

Working Group on Sustainability and Life Cycle Costing

# Society of Chartered Surveyors Ireland Guide to Life Cycle Costing



## Author

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## Nature of the Document

This document provides practical guidance and assistance for construction cost professionals in carrying out Life Cycle Cost Analysis (LCCA) and producing Life Cycle Cost Models (LCCM). The document puts forward a number of definitions of Life Cycle Costing (LCC), outlines how LCC calculations can be carried out and proposes a structure and methodology for presenting LCCM.

The document is not an Irish set of standards or specifications for LCC. It should not be quoted in tender or contract documents and its use is not intended as a standard method of measurement or rules of measurement. The documents purpose is to educate SCSI members on LCC and aid them in producing LCC models during the design and construction process.

## Life Cycle Cost Guidance Notes

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# 1.0 Life Cycle Costing

## 1.1 Definitions

The definitions of life cycle costing as defined in the International Standard BS ISO 15686-5: include:

### **Life Cycle Cost (LCC)**

***Life cycle cost (LCC) is 'cost of an asset, or its parts throughout its life cycle, while fulfilling the performance requirements'.***

(BS ISO 15686-5, 3.1.1.7)

***Life cycle costing is 'methodology for the systematic economic evaluation of life cycle costs over a period of analysis, as defined in the agreed scope'.***

Note: life cycle costing can address a period of analysis which covers the entire life cycle, or selected stage(s) or periods of interest therein.

(BS ISO 15686-5, 3.1.1.8)

There are also some references to whole life costing, which has a broader scope than life cycle costing:

### **Whole Life Costing**

***Whole life costing (WLC) is 'methodology for the systematic economic consideration of all whole life costs and benefits over a period of analysis, as defined in the agreed scope'.***

Note: the projected costs or benefits may include finance, business costs, income from land sale and user costs.

(BS ISO 15686-5, 3.1.1.15)

***The whole-life costs of a facility are the costs of acquiring it, 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.***

Office of Government Commerce (OGC)

Whole Life Cycle Costing and Cost Management: Achieving Excellence in Construction Procurement Guide, Part 07.

## 1.2 Life Cycle Costing and Whole Life Cycle Costing

As outlined above WLCC is an economic evaluation in which all costs arising from owning operating and maintaining a building over a certain study period or building life cycle are considered to be potentially important in option appraisal, design decisions and cash flow forecasting. Confusion can exist over the terminology as different publications use different terms to describe the concept of LCC. For the purposes of this publication the working group describes LCC as the costs arising from owning, operating and maintaining an individual building system or component throughout the components life cycle or throughout the estimated life cycle of the building itself. WLCC are then the accumulated sum of all the individual LCC calculations throughout the buildings life cycle or study period. A (W)LCCA or (W)LCCM can be described as the calculation and presentation of WLCC in a standard format, over a given study period, possibly using one of the international methodologies or standard method of measurement in measuring and presenting LCC.

WLCC can be carried out at different stages of the project process, depending on client requirements and the level of detail and information available. The different purposes of WLCC and the different stages that WLCC can be carried out are outlined in Section 4 of the BSI/BCIS document "Standardised Method of Life Cycle Costing for Construction: UK supplement to ISO 15686 Part 5 life-cycle costing for buildings and constructed assets".

## 1.3 Why use Life Cycle Costing

LCC is relevant throughout the design and construction process but in particular during the planning and design of the project. The quality of both the design and construction of the project has a significant bearing on the costs of the building in use. Projects where the design team solely focus on reducing capital costs can lead to a building which is expensive to maintain, operate, occupy and eventually dispose of. Decisions made early in the design process can have a considerable influence on LCC, thus careful consideration should be given during the design and procurement process to the costs of the building throughout its life cycle. The focus on WLCC should ideally start at the business justification stage when a conscious informed decision may be taken to increase value in an operational aspect while keeping maintenance as low as possible. Each stage a WLCC exercise is carried out is reflected in the same level of detail of its corresponding design stage. However making informed LCC decisions at early stages of a design may be difficult as there might not be enough detailed information to carry out calculations.

Typically, LCCA may be used during the following four key stages of the life cycle of any constructed asset:

- a) project investment and planning; WLC/LCC strategic options analyses; preconstruction;
- b) design and construction; LCC during construction, at scheme, functional, system and detailed component levels;
- c) during occupation; LCC during occupation (cost-in-use); post-construction; and
- d) disposal; LCC at end-of-life/end-of-interest.

(BS ISO 15686-5:2008)

### 1.3.1 Capital Works Management Framework

The Capital Works Management Framework (CWMF) is a structure that has been developed to deliver the government's objectives in relation to public sector construction procurement reform. It consists of a suite of best practice guidance notes, standard contracts and generic template documents that form four pillars that support the framework; the pillars are:

1. A suite of standard forms of construction contracts and associated model forms, dispute resolution rules, model invitations to tender, forms of tender and schedules;
2. The standard conditions of engagement for consultants, dispute resolution rules, model invitations to tender, forms of tender and schedules;
3. Standard templates to record cost planning and control information; and for suitability assessment; and
4. Extensive guidance notes covering the various activities in a project delivery process.

Pillar 3 consists of cost control & planning forms, cost plan templates and suitability assessment forms for construction works and services (see Planning and Control of Capital Costs, Guidance Notes 2.2. Page 9 for a list of forms and templates associated with Pillar 3). Pillar 4 provides guidance notes (GN 2.2) aimed at facilitating the implementation of the measures and forms outlined above to achieve greater cost certainty and better value for money on publicly funded projects.

### 1.3.2 The Capital Works Management Framework (CWMF) and Life Cycle Costing

The CWMF, 'Planning and Control of Capital Costs, Guidance Notes 2.2' state that "whole life costs are an important consideration throughout the design process, and should be integrated at each stage in cost plan development". The cost planning stages are outlined in the CWMF as:

- In the Outline Cost Plan – at Outline Sketch Scheme / Preliminary Planning
- In the Developed Cost Plan / Outline Cost Plan (revised) – at Developed Sketch Scheme/Preliminary Planning; and
- In the Pre-tender Cost Check

Comparison of a number of different design options can be evaluated during the cost planning process, taking into account and comparing the WLCC of each option. This exercise could facilitate decision making on whether to lease or construct a new facility, whether to refurbish an existing building or build a new one or in the evaluation of a more sustainable building solution.

(Planning and Control of Capital Costs, Guidance Notes 2.2.)

### 1.3.3 Life Cycle Costing and Sustainability

Sustainable construction presumes a whole systems approach that considers the environmental, social and economic consequences of any decision made within the construction industry. Clients implementing sustainable practices into their buildings should require the total cost of their investment in the building rather than just the initial capital cost. It is becoming increasingly paramount that clients use an investment appraisal technique that uses a whole life approach. Therefore leading construction clients are now insisting upon an analysis of WLCC. Design decisions related to the building's energy efficiency such as orientation, thermal efficiency and airtightness can influence the buildings costs in use and LCC can be used to evaluate whether additional sustainable attributes and energy efficiency measures are cost effective over a given study period. LCC can also be used to determine the maintenance and replacement cost of a component or system over a study period (see Section 6.0 Worked Example). This information can inform design decisions on issues such as cleaning, maintenance, energy efficiency, durability and disposal. Cost consultants can even build sophisticated maintenance plans and profiles, possibly consulting with facilities managers to devise a life cycle strategy and carry out maintenance and replacement works in accordance with the expenditure set out in the strategy, essentially providing a budget and template for cost control during the life of the building.

### 1.3.4 Risk Management

Traditionally cost consultants focused on the financial risk that could occur during the construction period. Costs during construction can be affected by unexpected ground conditions, inclement weather, labour and materials shortages, time overruns, defects and poor budgeting. Owners and lending institutions now realise that there is also risk and uncertainty related to the building in use. Designing and constructing a building that takes into consideration the whole life cycle of the asset may help future proof the client's investment against rising energy costs and excessive maintenance and replacement costs. This type of informed decision making may increase the owner's ability to pay back the initial investment, reduce costs and increase profit. Recognising this, clients are keen to introduce LCC into the procurement process. As outlined above the design team should strive to design a solution that is cost-effective, affordable and that delivers value for money both in capital and whole life cost terms. In this regard life cycle costing should be incorporated into the cost planning process and if possible the tender process.

### 1.3.5 Tendering

The majority of public sector work in Ireland is procured through the traditional procurement and tender process. The traditional tender process does not lend itself to a meaningful evaluation of LCC as the design is already completed prior to the tenderer receiving the tender documents. The contractor at this stage has no real influence outside the quality of construction, over the cost of the building in use and thus a WLCCA by the contractor would be of no real benefit. However in design build tenders the contractor does have input into the design process and thus has a significant influence on how the building will perform in use. Tenders must be evaluated as the 'Most Economic Advantageous Tender' (MEAT) and selecting design build tenders without an evaluation of potential future costs would not reflect the 'most economically advantageous' contractor. Careful LCC must especially be considered and evaluated in the preparation of Public Private Partnership (PPP) tenders. Without accurate profiling and analysis of maintenance and replacement costs covering the periodic redecoration, replacement, major refurbishment or renewal of the main assets and/or sub-components of a project, the tenderer could over bid the tender even if they submitted a very keen construction cost. The tenderer could also expose their company to significant risk during the PPP life cycle if they did not take account of all the potential life cycle costs over the maintenance period.

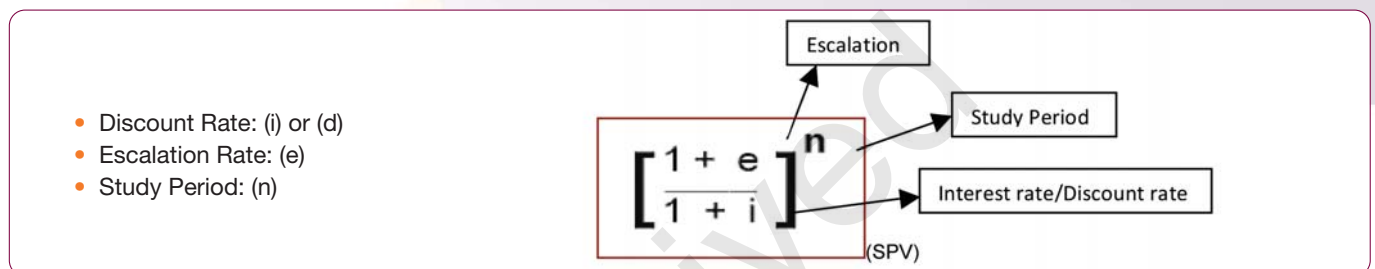


## 2.0 Calculating Life Cycle Costs

### 2.1 Data Requirements

LCC relies on predicting when elements of the building and its services will deteriorate to a condition where intervention is needed, and what the discounted cost of each intervention will be. LCC calculations therefore depend on numerous assumptions, all subject to a degree of uncertainty. When calculating LCC it is necessary to discount all future intervention costs to a comparable time base. All future expenditure should be discounted with Net Present Value (NPV) formulae to a cumulative sum in today's monetary value. These calculations incorporate escalation and discount rates to account for different operations taking place at different times. This provides the cost consultant with an opportunity to evaluate different systems, solutions and building options over a selected study period.

Calculating life cycle costing and discounting future costs requires a number of data requirements (or variables) to input into the relevant formulae. These variables are outlined below;



### 2.2 Discount Rate (i) or (d)

The discount rate is a key variable in discounting future costs. Discount rates can be derived from the opportunity rate of return possible from investing in an activity other than that activity being studied (i.e. in a deposit account, bond, shares and internal investment). Discount rates are used to bring future costs to a comparable time base (year 0 - today). Private sector investments generally generate a higher return than public sector investment and thus a higher discount rate is applied in private sector LCC calculations. On public financed projects the base discount rate is usually determined by the rate specified as the discount rate by the Government's Treasury Agency. In Ireland project discount and inflation rates are outlined on the Department of Public Expenditure and Reform's website; url <http://per.gov.ie/project-discount-inflation-rates/>.

#### **Example Question:**

If you estimate that to replace floor finishes in a classroom will cost €10,840 in 25 years, what is the present value of that future sum at a discount rate of 10%? To carry out this calculation you must discount the future value, €10,840 by 10%, this equates to a present value of €1,000 using a Single Present Value (SPV) calculation as outlined later in the document. Alternatively if I invest €1,000 today at an interest rate of 10%, I will have €10,840 to pay for floor finishes in 25 years. Thus the present value of €10,840 at a discount rate of 10% over 25 years is €1,000. All future owning, operating, occupancy and maintenance costs must be discounted in such a manner and accumulated to a total NPV.

### 2.3 Calculating Future Costs: Escalation Rates (e)

The escalation rate is the rate of increase in the price of a specific commodity. The easiest way to estimate future costs is to inflate costs known today with a relevant escalation rate. Applying escalation rates to energy costs, maintenance costs and replacement costs will produce estimated future (nominal costs) costs. Today's estimated costs are predominantly determined from the cost plan or bill of quantities, depending on what stage the LCC study is been carried out. When assessing the replacement costs of a building component or system in 25 years, a factor should be applied to the estimated cost (today's cost) for demolition and disposal of the existing component. The factored cost is then escalated with a relevant escalation rate to its future value.

## 2.4 Discounting and Escalating

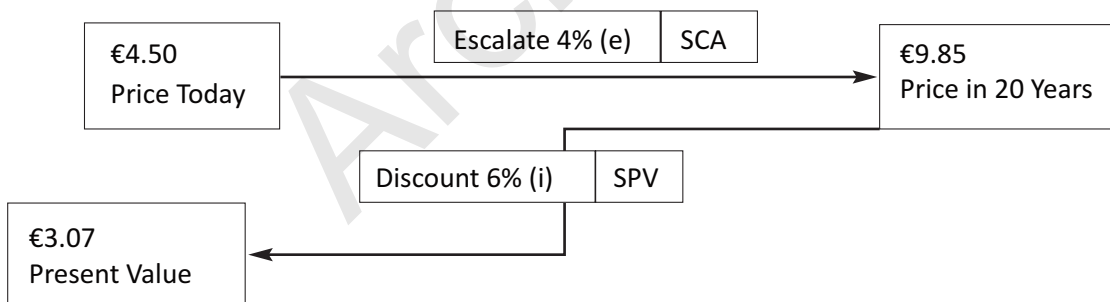
Present Value (PV) formulae include for both the escalation (e) and discounting (i) of future costs in the same calculation. It must be noted that confusion can arise when present costs (base or today's cost) can be mistaken for the present value of a future cost. This would be the case if the escalation rate and the discount rate were the same. The following example outlines the relationship between escalation and discounting:

### **Example Question:**

What is the PV of a cup of coffee that costs €4.50 today in 20 years escalating at 4% p.a applying a discount rate of 6%?

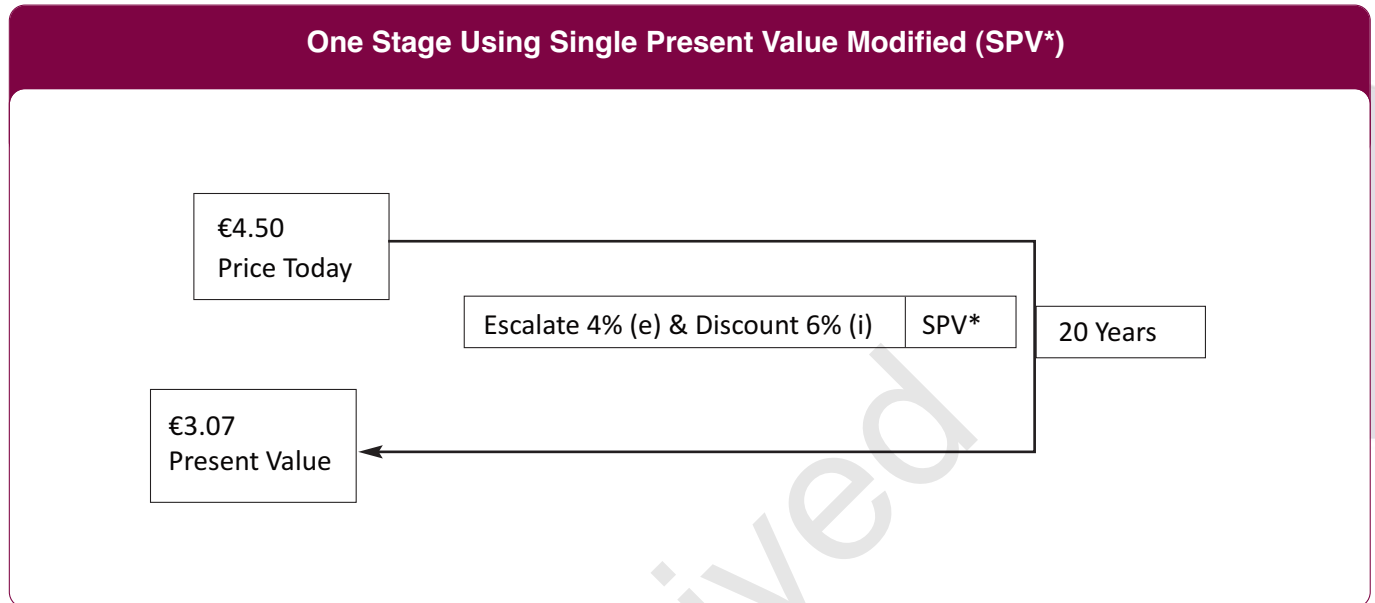
There are two elements to this calculation; the first stage is the escalation of the cost of the coffee today to the cost of the coffee in 20 years. Using a Single Compound Amount (SCA) calculation at an escalation rate of 4%, the escalated cost of the coffee in 20 years will be €9.85. The next stage of the process discounts that future cost to a present value. If you discount the future cost of €9.85 using a Single Present Value (SPV) calculation at a discount rate of 6% the PV of the cup of coffee will be €3.07. Alternatively if I invest €3.07 at 6% p.a I will be able to pay for my cup of coffee in 20 years. €3.07 is the present value while €4.50 is the present cost. How is the present value of the coffee at €3.07 less than the present cost of €4.50? This difference represents the difference between the escalation rate of 4% and the discount rate of 6%, where the cost today is being discounted at a greater rate than it is escalating. If the discount rate was the same as the escalation rate (4%) the present value of the cup of coffee would be the same as the present cost (€4.50).

### Two Stage. Using Simple Compound Amount (SCA) and Single Present Value (SPV).





The example above outlines a two stage process where the current price is escalated to a future sum and then that future sum is then discounted back to a present value. The following plate outlines a formulae that includes the escalation and discounting within the same calculation, Single Present Value Modified (SPV\*). These Present Value formulae are outlined in greater detail in section 3.0 of the document.



## 2.5 Study Period (n)

The study period is that period of time for which the investor has an interest in the building's life. In a WLCCA this may be represented as the estimated physical life of the building or possibly the estimated period of use. In Public Private Partnership's (PPP) the life cycle study period is determined by the hand over date. The study period may also be determined by the investors expected payback period on their initial investment.

## 3.0 Present Value Calculations

### 3.1 Present Value Calculations

Present Value (PV) can be defined as:

The amount to be invested in the bank today to pay for all future costs at a given interest rate (discount rate) over a known time horizon. Alternatively it can be described as the present day worth of a future cost discounted at a given interest rate.

LCC as explained earlier are calculated in PV euro. In order to evaluate LCC of a building or a building component you can use a number of PV factors or formulae. Single Present Value (SPV), Uniform Present Value (UPV), Single Present Value Modified (SPV\*) and Uniform Present Value Modified (UPV\*).

### 3.2 Single Present Value (SPV)

The SPV calculation is used when a one off discount of a single future cost is required. SPV does not include an adjustment for escalation. This calculation may be used where 'the nominal cost' (costs that already include escalation) related to a specific year (n) is discounted to a present value. An example of this would be replacement of a building component whose future cost is known or can be reasonably estimated and discounted (i) to a PV. A building component may have a number of life cycles within the whole building life cycle and thus an SPV calculation will have to be applied at each replacement year.

SPV	$\frac{1}{(1 + i)^n}$
-----	-----------------------

### 3.3 Uniform Present Value (UPV)

A UPV calculation is used where a fixed uniform sum of money is paid on a yearly basis throughout the life cycle of the building. A UPV calculation does not include escalation and thus the payment does not change from year to year. The UPV calculation allows for all annual payments to be discounted (i) proportionally throughout the life cycle or study period (n).

UPV	$\frac{(1 + i)^n - 1}{i (1 + i)^n}$
-----	-------------------------------------

### 3.4 Single Present Value Modified (SPV\*)

The SPV\* factor is similar to the SPV calculation outlined previously, except SPV\* allows for the incorporation of escalation (e) into the calculation. This factor is used when the cost today is known (or estimated) and a relevant escalation rate is applied over a certain period of time to estimate the future cost of the building component. The formulae allows for the escalation and discounting factors to be incorporated in the same calculation.

SPV*	$\left[ \frac{1 + e}{1 + i} \right]^n$
------	----------------------------------------

### 3.5 Uniform Present Value Modified (UPV\*)

The UPV\* calculation is similar to the UPV calculation outlined previously. The original amount is escalated on a yearly basis and is discounted proportionally throughout the building life cycle. An example of this is energy costs which can be reasonably estimated in today's costs. Applying an escalation rate (e) to energy costs on a yearly basis over the life cycle and discounting (i) the costs will provide you with a cumulative PV cost.

UPV*	$\frac{1 - \left[ \frac{1 + e}{1 + i} \right]^n}{\left[ \frac{1 + i}{1 + e} \right]^{-1}}$
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## 4.0 Using the Formulae

### 4.1 Scientific Calculator

A scientific calculator can be used to carry out the PV calculations outlined previously. This method can be quite time consuming as each variable must be inputted to determine the relevant factor. This calculation is repeated for each LLC calculation to determine the cumulative present value LCC.

### 4.2 Financial Tables

Financial tables allow for PV calculations to be performed without the use of calculators. Most financial tables cover a wide range of discount rates, escalation rates and time periods. SPV and UPV factors can be calculated by searching for the discount rate (d) for the relevant study period. SPV\* and UPV\* calculations allow for the incorporation of an escalation rate into the formulae. The following examples, 4.2.1 and 4.2.2 outlines how financial tables are used in LCC calculations.

#### 4.2.1 Single Present Value (SPV) calculations with Financial Tables

##### Example Question:

Calculate the PV of a future amount of €1,000 in 30 Years at a discount rate of 8%.

$F = €1,000$   $n = 30$  &  $d = 8\%$

$PV = F \times SPV$

<b>d=8%</b>		<b>DISCOUNT FACTORS</b> Discount Rate d = 8%					
Year	Single Compound Amount SCA	Single Present Value SPV	Uniform Capital Recovery UCR	Uniform Present Value UPV	Uniform Sinking Fund USF	Uniform Compound Amount UCA	
1	1.0800	0.9259	1.0800	0.9259	1.0000	1.0000	
2	1.1664	0.8573	0.5608	1.7833	0.4808	2.0800	
3	1.2597	0.7938	0.3880	2.5771	0.3080	3.2464	
4	1.3605	0.7350	0.3019	3.3121	0.2219	4.5061	
5	1.4693	0.6806	0.2505	3.9927	0.1705	5.8666	
6	1.5869	0.6302	0.2163	4.6229	0.1363	7.3359	
7	1.7138	0.5835	0.1921	5.2064	0.1121	8.9228	
8	1.8509	0.5403	0.1740	5.7466	0.0940	10.637	
9	1.9990	0.5002	0.1601	6.2469	0.0801	12.488	
10	2.1589	0.4632	0.1490	6.7101	0.0690	14.487	
11	2.3316	0.4289	0.1401	7.1390	0.0601	16.645	
12	2.5182	0.3971	0.1327	7.5361	0.0527	18.977	
13	2.7196	0.3677	0.1265	7.9038	0.0465	21.495	
14	2.9372	0.3405	0.1213	8.2442	0.0413	24.215	
15	3.1722	0.3152	0.1168	8.5595	0.0368	27.152	
16	3.4259	0.2919	0.1130	8.8514	0.0330	30.324	
17	3.7000	0.2703	0.1096	9.1216	0.0296	33.750	
18	3.9960	0.2502	0.1067	9.3719	0.0267	37.450	
19	4.3157	0.2317	0.1041	9.6036	0.0241	41.446	
20	4.6610	0.2145	0.1019	9.8181	0.0219	45.762	
21	5.0338	0.1987	0.0998	10.017	0.0198	50.423	
22	5.4365	0.1839	0.0980	10.201	0.0180	55.457	
23	5.8715	0.1703	0.0964	10.371	0.0164	60.893	
24	6.3412	0.1577	0.0950	10.529	0.0150	66.765	
25	6.8485	0.1460	0.0937	10.675	0.0137	73.106	
26	7.3964	0.1352	0.0925	10.810	0.0125	79.954	
27	7.9881	0.1252	0.0914	10.935	0.0114	87.351	
28	8.6271	0.1159	0.0905	11.051	0.0105	95.339	
29	9.3173	0.1073	0.0896	11.158	0.0096	103.97	
30	10.063	0.0994	0.0888	11.258	0.0088	113.28	
35	14.785	0.0676	0.0858	11.655	0.0058	172.32	
40	21.725	0.0460	0.0839	11.925	0.0039	259.06	
45	31.920	0.0313	0.0826	12.108	0.0026	386.51	
50	46.902	0.0213	0.0817	12.233	0.0017	573.77	

Robert P. Charette, May 2005, Rev. 2.

Locate the relevant SPV discount rate in the financial tables (8%). Locate the PV factor on the table above by locating the factor at the intersection between the SPV and the relevant year. Multiply the factor by the future amount to establish the PV of that future amount at the relevant interest rate (8%).

**Answer = €1,000 x .0994 = €99.40.**

The PV of €1,000 in 30 years at a discount rate of 8% is €99.40. If I invest €99.40 today at an interest rate of 8%, I will be able to pay that future of €1,000 in 30 years.



#### 4.2.2 Uniform Present Value Modified (UPV\*) calculations with Financial Tables

##### Example Question:

Calculate the PV of a payment of €1,000 yearly for thirty years at a discount rate of 8% and an escalation rate of 6%.

$A_0 = €1,000$ ,  $n = 30$ ,  $d = 8\%$ ,  $e = 6\%$

$PV = A_0 \times UPV^*$

d= 8%													d= 8%												
UPV* - Modified Uniform Present Value Factors																									
Discount Rate d = 8%																									
Escalation Rates																									
0% 1% 2% 3% 4% 5% 6% 7% 8% 9% 10% 11% 12%																									
Year	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	Year											
1	0.926	0.935	0.944	0.954	0.963	0.972	0.981	0.991	1.000	1.009	1.019	1.028	1.037	1											
2	1.783	1.810	1.836	1.863	1.890	1.917	1.945	1.972	2.000	2.028	2.056	2.084	2.112	2											
3	2.577	2.628	2.679	2.731	2.783	2.836	2.890	2.945	3.000	3.056	3.112	3.170	3.228	3											
4	3.312	3.393	3.474	3.558	3.643	3.730	3.818	3.908	4.000	4.093	4.189	4.286	4.384	4											
5	3.993	4.108	4.226	4.347	4.471	4.598	4.729	4.863	5.000	5.141	5.285	5.432	5.584	5											
6	4.623	4.777	4.936	5.099	5.268	5.443	5.623	5.809	6.000	6.197	6.401	6.611	6.828	6											
7	5.206	5.402	5.606	5.817	6.036	6.264	6.500	6.745	7.000	7.264	7.538	7.823	8.118	7											
8	5.747	5.987	6.239	6.501	6.776	7.062	7.361	7.674	8.000	8.341	8.696	9.068	9.455	8											
9	6.247	6.534	6.837	7.154	7.488	7.838	8.207	8.593	9.000	9.427	9.876	10.35	10.84	9											
10	6.710	7.046	7.401	7.777	8.173	8.593	9.036	9.505	10.00	10.52	11.08	11.66	12.28	10											
11	7.139	7.525	7.935	8.370	8.834	9.326	9.850	10.41	11.00	11.63	12.30	13.01	13.77	11											
12	7.536	7.972	8.438	8.937	9.469	10.04	10.65	11.30	12.00	12.75	13.55	14.40	15.32	12											
13	7.904	8.391	8.914	9.476	10.08	10.73	11.43	12.19	13.00	13.87	14.82	15.83	16.92	13											
14	8.244	8.782	9.363	9.991	10.67	11.41	12.20	13.07	14.00	15.01	16.11	17.30	18.59	14											
15	8.559	9.148	9.787	10.48	11.24	12.06	12.96	13.94	15.00	16.16	17.43	18.81	20.31	15											
16	8.851	9.490	10.19	10.95	11.79	12.70	13.70	14.80	16.00	17.32	18.77	20.36	22.10	16											
17	9.122	9.810	10.57	11.40	12.31	13.32	14.43	15.65	17.00	18.49	20.13	21.95	23.96	17											
18	9.372	10.11	10.92	11.82	12.82	13.92	15.14	16.50	18.00	19.67	21.53	23.59	25.88	18											
19	9.604	10.39	11.26	12.23	13.31	14.51	15.84	17.33	19.00	20.86	22.94	25.27	27.88	19											
20	9.818	10.65	11.58	12.62	13.78	15.08	16.53	18.16	20.00	22.06	24.39	27.00	29.95	20											
21	10.02	10.90	11.88	12.99	14.23	15.63	17.21	18.99	21.00	23.28	25.86	28.78	32.09	21											
22	10.20	11.13	12.17	13.34	14.67	16.17	17.87	19.80	22.00	24.50	27.35	30.61	34.32	22											
23	10.37	11.34	12.43	13.68	15.09	16.69	18.52	20.61	23.00	25.74	28.88	32.48	36.63	23											
24	10.53	11.54	12.69	14.00	15.49	17.20	19.16	21.41	24.00	26.99	30.43	34.41	39.02	24											
25	10.67	11.73	12.93	14.30	15.88	17.69	19.79	22.20	25.00	28.24	32.01	36.40	41.50	25											
26	10.81	11.90	13.15	14.59	16.25	18.17	20.40	22.99	26.00	29.52	33.62	38.44	44.08	26											
27	10.94	12.07	13.37	14.87	16.62	18.64	21.00	23.77	27.00	30.80	35.27	40.53	46.75	27											
28	11.05	12.22	13.57	15.14	16.96	19.10	21.60	24.54	28.00	32.09	36.94	42.69	49.52	28											
29	11.16	12.36	13.76	15.39	17.30	19.54	22.18	25.30	29.00	33.40	38.64	44.90	52.39	29											
30	11.26	12.50	13.94	15.63	17.62	19.97	22.75	26.06	30.00	34.72	40.37	47.17	55.37	30											
35	11.65	13.05	14.70	16.68	19.06	21.94	25.45	29.73	35.00	41.50	49.54	59.53	71.99	35											
40	11.92	13.44	15.27	17.51	20.25	23.66	27.91	33.25	40.00	48.59	59.58	73.71	91.93	40											
45	12.11	13.72	15.70	18.16	21.24	25.15	30.15	36.60	45.00	56.03	70.59	89.96	115.8	45											
50	12.23	13.92	16.02	18.67	22.06	26.44	32.18	39.80	50.00	63.81	82.66	108.6	144.5	50											

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Locate the relevant UPV\* discount rate in the financial tables (ie 8%). Locate the PV factor on the table above by locating the factor at the intersection between the relevant escalation (6%) on the 'X' axis and relevant year (30) on the 'Y' axis. Multiply the factor by the annual amount to establish the PV of that annual amount.

**Answer = €1,000 x 22.75 = €22,750.**

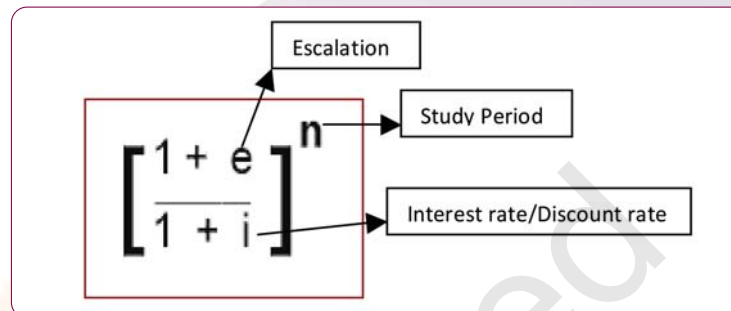
The present value of an annual sum of €1,000 euro escalating at 6% every year for 30 years and discounted at 8% is €22,750. Alternatively if I invest €22,750 at an interest rate of 8%, I will be able to pay the equivalent of €1,000 escalating at a rate of 6% every year for 30 years.

## 5.0 Using Excel

### 5.1 Present Value Calculations Using Excel

PV calculations can be written into a formula in an excel cell. Once you have completed the formula you can copy and paste it as required throughout your spreadsheet.

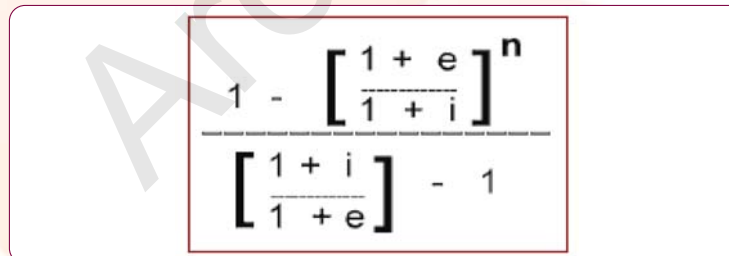
### 5.2 SPV\* Single Present Value Modified in Excel



The SPV\* formula shown above could be written into an excel cell as follows;

$$=((1+e)/(1+i))^n$$

### 5.3 UPV\* Uniform Present Value Modified in Excel



$$\frac{1 - \left[ \frac{1+e}{1+i} \right]^n}{\left[ \frac{1+i}{1+e} \right] - 1}$$

The UPV\* formula above could be written into an excel cell as follows;

$$=(1-((1+e)/(1+i))^n)/(((1+i)/(1+e))-1)$$

That formula can be copied and pasted as required throughout a life cycle cost analysis in Excel.

#### **Example Question: UPV\* calculation using excel formulae.**

Calculate the PV of a payment of €1,000 yearly for thirty years at a discount rate of 8% and an escalation rate of 6%.

$$A0 = \text{€}1,000, n = 30, d = 8\%, e = 6\%$$

$$PV = A0 \times UPV^*$$

Using the same example for UPV\* as outlined in 4.2.2, calculate the PV factor in excel. Type the formulae into the relevant cells.

**Solution**

$$1 - \left[ \frac{1+e}{1+i} \right]^n$$

$$\left[ \frac{1+i}{1+e} \right] - 1$$

$$= (1 - ((1+B2)/(1+C2))^D2) / (((1+C2)/(1+B2)) - 1)$$

$$= E2 * A2$$

	A	B	C	D	E	F
1	A <sub>0</sub>	e	d	n	f	Total
2	1000	0.06	0.08	30	22.74904	22749.04

= 1,000 x 22.75 = 22,750.



## 6.0 Example Calculation

### 6.1 Question

Financial tables and solutions are extracted from *Life Cycle Costing (LCC) for Green Building Design, Seminar/Workshop Robert P. Charette P.E., CVS, PQS(F) hosted by RICS/DIT May 2010.*

A client is considering replacing their boiler. System A is an oil boiler system whereas System B is a gas boiler system. Evaluate the Life Cycle Cost (PV) of both alternatives over the life of the building considering the following criteria. You may use the Financial Tables below to calculate UPV and SPV's.

Recurring Costs	System A	System B
Acquisition cost	4450	5000
Annual Maintenance Costs at present (today's) costs	100	75
Component Replacement every 10 years at present (today's) costs	4450	5000
Annual Energy Cost at (today's) present costs	500	460
Study Period – Years	20	20
Residual Value at end of study period at present (today's) costs	500	1000
Discount Rate	5%	5%
Escalation Rate	3%	3%

## 6.2 SPV\* Financial Tables

**d= 5%**

**SPV\* - Modified Single Present Value Factors**

Discount Rate d = 5%

Year	Escalation Rates							
	0%	1%	2%	3%	4%	5%	6%	7%
1	0.952	0.962	0.971	0.981	0.990	1.000	1.010	1.019
2	0.907	0.925	0.944	0.962	0.981	1.000	1.019	1.038
3	0.864	0.890	0.917	0.944	0.972	1.000	1.029	1.058
4	0.823	0.856	0.891	0.926	0.962	1.000	1.039	1.078
5	0.784	0.823	0.865	0.908	0.953	1.000	1.049	1.099
6	0.746	0.792	0.840	0.891	0.944	1.000	1.059	1.120
7	0.711	0.762	0.816	0.874	0.935	1.000	1.069	1.141
8	0.677	0.733	0.793	0.857	0.926	1.000	1.079	1.163
9	0.645	0.705	0.770	0.841	0.917	1.000	1.089	1.185
10	0.614	0.678	0.748	0.825	0.909	1.000	1.099	1.208
11	0.585	0.652	0.727	0.809	0.900	1.000	1.110	1.231
12	0.557	0.627	0.706	0.794	0.892	1.000	1.120	1.254
13	0.530	0.604	0.686	0.779	0.883	1.000	1.131	1.278
14	0.505	0.581	0.666	0.764	0.875	1.000	1.142	1.302
15	0.481	0.558	0.647	0.749	0.866	1.000	1.153	1.327
16	0.458	0.537	0.629	0.735	0.858	1.000	1.164	1.352
17	0.436	0.517	0.611	0.721	0.850	1.000	1.175	1.378
18	0.416	0.497	0.593	0.707	0.842	1.000	1.186	1.404
19	0.396	0.478	0.577	0.694	0.834	1.000	1.197	1.431
20	0.377	0.460	0.560	0.681	0.826	1.000	1.209	1.458
21	0.359	0.442	0.544	0.668	0.818	1.000	1.220	1.486
22	0.342	0.426	0.528	0.655	0.810	1.000	1.232	1.515
23	0.326	0.409	0.513	0.643	0.802	1.000	1.244	1.543
24	0.310	0.394	0.499	0.630	0.795	1.000	1.255	1.573
25	0.295	0.379	0.484	0.618	0.787	1.000	1.267	1.603

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SPV\* factor at a discount of 5% and an escalation rate at 3% for 10 years and 20 years respectively.

## 6.3 UPV\* Financial Tables

**d= 5%**

### UPV\* - Modified Uniform Present Value Factors

Discount Rate d = 5%

Year	Escalation Rates							
	0%	1%	2%	3%	4%	5%	6%	7%
1	0.952	0.962	0.971	0.981	0.990	1.000	1.010	1.019
2	1.859	1.887	1.915	1.943	1.972	2.000	2.029	2.058
3	2.723	2.777	2.832	2.887	2.943	3.000	3.058	3.116
4	3.546	3.633	3.722	3.813	3.906	4.000	4.096	4.194
5	4.329	4.457	4.587	4.721	4.859	5.000	5.145	5.293
6	5.076	5.249	5.428	5.612	5.803	6.000	6.203	6.413
7	5.786	6.011	6.244	6.487	6.738	7.000	7.272	7.554
8	6.463	6.744	7.037	7.344	7.665	8.000	8.351	8.717
9	7.108	7.449	7.808	8.185	8.582	9.000	9.440	9.902
10	7.722	8.127	8.556	9.010	9.491	10.000	10.54	11.11
11	8.306	8.779	9.283	9.819	10.391	11.00	11.65	12.34
12	8.863	9.407	9.989	10.61	11.28	12.00	12.77	13.59
13	9.394	10.010	10.68	11.39	12.17	13.00	13.90	14.87
14	9.899	10.591	11.34	12.16	13.04	14.00	15.04	16.17
15	10.380	11.15	11.99	12.91	13.91	15.00	16.20	17.50
16	10.84	11.69	12.62	13.64	14.76	16.00	17.36	18.85
17	11.27	12.20	13.23	14.36	15.61	17.00	18.53	20.23
18	11.69	12.70	13.82	15.07	16.46	18.00	19.72	21.64
19	12.09	13.18	14.40	15.76	17.29	19.00	20.92	23.07
20	12.46	13.64	14.96	16.44	18.12	20.00	22.13	24.53
21	12.82	14.08	15.50	17.11	18.93	21.00	23.35	26.01
22	13.16	14.51	16.03	17.77	19.74	22.00	24.58	27.53
23	13.49	14.92	16.54	18.41	20.55	23.00	25.82	29.07
24	13.80	15.31	17.04	19.04	21.34	24.00	27.08	30.64
25	14.09	15.69	17.53	19.66	22.13	25.00	28.34	32.25

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UPV\* factor at a discount of 5% and an escalation rate at 3% over 20 years.



## 6.4 Solutions

**LCC System: Oil Furnace**

**Criteria:  $d = 5\%$**

A	B	C	D	E	
Cost Items	Cost Base Yr	Occurrence - initial	PV Factor	PV	
	(B) Future (F)	- annual - future - year	And Value	(BxD)	
<b>1. Investment Costs</b>				<b>7781</b>	<p><b>1.1</b> You do not discount or escalate the original investment as it is already in Present Value (Year 0)</p> <p><b>1.2</b> Replacement – every 10 years. But you do not replace at year 20 as it is the end of the Building Life Cycle.</p> <p><b>1.3</b> The Residual Value is the value at which you could sell the asset at the end of its life cycle</p>
1.1 Acquisition cost	4,450 (B)	INITIAL (0)	1.0	4,450	
1.2 Capital Replacement	4450	Year 10	<b>SPV*0.825</b>	3671	
1.3 Residual Value (+ or -)	500 (B)	Year 20	<b>SPV* 0.681</b>	(340)	
1.4 Other					
<b>2. Operational Costs</b>				<b>9864</b>	<p><b>2.1 &amp; 2.2</b> Annual Costs, Escalating every year = UPV*</p>
2.1 Energy Costs	500 (B)	ANNUAL	<b>UPV*16.44</b>	8220	
2.2 Maintenance Costs	100 (B)	ANNUAL	<b>UPV*16.44</b>	1644	
2.3 Other					
<b>3. Total LCC(1+2)</b>				<b>17645</b>	

## 6.4 Solutions (continued)

**LCC System:** Gas Furnace

**Criteria:**  $d = 5\%$

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
	<b>Cost Items</b>	<b>Cost Base Yr</b>	<b>Occurrence - initial</b>	<b>PV Factor</b>	<b>PV</b>
		<b>(B) Future (F)</b>	<b>- annual - future - year</b>	<b>And Value</b>	<b>(BxD)</b>
<b>1.</b>	<b>Investment Costs</b>				<b>8444</b>
	1.1 Acquisition cost	5000 (B)	INITIAL	1.0	5000
	1.2 Capital Replacement	5000	Year 10	<b>SPV*0.825</b>	4125
	1.3 Residual Value (+ or -)	1000 (B)	Year 20	<b>SPV* 0.681</b>	(681)
	1.4 Other				
<b>2.</b>	<b>Operational Costs</b>				<b>8796</b>
	2.1 Energy Costs	460 (B)	ANNUAL	<b>UPV*16.44</b>	7563
	2.2 Maintenance Costs	75 (B)	ANNUAL	<b>UPV*16.44</b>	1233
	2.4 Other				
<b>3.</b>	<b>Total LCC(1+2)</b>				<b>17240</b>

Option A = 17,645 & Option B = 17,240 Option B

## 7.0 Presentation of Life Cycle Cost Estimate

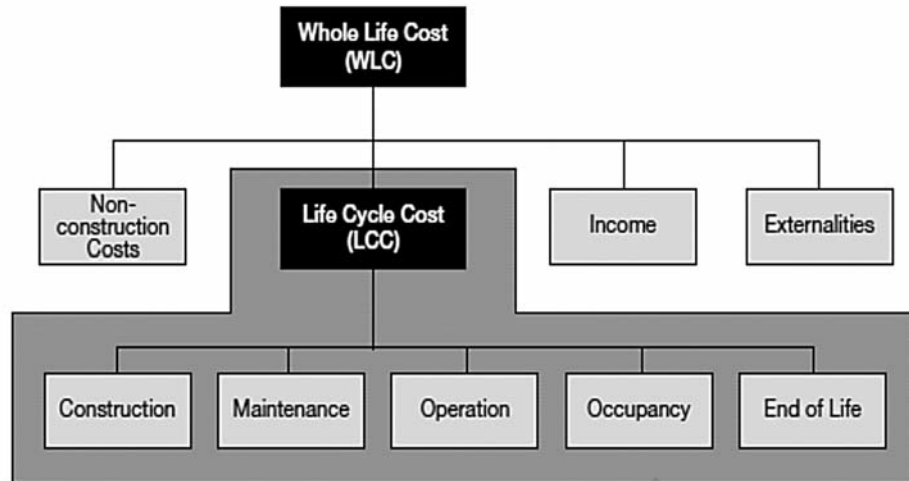
### 7.1 Methods of Measurement for Life Cycle Costing

There are a number of methodologies and standard method of measurements on WLCC. In the United States there is the NIST handbook 135 (1995), *'Life Cycle Costing Manual for the Federal Energy Management Programme'*. NIST is the National Institute of Standards and Technology in the US and the institute produced handbook 135 in 1995, 13 years before a similar standard methodology from The International Standard Organisation (ISO) outlined below. The NIST handbook outlines in detail the LLC method defining the criteria used and describing the assumptions and procedures to follow in performing evaluations and gives some very good examples on to how to carry out LCC calculations. The handbook however does not give a breakdown structure for preparing LCC like its ISO counterpart. In 2007 Davis Langdon published a report on *'Life Cycle Costing (LCC) as a Contribution to Sustainable Construction: a Common Methodology'*. The report provides an account of a research and development project to develop a common European methodology for LCC in construction. A research paper from the RICS, *'Life Cycle Costing of Sustainable Design'* published in February 2009 also considers LCC as an economic evaluation of sustainable construction. The Office of Government Commerce (OGC) in the UK provides as part of their suite in *'Achieving Excellence in Construction Procurement Guides'*, a guide for *Whole Life Cycle Costing and Cost Management*. The guide outlines the principles of whole life costing and describes a process made up of a framework for cost management and whole life costs. In 2009 the Department of Finance published *Guidance Notes 2.2, Planning and Control of Capital Costs* which is one of a number of guidance notes aimed at facilitating the implementation of the measures in the Capital Works Management Framework (CWMF). As outlined in section 2.0 above the guidance notes briefly deals with LCC in chapter 3. Although the OGC and the CWMF documents are guides rather than methodologies the CWMF guidance notes do provide a simple summary page for presenting LCC and sets out the different stages that LCC should be carried out on publically procured projects in Ireland. However in order to carry out a detailed LCC or provide backup to the CWMF summary page you must consult with one of the methodologies outlined above or refer to the International Standard Organisation, BS ISO 15686 - Part 5 or its BSI/BCIS supplement, a *'Standardized Method of Life Cycle Costing for Construction Procurement'*.

### 7.2 BSI/BCIS 'Standardized Method of Life Cycle Costing for Construction Procurement

International Standards Organisation, BS ISO 15686 is a multi-part series of international standards giving guidance on various aspects of planning the service life of buildings and constructed assets. Part 5 of the series provides guidelines, definitions, principles and informative text on the application of LCC techniques in the context of service-life planning. In 2008 the British Standards Institute (BSI) and the British Cost Information Service (BCIS) in the UK published a *'Standardized Method of Life Cycle Costing for Construction Procurement, A supplement to BS ISO 15686-5:2008 Buildings and constructed assets – Service life planning – Part 5: Life cycle costing'*. The document provides construction cost professionals with a standardised method of applying LCC, applicable to the Irish/UK construction industry and to the key stages of the procurement process. Importantly the document provides a cost data structure and a method of measurement for LCC which aligns with the ISO 15685-5. The taskforce used this methodology and standard format in the production of the suggested LCC template and LCC example. The standard can be bought online from the RICS bookshop at [url](#); or from the BCIS website at [url](#); . The BCIS also provide cost information on building running costs both online and in standard paperback. The figure below represents the cost breakdown structure applicable to both the ISO document and BSI/BCIS supplement documentation. Further detail and breakdown are included in the ISO documents and the SCSL LCC template provided.





BSI/BCIS 'Standardized Method of Life Cycle Costing for Construction Procurement'

### 7.3 Life Cycle Cost Template

The SCSi working group on LCC has included on the SCSi website a model WLCC template for your review and use. This template can be used to aid construction professionals in producing LCCM. The template is designed and formatted per the ISO standard for LCC 15868-5 and is also produced in consultation with the BSI/BCIS supplement to the standard 'Standardized Method of Life Cycle Costing for Construction Procurement'. This is a suggested template and can be changed and manipulated to suit the building, client requirements and the stage of the project the WLLC analysis is carried out. The template includes examples of PV formulae required to carry out LCC calculations under a number of coded categories. It is recommended that the PV formulae and LCC calculations are carried out outside the print area or hidden in the cells in accordance with the examples outlined above. Additional comments are included in the template to aid in the production of an LCCA in accordance with the ISO standard.

### 7.4 Life Cycle Cost Example

The SCSi working group has included online for your reference an example LCCA for Colasite Bhríde, Secondary School in Clondalkin. This LCCA is in PDF but was prepared in excel using the template outlined above. This LCCA was carried out with information provided by Kerrigan Sheanon Newman (KSN) Quantity Surveyors. The LCCA was prepared by KSN and the author in conjunction with the working group to provide an example of how LCC analysis could be carried out and presented on a school building. The LCCA example is also included online on the SCSi website.

## Appendix 1 - Definitions

**Acquisition cost** - all costs, including capital costs, incurred prior to time zero in acquiring an asset.

**Capital cost** - initial cost of the asset.

**Cost** – the total paid for labour, materials, plant and equipment, overheads and profit.

**Depreciation** - the distribution of the monetary value of an asset over a period of time commonly related to its productive or useful

**Discounted cost** - the result of discounting a cost to be incurred in the future at a given interest rate

**Disposal cost** - the costs associated with the disposal of an asset at the end of its life cycle.

**Escalation/de-escalation** - a sustained and measurable increase/decrease in the price of a specific commodity

**Hard facilities management cost** - the cost of necessary replacement, redecoration, repair and corrective, responsive and preventative maintenance necessary for the continued specified functional performance of the asset.

**Net present value** - the total present day worth of a future cash flow discounted at a given interest-rate

**Nominal cost** - the estimated future amount to be paid, including the estimated changes in price due to inflation, deflation, technological advances, etc.

**Present value** - the present day worth of a future cost discounted at a given interest-rate. It can be considered to be the amount to be invested in a bank today at a given interest rate to accrue a required amount at a given point in the future

**Present cost (current costs)** – the initial present day cost of an asset

**Real opportunity cost of capital** – the interest rate reflecting the earnings possible from an activity other than that being studied.

**Residual value** - the value assigned to an asset at the end of the period of analysis

**Terminal value** - the scrap value of a component or asset at the point of its replacement.

**Treasury Discount Rate** – the rate specified as the discount rate by the Government Treasury to be used as the discount rate in public sector life cycle cost calculations.

**Nominal interest rate** – the actual interest rate applied not adjusted for inflation. Note Fisher equation (real interest rate = nominal interest rate – inflation).

**Real interest rate** – the rate adjusted for inflation.

**Period of analysis/period of study** – the length of time over which the life cycle cost assessment is analysed.

**Physical life of a component** – the time at which a component fails to meet the performance criteria required of it and has to be removed and replaced.

**Time zero (Year 0)** – the point in time from which the study period commences. All relevant costs accrued prior to time zero are deemed to be capital costs.

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