	0	12,752	5,812	17,138	0	4,954	9,769	0	0	57,245
Solar PV (used on site, per kW installed)	0	0	0	0	0	0	55,267	0	0	0	14,303	0	0	69,570
WC, Commercial Cubicle	0	0	0	75,100	1,495	1,042	65,142	0	1,208	55,687	2,395	0	0	202,069
Windows commercial aluminium double glaze	0	0	0	0	79,080	0	0	0	132,814	0	0	0	0	211,894
⊟3.0 Operational Costs														
0	0	271,979	284,159	296,884	310,179	324,069	338,581	353,743	369,584	386,135	403,426	421,492	440,367	4,200,598
(TS) Whole building office tenant fit-out Cat A	0	110,918	105,162	99,706	94,532	89,627	84,976	80,567	76,387	72,423	68,665	65,102	61,724	1,009,789
_Minor Items	0	-17,145	-18,442	-19,770	-21,130	-22,527	-23,963	-25,442	-26,965	-28,537	-30,160	-31,838	-33,575	-299,496
⊞End of Life Costs	0	0	0	0	0	0	0	0	0	0	0	0	1,940,013	1,940,013
Grand Total	6,537,757	398,142	552,232	652,204	553,279	684,920	1,166,580	643,295	629,785	634,687	681,969	473,767	2,503,667	16,112,284

Disclaimer: Any recommendations in this report are for guidance based on environmental impact and lifecycle cost assessment only. Before taking any recommendations forward into the design process, they should be reviewed by the relevant professionals appointed to the design team including the architect, structural engineer, principal designer, and principal contractor to assess suitability and safety. This applies to recommendations involving cladding and other recommendations equally.

The following information is required for BREEAM assessments where the Management 02 Life Cycle Cost and Materials 01 Environmental Impacts from Construction Products: Building Life Cycle Assessment credits are targeted. This credit will require the input of the design team to demonstrate how the LCC/LCA analysis has been integrated into the wider design decision-making process. The individual assigned responsibility for coordinating this should fill in the below.

Please complete this proforma document as follows;

1. Complete and sign the declaration below.

2. Fill in a copy of the table below for the relevant RIBA Stage and applicable Construction Elements including appropriate examples of how the design has developed in response to LCC/LCA analysis.

Confirmation of credit criteria compliance

We hereby confirm that the Stage 2 Life Cycle Cost and Life Cycle Assessment Options Appraisal report has been received at the appropriate RIBA stage in order for the analysis to inform wider design-decision making in terms of influencing the building and systems design and specification to minimise life cycle cost and environmental impact:

Project name:	Date:
Name:	Position:
Signature:	Company:

RIBA Stage	Construction Element	Have LCC/LCA options from the report been discussed within the design team?	In response to this discussion: How has the design developed in order to minimize life cycle cost & maximize critical value?	In response to this discussion: How has the design developed in order to minimize life cycle environmental impact?
Stage 2: Concept Design	Superstructure			
Stage 2: Concept Design	Substructure			
Stage 2: Concept Design	Hard Landscaping			
Stage 2: Concept Design	Building Services	*No*	*N/A*	