ARE YOUR BUILDINGS COSTING THE EARTH?
THE CONCEPT AND APPLICATION OF LIFE COSTING

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Abstract: 'Life Costing' is of growing interest to many clients concerned that it is not enough to make decisions based on the financial cost alone, without giving due consideration of any environmental impact that may be experienced throughout the life of the project.

The initial selection of building materials and components is intrinsically linked to the performance of the facility throughout its life. Every time an asset is replaced, it results in both a financial and an environmental cost, and therefore it is important that these issues should no longer be considered independently when appraising a project.

The awareness of cost and environment coupled with legislative pressures, spiralling energy costs and higher profile public ethics, is resulting in a need to demonstrate design choices that incorporate intelligent and sensible green sustainable solutions.

The presentation and associated paper addresses the concept and methodology of life costing, in order to stimulate discussion and debate on its uses and application in the construction industry.

1.0 Introduction

Climate change is considered to be one of the greatest environmental threats facing the world today. Carbon Dioxide (CO_2) is the most significant of the greenhouses gases contributing to this threat and the construction industry is one of the worst contributors to the creation of it, in fact the construction materials sector alone accounts for over 5% of total UK CO_2 emissions.

In the UK construction industry, demand has been increasing for the calculation of whole life costs or life cycle costs as a means of picking the cheapest or best value specification options for construction designs. In the same way as plotting future financial performance of a construction design, legislation is now also pointing toward the need to plot the future carbon performance. The UK has entered into a legally binding target to reduce its CO_2 emissions to 80% below 1990 levels by 2050. The impact of this is about to gain substance this April when the Carbon Reduction Commitment (CRC) comes in to play exactly a decade after the Climate Change Levy was introduced.

Environment aside, if we are likely to be charged annually for our CO_2 emissions, it is important that we do not unwittingly build something now that will result in high CO_2 emission performance going into the future.

There are of course many environmental measures that can be reported. In the main the predominant reporting need, driven by legislation and awareness, is CO_2 but life costing can also embrace others such as NO_2 SO_2, dust and water amongst others. Within this brief paper CO_2 is the only environmental measure addressed.

This paper addresses the concept of Life Costing, a method to evaluate the CO_2 and cost impacts of construction for both capital works and the on-going maintenance associated of the life of the building.

1.1 Carbon Emissions

The threat carbon emissions pose to civilisation has never been so widely discussed, as concern mounts, new research continues to illustrate the potential dangers which may await. World leaders have been attempting to compromise on a strategy for many years, the Kyoto Protocol which took place in 1997 many regard to be the stimulus and acts as the foundation for which future discussions refer to, still today. Since the protocols inception back in 1997 the number of countries signed up has steadily increased to 187 members, all of which have ratified the protocol that is apart from the United States who in 2007 were solely accountable for 20% of the world's total CO_2 emissions.

The United States alongside other countries who are not members of the protocol are working towards negotiating a compromise; only just recently they showed their intent alongside other delegates by co-drafting and recognising the Copenhagen Accord at the end of 2009 in the latest United Nations Climate Change Conference.

Today, electricity and heat is accountable for the largest contribution to CO_2 emissions throughout the world, responsible for the generation of over 40%. We can begin to appreciate the magnitude of this when considering it is almost equal to the collective emissions made by the world's industrial sector and emissions from all forms of transport.

1.2 Legislation

Environmental policies are emerging and in particular a number of countries have implemented taxes based on the carbon or energy content of the energy products (Sweden, Norway, The Netherlands, Denmark, Finland, Austria, Germany and Italy). Several other countries, like Switzerland, France and the United Kingdom, are currently discussing proposals for their implementation.

As of the first of April this year, the UK introduces the Carbon Reduction Commitment (CRC). Organisations that need to comply with the legislation (forecast at some 200,000) will need to report their CO_2 emissions which, following the first year, they will be charged for.

Considering the UK's pledge to reduce emissions by 80%, the current legislation will only go some way to meeting this target. Other measures are expected to be introduced in the future in order to incentivise lower emissions.

2.0 What is Life Costing?

Life Costing is term used by the author to describe a combination of three reporting tasks: Economic (LCC), Environmental (CO_2) and an element of Social. It is a scientific approach to appraising design and specification options over the design or functional life of a project based on more than just initial capital cost.
Life costing is possible when you link the measurement of resources to both financial cost and carbon. Through the quantification of the amount of resources in each construction activity conducted on a building component throughout its life, it is possible to calculate the capital

cost, life cycle cost, the CO_2 emission from the capital works, and the CO_2 from the on-going maintenance activities.

As each activity is calculated from the resource build-ups, it is therefore possible to quantify the total resource demand at any stage of the project's life. By plotting waste levels against each activity it is also possible to quantify the quantities of waste generated at any given time. Two measures useful in modelling the social impacts of construction.

The relationship of linking resources to both cost and carbon is best demonstrated as a figure:

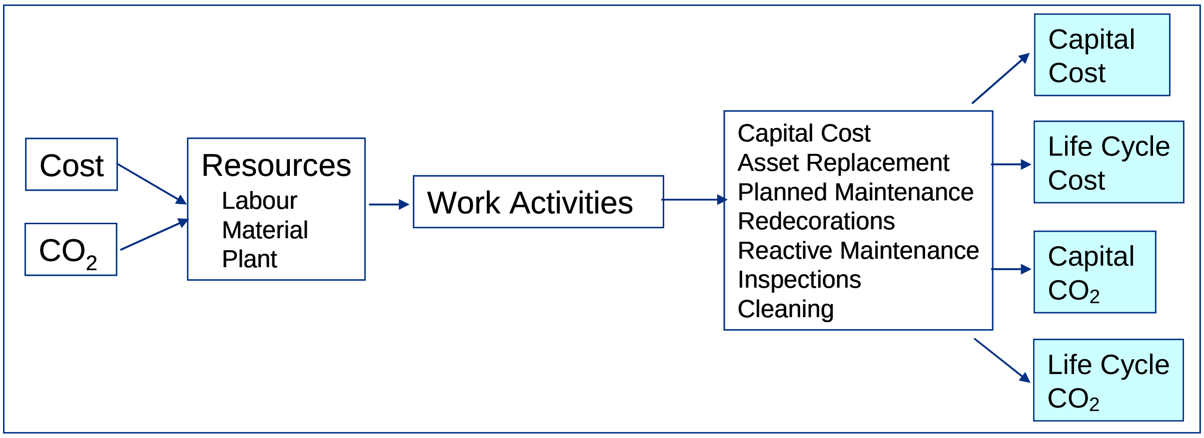

Figure 1: Linking Cost and Carbon

The following section of the paper addresses the terminology for each of three reporting areas Economic (LCC), Environmental (CO_2) and Social.

2.1 Economic (Life Cycle Costing)

The ISO for Life Cycle Costing gives clear guidance on the methodologies of Whole Life Cost and Life Cycle Cost, this paper therefore will not focus in detail on this element. It is however worth underlining the ISO's definition of Whole Life Costing and Life Cycle Costing, as these terminologies are generally still confused within the construction industry.

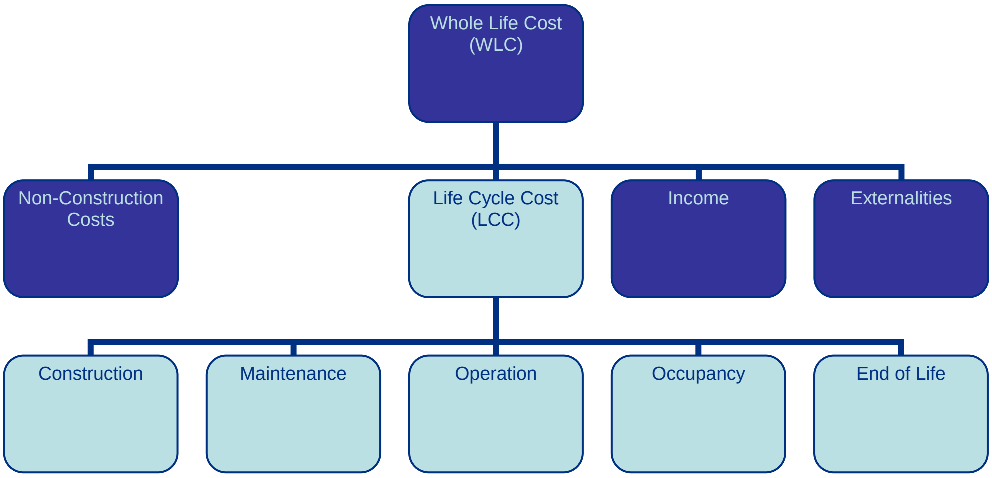

Figure 2: ISO Definition of LCC and WLC

2.2 *Environmental (Carbon Accounting)*

Although standards exist for carbon accounting, these are considered to be less well known in the industry considering its current state of evolution. This section of the report identifies some of the terminologies and issues faced.

Simplistically speaking there are two categories of CO_2 emissions, embodied and direct. Embodied relates to the CO_2 emissions made during the production of something, direct is that produced physically during a process or activity.

Materials used in the construction industry will therefore generally have a level of embodied CO_2 from the emissions made during the extraction of the material and the production of the component. Whereas heating a building would have a direct CO_2 emission through the usage of utilities such as gas and electricity. A life costing study would look to quantify both of these measures of emission.

2.2.1 Study Boundaries

It is essential to understand the boundaries of any study, and it is important to understand what boundaries the data has that you are using if you want to ensure that you are not double counting or missing elements of the measure.

Generally, published embodied CO_2 data will have one of four boundaries:

1) Cradle to Gate
2) Cradle to Site
3) Cradle to Grave
4) Cradle to Cradle

Cradle to gate measures all of the CO_2 emissions relating to the material to get it to factory gate ready for transportation to site. Cradle to site also contains an estimate of the transport. Cradle to site also makes an allowance for its final disposal.

As the latter three boundaries make allowances for project specific issues such as how for to transport to site, how it will be disposed, and how it will be recycled. In order to maintain the highest level of accuracy it is recommended that the first metric is used wherever possible. Further allowances can then be made by the user for transport and if needed disposal and recycling.

2.2.2 Labour

The CO_2 impact of labour is not included within the calculations as these impacts would occur regardless of if undertaking construction activity. Allowances for hand tools are made within any plant calculations. The impact of transporting labour or any temporary accommodation is generally included within the carbon accounting process.

2.2.3 Materials

With any material the embodied CO_2 figures will be different for each material supplier depending on the manufacturing process adopted e.g. a supplier adopting a renewable energy source will have a lower figure than another. In the absence of detailed specification information a life costing study may represent an estimate of likely embodied CO_2 for materials, as with any estimate the figures should be superseded with actual manufacturer data when available.

The use of recycled materials will also have an impact on the embodied CO_2 for materials. For initial estimates typical recycled content may have to be used but allowances or adjustments should be made in the instances of specific data being known.

As with the estimates of cost, elements of waste should be included to truly represent the full impact of the construction specification adopted.

2.2.4 Plant

The embodied CO_2 of the production and maintenance of plant is generally not included within a study. It is therefore the fuel consumption of the plant that is quantified in order to calculate the CO_2 emission.

As with the estimates of cost, elements of non-productive standing time should be included, but additional allowance would need to be made for project specifics such as ground conditions and weather.

2.2.5 Transportation

It is important that quantification of transport is included when you are considering procurement options for any of the above for locations with variations in transportation distance as this will have a significant impact on the final result, especially when quantifying international procurement options.

2.3 Social

From our project experience we would consider that social impacts of construction are in the main very hard to quantify. What we look to include within Life Costing is any quantifiable aspects including a projects resource requirements, transportation and waste. These areas can be modelled by looking at certain scenarios including locally procured labour against imported, additional transportation likely due to the transportation of materials to site, and waste.

2.4 Why do Life Costing?

The benefits of producing these studies individually are well known. For example some of the common benefits of completing a Life Cycle or Whole Life Costing study are:

- Procure on the basis of life-time cost performance, a specification with a cheaper capital cost may result in higher maintenance.
- Without thinking about the logistics of replacement and maintenance your design may result in producing hard to maintain or replace component parts.
- Investment procedures and controls often require LCC to be carried out.
- BREEAM and others require LCC.
- Understand the maintenance cycles and associated budgets.
- Produce option studies on a consist basis.

Some of the benefits of quantifying the environmental impacts over the life are:

- Produce an solution with a lower impact on the environment.
- Associated good public image.
- Legislation to encourage lower emissions is likely to mean that there may be charges for anything that produces emissions. Through analysis at the early stage you can help minimise these charges throughout the life of your project.

Some of the benefits of quantifying the social impacts over the life are:

- Enable you to plot resource demands and identify any associated impacts on the local infrastructure through their procurement.
- Encourage the use of recycling and reusing any spare resource in other aspects of a portfolio.
- Model and understand likely impacts of transport.

The additional benefits of producing an analysis of the three reporting aspects together may not be initially as obvious. The three reporting groups (Economic, Environmental and Social) all require a similar level of measurement and quantification. Traditionally on projects these areas are handled by three separate teams who often measure separately with separate boundaries. Resultantly there is much efficiency to be gained if we can combine some of the tasks and measurement. Also through adoption of the concept of life costing we can begin to offer additional reports and outputs that could be used to influence the construction process, at minimal additional effort.

3.0 LifeCYCLE

It is through a combination of legislation and procurement best practice that the UK construction industry is beginning to quantify the whole life cost and carbon impacts of construction activities. For this reason Franklin + Andrews embarked on a three year programme to develop the LifeCYCLE building system alongside the recent publication of a new edition of the Hutchins UK Building Blackbook 2010 that sets a new standard in the construction industry. This is the first construction book to include an estimate of CO_2 emissions for activities of construction work – as well as retaining the pricing guidance that the book has traditionally provided.

In order to help our clients pick the best design options, Franklin + Andrews has developed LifeCYCLE, the industry-first internet based life cost modelling tool. The tool quantifies capital cost, maintenance costs, operational costs direct and embodied carbon emissions over the life-time of a building as well as quantifying waste, resources and transportation.

The database used within the system is based on comprehensive surveys of component performance combined with bottom-up data build-ups, all of which have been validated with ‘live’ project data. LifeCYCLE allows the user to see and adjust any assumption made, even down to the distance and method of transporting to site.

3.1 Case Study

Using the Franklin + Andrews LifeCYCLE system, we have studied the life-time performance of a typical UK administrative building in order to see the economic cost and environmental impact.

The gross floor area of the building studied is approximately 765 m2. The exercise was run for 30 years and the prices are at first quarter 2010 levels and at UK average location.

The performance of the assets selected can vary dramatically depending on specification, thickness, installation method, usage, location in building, cleaning method and many other factors that can be selected by the user, for the purpose of this high-level study a mid range theoretical specification and maintenance regime has been adopted.

The summary table (Table 1) which follows plots totals for cost (£) and environmental impact (Kg CO_2) for the initial capital and life time activities over the 30 year period studied.

The building specification was steel frame with block / rendered walls, partially copper clad, suspended pre-cast floor slab, aluminium insulated roofing system, aluminium windows, concrete blockwork walls, plaster / paint finish, carpet / ceramic tile flooring, suspended ceilings. Building services consist of commercial kitchen, BMS, LTHW system with gas boiler, security / CCTV, electrical, IT and telecoms distribution throughout.

	Capital Cost		Embodied CO2		Life Cycle Cost (excl Capital Cost)		Life Cycle CO2	
	£	%	Kg	%	Total (£)	%	Kg	%
Substructure	**70,836.73**	**6.1%**	**96,114.94**	**14.3%**	**0.00**	**0.0%**	**0.00**	**0.0%**
Superstructure	**360,185.41**	**31.2%**	**346,434.63**	**51.4%**	**241,483.02**	**10.4%**	**1,543.60**	**0.9%**
Frame	98,066.33	8.5%	143,831.28	21.3%	23,271.54	1.0%	793.67	0.5%
Upper floors	29,042.00	2.5%	14,654.09	2.2%	15,014.41	0.6%	0.00	0.0%
Roof	62,589.11	5.4%	35,629.92	5.3%	23,961.75	1.0%	0.00	0.0%
Stairs	27,941.24	2.4%	8,415.31	1.2%	66,317.52	2.9%	0.00	0.0%
External walls	73,644.83	6.4%	92,022.29	13.7%	33,414.17	1.4%	0.00	0.0%
Windows and external doors	23,786.52	2.1%	9,023.27	1.3%	37,716.38	1.6%	171.70	0.1%
Internal walls and partition	29,609.22	2.6%	41,486.34	6.2%	20,538.16	0.9%	0.00	0.0%
Internal doors	15,506.16	1.3%	1,372.13	0.2%	21,249.09	0.9%	578.23	0.3%
Finishes	**114,159.44**	**9.9%**	**82,049.19**	**12.2%**	**788,199.66**	**34.0%**	**82,937.59**	**49.7%**
Wall finishes	45,442.61	3.9%	6,856.70	1.0%	337,320.62	14.6%	8,691.34	5.2%
Floor finishes	49,128.08	4.3%	54,403.16	8.1%	409,095.79	17.7%	53,456.92	32.0%
Ceiling finishes	19,588.75	1.7%	20,789.33	3.1%	41,783.25	1.8%	20,789.33	12.4%
Fittings & Furnishings	**12,536.65**	**1.1%**	**14,741.00**	**2.2%**	**85,082.65**	**3.7%**	**14,778.19**	**8.8%**
Services	**424,032.00**	**36.8%**	**40,510.00**	**6.0%**	**885,631.00**	**38.2%**	**65,226.00**	**39.1%**
External Works	**171,433.00**	**14.9%**	**94,284.00**	**14.0%**	**316,175.00**	**13.6%**	**2,526.44**	**1.5%**
Total	**1,153,183.23**	**100.0%**	**674,133.76**	**100.0%**	**2,316,571.33**	**100.0%**	**167,011.82**	**100.0%**
Per m2	**1,507.43**		**881.22**		**3,028.20**		**218.32**	

Table 1: Case Study Summary Table

The results of the study demonstrate the impact of the selection of components on a building's initial cost and carbon footprint. This study shows that superstructure is the most significant element, accounting for approximately 46% of CO_2 emissions and in cost terms equates to around 23% of the total capital cost.

The study illustrates that Finishes and Services contribute the most to life cycle costs and carbon emissions. These elements are those that need more frequent maintenance / replacement works throughout the life of the building.

In order to demonstrate the annual and cumulative distribution of costs and carbon over the study period of the building, Figure 3 and 4 below are reproduced from the LifeCYCLE system.

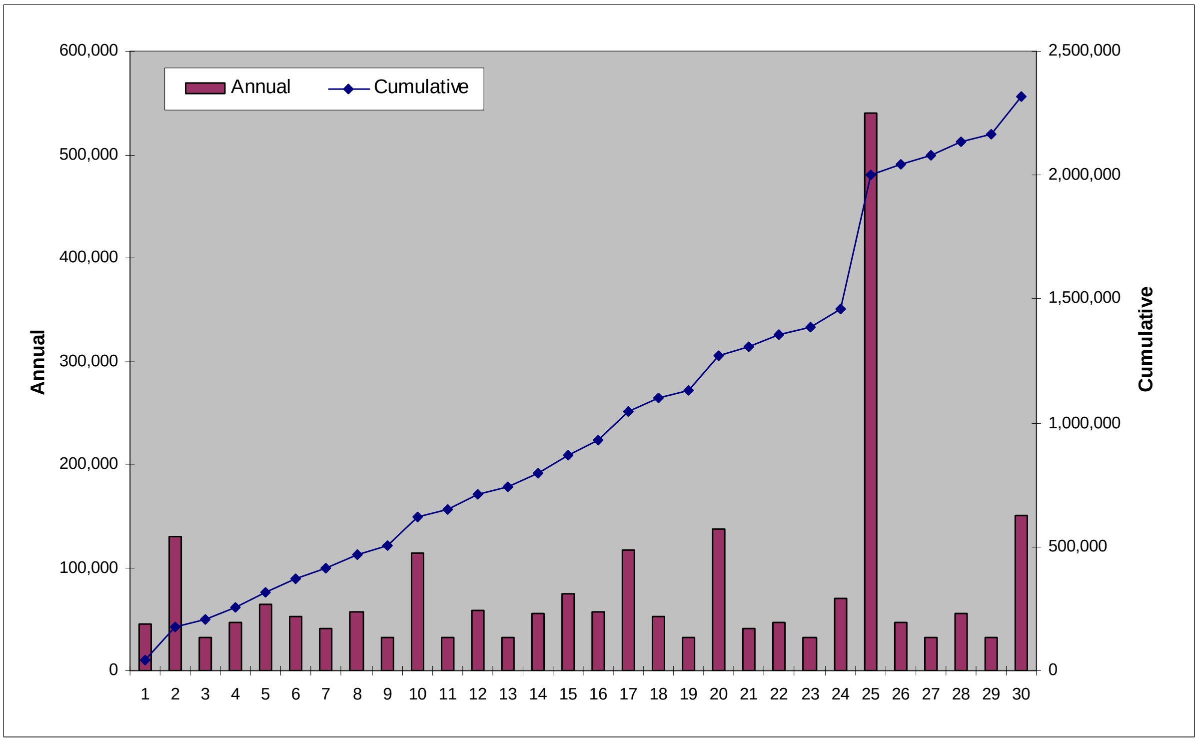

Figure 3: Cost (£) over 30 years (excludes capital works and utilities)

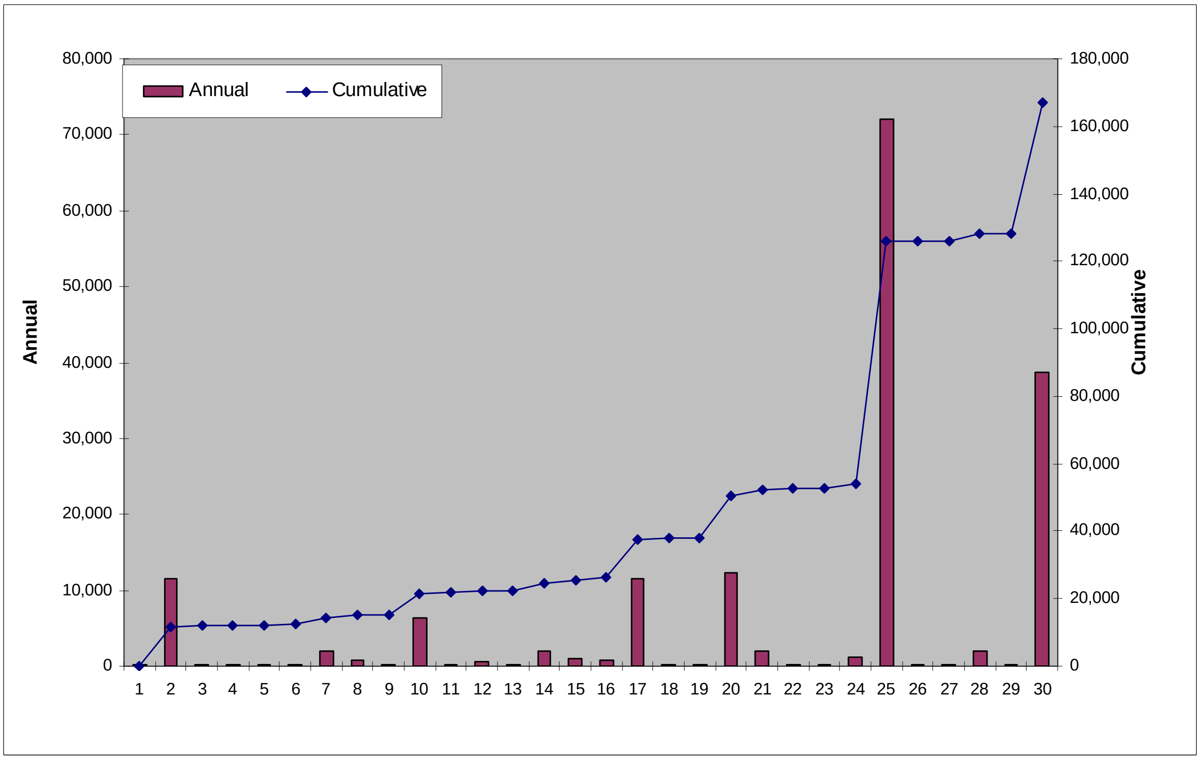

Figure 4: CO_2 (Kg) over 30 years (excludes capital works and utilities)

While some cost-to-carbon ratios were relatively proportionate across elements, building services in particular represented a high capital cost with proportionately lower capital carbon emission value.

The table above excludes the utility cost / carbon figures from the operation of the building which would equate to the largest aspect of carbon emissions over the life of the building. In order to understand this, Figure 5 below plots the percentage share of this Cost and CO_2 emission against that totaled in the main categories of construction activity over the 30 year study period of the building.

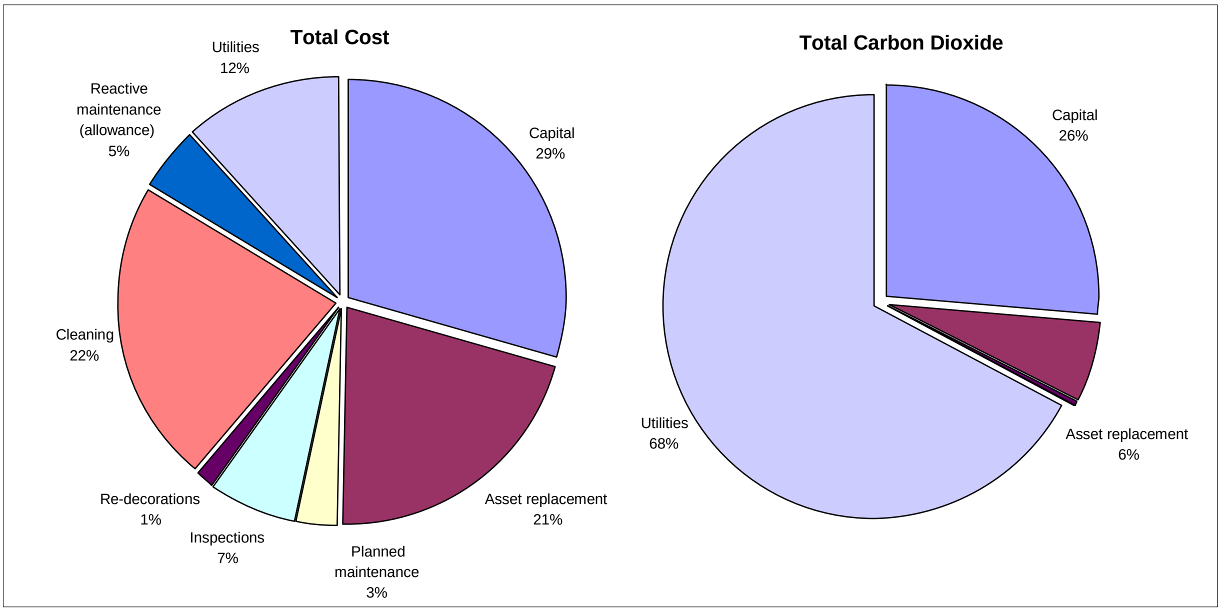

Figure 5: Total Cost (£) and Carbon Emissions (Kg CO2) over 30 years (including capital and utilities)

The real value of using a system like LifeCYCLE is the ability to optioneer between different design options and identify what the impacts on future cost and carbon is likely to be. Our study has identified that by changing the specification or components of the base building above, life cost and carbon savings of up to 30% are achievable.

4.0 Summary

It is increasingly being understood by the industry that is important that we do not unwittingly build something now that will result in a high cost or CO_2 emission performance going into the future. The future impact of our design choices therefore need to be modelled and understood.

Through the concept of Life Costing, it is possible to quantify the measurements required for Economic and Carbon Calculation in a single operation, offering potential savings and efficiencies to the design teams responsible for delivering these areas. As the analysis is conducted at a detailed bottom-up level, it is also possible to quantify the resource requirements and wastage levels. As these resources are used in different activities at different stages of a components life, through life costing we can calculate the financial and environmental impacts at any stage over a buildings life.

This detail will enable data assumption to be reduced and also enables a greater understanding of what is included within on-going maintenance activities. This would offer significant improvements on a number of the methodologies currently employed to calculate LCC including lump-sums and percentages of capital works.

Linking capital cost, capital carbon, life cycle costs and life cycle carbon together in a modelling system such as LifeCYCLE enables the user to quickly scenario design options and even change the use of different resources over the whole life of a building, for example changing a JCB powered by diesel to one using bio-fuels in order to identify any savings in on-going cost or environmental impact.

One thing is for certain, sustainability and emissions are set to remain in our focus for the foreseeable future. With reduction targets, legislation and pledges in place, it is now up to industry to rise to the challenge in our fight against damage to the environment.

4.1 Points of further theoretical discussion

4.1.1 Setting consistent boundaries to studies

Often, due to the evolution of the industry and its lack of understanding, different boundaries have been selected for carbon accounting in particular. This results in inconsistent reports for buildings or projects making the results incomparable. This inconsistent reporting could also identify a design solution as producing the lowest environmental impact, when in fact its boundary has skewed the results artificially.

4.1.2 What's the point of LCC – we only have an annual budget

There are still instances where annual budgets are set by funding departments that do not take into account of building cycles. Therefore what is the point of completing any LCC?

4.1.3 How can we deal with technology and occupancy changes?

Life Costing will only model the known aspects of the future maintenance and replacement cycle, unknown such as technology changes, legislation changes and occupancy changes that could impact on the buildings assets are not known. Life Costing is not therefore designed to produce a detailed account for costs or carbon for cash-flow purposes, but is designed as a scientific method of appraising options.

4.1.4 How reliable is manufacturer's data for new products?

Connected to 6.1.1 above, how reliable is manufacturer's data and if it is a new component how can we validate against live data?

4.1.5 Is real live data out of date as soon as it's available?

It is argued that the use of historical project data is unrepresentative on new projects due to building regulation and general design performance changes.

4.1.6 Strategy for emerging international economies?

With different countries at different stages of development, a suitable metric must also be determined in order to help incentivise those countries producing emissions through development to embrace the most efficient processes. A number of technologies are emerging as possible solutions like carbon capture and storage, where emissions are trapped, rather than released into the atmosphere.