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http://www.isarc2008.vgtu.lt/

The 25th International Symposium on Automation and Robotics in Construction

June 26–29, 2008

ISARC-2008

TOTAL LCC AND PROBABILISTICS

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ABSTRACT

To support sustainability in the Construction and Real Estate Cluster - CREC, this paper describes the ongoing development towards Total LCC to cover not only the initial capital and direct future costs of a building or other constructed assets but also externalities and intangibles (occupational, locational, environmental and societal costs), as well as towards LCC with Probabilistics – LCCP to replace deterministic (read: historic singular) values for costs and performance (read: service life) with a probabilistic approach.

KEYWORDS

Sustainable, Life cycle costing - LCC, Monetarisation, Discounting, Probabilistic

1. WHY SUSTAINABLE CONSTRUCTION IS IMPORTANT?

In Finland construction represents 10% of GDP (or 13% if repairs & renovation are counted in). CREC represents 25% of the same GDP. Accordingly, in the EU the percentages are more or les same (Figure 1).

By weight, construction activities consume up to 50% of all raw materials used and produce over 40% of waste (yet, mostly recyclable, and reducing rapidly in enlightened countries). Buildings consume 40% of total energy and account for 30% of CO_2 emissions, thus environmentally alone, CREC's sustainability is most important for whole society!

In 2001, a task group TG4 (OT a member) was established by the EC DG Enterprise to "Draw up recommendations and guidelines on Life Cycle Costs - LCC of construction aimed at improving the sustainability of the built environment". The group tried to find models for practical application of sustainable construction based on present value – PV of economic and environmental factors. Societal factors (social, cultural, ethical etc) were unfortunately left out.

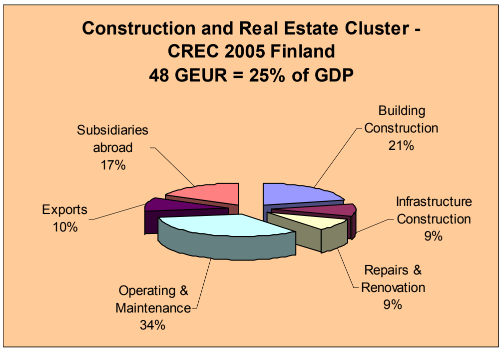

Figure 1. CREC, year 2005 Finland (source: VTT)

The final report *Life cycle costs in Construction* [1] was approved 29.10.2003 in a tripartite meeting in Brussels, comprising representatives from the Commission, member states and industry (OT a member). The paper, printed July 2004 and supposedly distributed to all member states, makes seven recommendations to advance the use of LCC.

This work was continued by Davis Langdon Ltd contracted by the DG Enterprise; their report *Life cycle costing (LCC) as a contribution to sustainable construction: a common methodology* [2] came out in 2007 (also here OT was a contributor).

These reports leave, however, one important point unsolved: how to solve a formula of Total = LCC (money) + environmental LCA (scoring points). It is possible to calculate 3 apples + 2 oranges = 5 fruits, but 3 euros + 2 points = nil Some trials made by using the newest generic software for multi-criteria decision making (eg *Logical Decisions 5.1*) proved not to be successful.

2. WHAT ARE LCC AND LCA?

Derived from ISO 14040: In CREC, environmental life cycle assessment - LCA is for assessing the total environmental impact associated with a product's manufacture, use and disposal and with all actions in relation to the construction and use of a building or another constructed asset. LCA does not address economic or societal aspects!

Derived from ISO 15686: In CREC, Life cycle costing is a technique which enables comparative cost assessments to be made over a period of analysis, taking into account all relevant economic factors both in terms of initial capital costs and future operating costs less residual value.[1] It can be defined as the net present value (NPV) of the total costs of an asset over the period of analysis.

3. TOTAL LCC – THE ULTIMATE SOLUTION

To advance sustainable construction, we should be able to calculate LCC+LCA, ie money plus points! To overcome this problem, I try to look at it purely arithmetically. In the book *Construction Can!* [3] published by arrangement of ENCORD[2] in 1998, I introduced a fresh approach to LCC to cover not only the initial capital and direct future costs of a building or other constructed assets but also externalities and intangibles (occupational, locational, environmental and societal impacts), as shown in the figure 2, below.

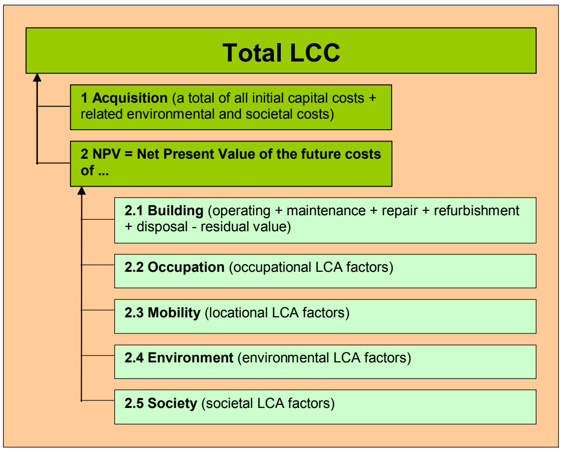

Figure 2. Total LCC – monetarising all impacts

[1] *ISO/FDIS15686-5 Life cycle costing: "Methodology for systematic economic evaluation of life cycle costs over a period of analysis."*

[2] *ENCORD - European Network of Construction Companies for Research and Development*

To put it simply, Total LCC just tries to convert all various LCA impacts to money, EUR or USD. After this monetarisation everything can be calculated mathematically as Total LCC = NPV of all effective costs (C), over a period of analysis (t), eg 25 years (N), at an agreed discount rate, eg 2% pa (d=0.02), as shown in the following formula (1).

$$NPV = \sum_{t=0}^{N} \frac{C_t}{(1+d)^t} \tag{1}$$

During 2008 a Total LCC model is developed and initial case study applications for a building and a roadway/bridge performed. The outcome shall be reported in ISARC 2008, Vilnius Lithuania.

Due to the contribution of this author, this idea has now been already incorporated in the *"ISO15686-5 Life cycle costing"* going to its final voting closing 15 Apr 2008. Yet not materially developed.

3.1. Acquisition

Acquisition (capital costs + environmental and societal costs) refer to costs directly related to the whole building and its components and assemblies, including lot, planning, design, construction, installation, fees and charges and other acquisition costs, plus related environmental and societal costs.

3.2. NPV - Building

Building (operating + maintenance + repair + renovation + disposal - residual value) refers to the future costs of all the different activities necessary to run the building over a period of analysis.

Period for LCC is determined as per the planned/-ongoing activity and can be whatever up to the end of the service life of the building.

3.3. NPV - Occupation

Occupational factors refer to usability, ie health, comfort, productivity, safety and security of the building (eg office). It is here important to realise the relationship of different accumulated costs for an office building with eg 30-year ownership:

1 : 5 : 200

- 1 = acquisition
- 5 = building operating and maintenance (see 2.1 above)
- 200 = business operational costs
  ⇨ here the biggest benefits are easiest to achieve through better comfort and productivity ⇨ good indoor environment/climate/air.

Example Finland - *Productive office 2005* (final report 2004):

High office temperatures: 1 person per room; work value 50kEUR/a:

> Before: Temp max = 32.7C; 890Ch >25C
> [optimal 21…25C = reference temp; productivity loss percentage = 2*(t-25)%]
> Productivity loss = 330EUR/a
> Improvement: Centralised cooling 20W/m2, usage increased 10 ⇨24h/d
> Investment: 316EUR/room; annual cost = 35EUR/a
> Increased energy cost: 68EUR/a
> After: Temp.max = 27.3C; 51Ch >25C
> Productivity loss = 19EUR/a
> Improved productivity: 311EUR/a (=0.6%*50kEUR/a)
> Beneficial return: 208EUR/a (= 311-68-35)
>
> ⇨ **Occupational impact monetarised**, and improvement profitable!

In the Finnish case study object Intentia HQ, a **Post Occupancy Evaluation – POE** was performed utilising the BUS method from the UK, licensed by Villa Real; report is available free of charge in our online bookshop at www.villareal.fi/.

3.4. NPV – Mobility

Mobility or commuting refers to locational factors ie the location of a (industrial, commercial, office, school etc) building. We should calculate LCC not for the building alone but also its location in relation to incoming material and outgoing product flows, employees' daily commuting, customer traffic to a shopping centre, or school children's daily transport, ie the mobility the building is causing.

Example Finland – Intentia HQ Road traffic costs (2000/2005), simplified:

Travel to/from work: by car, alone; 20km, 30min

Vehicle cost: 0.40EUR/km (private/-company car), 0.15EUR/km (society)
Time cost: 31EUR/h (private/society)
Mobility cost = 16.00/47.00EUR/d (private)
= 16.00EUR/d (company)
= 6.00/37.00EUR/d (society)

⇨ **Mobility impact monetarised!**

3.5. NPV - Environment

Environmental factors refer to different environmental impacts that various materials and actions cause; environmental profiles. Environmental factors still need quite a lot of RTD at European and international levels to define their features and properties and, to give them generally accepted monetary values.

Example Finland - *Environmental declaration of building products*: Environmental profile - altogether 31 properties defined & quantified. Today 34 products certified.

Concrete roofing tile, manufactured by Lafarge Roofing Ltd

Emissions to air (10 properties):
CO_2 = 0.137kg/kg = 137kg/ton
European (Kyoto) market price for CO_2 = 10EUR/ton
Environmental impact cost = 1.37EUR/ton = 0.006EUR/tile (@4.3kg)

⇨ **Environmental impact monetarised!**

3.6. Society

Societal factors finally need to be taken into account. This area is very little covered so far. Yet, for the CREC industries, cultural and other societal phenomena are necessary everyday considerations (eg concerning a new road through a village).

As a summary: It is important to realise that it is not environmental LCA factors only to count in. And, that without economic considerations, there is no future for environmental LCA considerations.

Finally, a probabilistic approach could be incorporated in all impacts and all costs, delivering a Total LCCP (using @Risk 4.5 and Monte Carlo/ Latin Hypercube simulation).

All the above is being carefully studied in the PhD work of this writer at Helsinki University of Technology, to be concluded in 2008.

4. WHAT DISCOUNT RATES FOR WHAT ECONOMIES?

4.1. Real or nominal?

NPV can be calculated using nominal costs and discount rate based on projected actual future costs to be paid, including general inflation or deflation, and on projected actual future interest rates. Nominal costs are generally appropriate for preparing financial budgets, where the actual monetary amounts are required to ensure that actual amounts are available for payment at the time when they occur.

NPV can be calculated also using real costs and discount rate, ie present costs (including forecast changes in efficiency, technology etc, but excluding general inflation or deflation) and real discount rate (d_{real}), which is calculated according to the following formula, where (i) = interest rate and (a) = general inflation (or deflation) rate, all in absolute values pa.

$$d_{real} = \frac{1+i}{1+a} - 1 \qquad (2)$$

To make the LCC approach significant for improving the sustainability of the built environment and the related calculations easier to understand, real costs and discount rate are useful. At low discount rates long-term future costs and savings are meaningful also at present.

4.2. Problems and observations

LCC = NPV calculations should be easy, it is just arithmetics. Yet, after my ten years' research, it appears that the lack of knowledge (note: noise ⇨data ⇨information ⇨knowledge ⇨wisdom) and misconception are prevalent within the decision-makers and experts alike, as well as the various CREC stakeholders. Some examples follow, mainly concerning Public Private Partnership - PPP projects funded by tax payers' money:

– Wide variation on the discount rates used; in EU27/10a: 2...12% pa.

- Constant discount rates used unchanged for years, although the actual rates have fluctuated >50%; eg the UK 6% pa.
- Generally too high discount rates used, which makes future costs/savings meaningless; In EU11/10a: interest rate i=3%, general inflation a=2% ⇨discount rate d_{real}=0.98%. In EU27/20a: d_{real} <0% in several years.
- Real (ie today's) discount rate used together with nominal (ie future) costs; wrong formula leads to wrong/meaningless results.
- Nominal discount rate used together with real costs; wrong formula leads to wrong/meaningless results.
- In some PPP project invitation documents (eg in the UK) the client has left the discount rate open. Thus the tenderer must present their own discount rate as part of their tender; here the tenderer may take an additional calculated risk (probabilistics with different scenarios and sensitivity analyses help). To avoid major failures, here all stakeholders must thoroughly understand the concept the same correct way.

4.3. Discount rate is important

For any long-term (investment) calculation discount rate is necessary. Simple payback is too crude, and too high discount rate nullifies the future costs/savings. Thus a correct discount rate must be used.

- For any professional investor the use of discount rate is a must. The rate used depends on the return of investment required/expected. In addition, the selected discount rate also depends on the risk involved; the higher the risk ⇨ the higher the discount rate; see eg *The Real Cost of Capital* [4]. As the risk in public works does not exceed the risk characters of a nation in general, thus a low d_{real} is truly applicable.
- For PPP projects real discount rate and real costs should be used. For the good of society and to avoid escalating future operating costs, optimally d_{real}=1...2% pa in the today's EU11 economic environment.
- A winner can be always selected at whatever predetermined discount rate, yet the eventual outcome may be disastrous for the stakeholders and society! Particularly so, if too high d_{real} or wrong formulas are used.

The net present value - NPV of accumulated future costs depends on the used discount rate(s). In the figure 3 I introduce four "rooms" of different stakeholders. For each room a certain level of discount rate is applicable, dependant on the return of investment required/expected by the particular stakeholder. These rooms I descriptively call **Natural** (d=0% = simple payback), **National** (3%), **State** (6%) and **Business** (9%) Economies. The chart shows how NPV is accumulating over 1…25 years in each room/economy at their respective nominal discount rates. In addition, I offer 1% pa as a suitable real discount rate for public works in EU11.

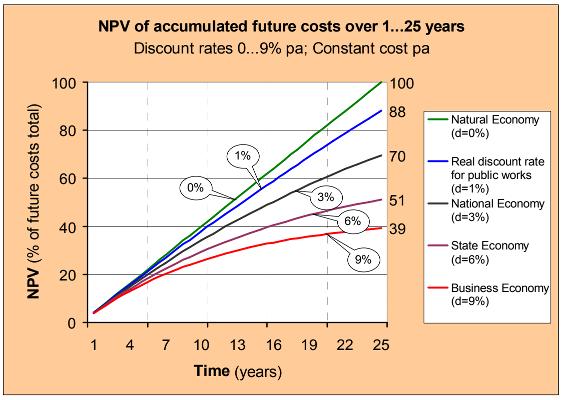

Figure 3. NPV of accumulated future costs in different economies

The actual rate of return available through LCC considerations on the operating costs of buildings and other constructed assets may be lower than that offered by alternative long-term investment: as a nominal annual rate of return, stock market 15% (-90% for dot.coms ⇨risk), 9% business ROC/ROE (⇨risk), 6% bonds, 3% bank deposits.

Yet, buildings, roads, bridges and other constructed assets have long service lives. At low discount rates long-term future costs and savings are immediately meaningful, as can be seen in the above figure at 1% rate. Then investment for the better future looks more rewarding. Also, it can be claimed that future operating costs will be increasing due to higher energy prices and new environmental and other regulatory requirements. This development will raise the calculated return in Euros or Dollars and enable market-driven LCC considerations. And, often the investment for lower operating (eg energy) costs is only marginally higher than for a “standard” design.

5. PROBABILISTICS TO REPLACE DETERMINISTIC VALUES

For LCC to become widely accepted, concerns about uncertainties in forecasting must be overcome: costs and performance of a building, its components and assemblies. An important European RTD project *EuroLifeForm* is to develop a design methodology and supporting data, using a probabilistic approach, with a budget of 3.8 MEUR over 2001…05. Villa Real (FI) is the originator and a major partner, and Taylor Woodrow (GB) the coordinator. The newest theories and software are used for probability, risk, sensitivity analyses and optimisation (@Risk 4.5 Industrial using Monte Carlo/Latin Hypercube simulation) and for complex multi-objective/multi-criteria decisions (Logical Decisions 5.1). In all seven partner countries data and information is collected; generic and on 11 case studies.

The principal outcome is a model for **LCC with Probabilistics - LCCP**, in a software format, to replace deterministic (read: historic singular) values for costs and performance (read: service life) with a probabilistic approach, good for investors/-developers/owners, designers, contractors, facilities managers, users and other stakeholders. Plus a stint of environmental LCA incorporated.

Here it is worthwhile to recognise two fresh CIB reports: *Performance Based Methods for Service Life Prediction - State of the Art Reports [5] and Guide and Bibliography to Service Life and Durability Research for Building Materials and Components* [6]. They both strongly support the use of probabilistics in the service life planning and LCC-computing.

As an example, a contractor can use LCCP software in his tendering for a BOOT or other type PPP or private project. As shown in the chart below, he is able to make a well informed decision on the final tender price based on probability, or risk he is ready to take. Risk involved he can also reduce by scenarios and more accurate source data (Figure 4).

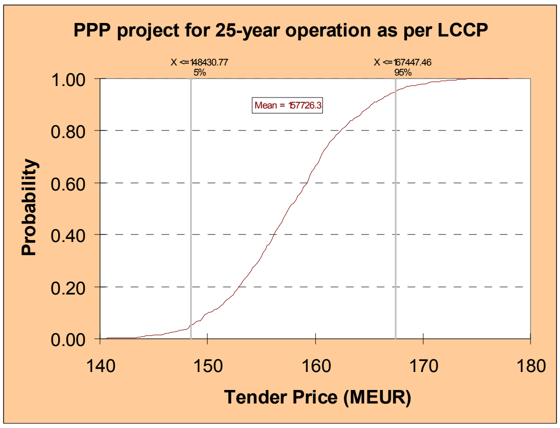

Figure 4. The outcome of tender computing utilising FutureConstruct® LCCP software

A pack of models to enable a lifetime design process utilising the LCCP approach was developed. The under-listed related software tools are now near completion, soon ready for national and international customisation, commercialisation and consulting services. Visual Basic 6 is utilised to increase versatility, enable integration and to improve user friendliness. The integrated pack and its modules are superior to and ultimate winners over the insular deterministic tools currently in use.

– **LCCP Gate**: A gateway to the other LCCP tools, registries for computation results & decisions made, and database repositories.
– **LCCP DB Life**: Database with min/most likely/max reference service life values for building elements (components, services, parts).
– **LCCP Life**: Deterioration model at @Risk & Excel, utilising ISO 15686-1 factor method. It provides estimated service life for replacement, as expected in the particular project on hand, plus data for planned preventive maintenance and reactive maintenance, all in a probabilistic format. Integrated with LCCP All.
– **LCCP DB Cost**: Database with min/most likely/max cost values for building elements (components, services, parts). Usually this data is

highly commercially sensitive, kept secret and not available for the public. Contractors, quantity surveyors etc can use their own data.

- **LCCP All**: A calculator at 3 levels, Client brief, Concept design and Detailed design based on @Risk; most important and advanced.
- **Sustain**: Excel-based screener to assess environmental impact.

Villa Real has global rights to this pack. The commercial software and services under the EU-wide registered brand name ***FutureConstruct*®** shall be introduced in 2008…09.

6. CONCLUSIONS

Where we are today:

- Acquisition capital costs govern.
- LCC is up and coming, today mainly for future energy costs.
- Probabilistics is new and "difficult". Yet, advanced CREC partners are already applying it.
- Total LCC gives valid answers easy to understand to support sustainable construction.
- After further development Total LCC and LCCP will be incorporated, thus creating a super tool for the needs of sustainable construction.
- This writer is confident that **eventually the Total LCC/LCCP will be taken to use in the EU**. It was already initially approved in 2001 by the task group TG4 of the EC DG Enterprise!

Updated information, related publications plus the EU documents mentioned, all are available at http://www.villareal.fi and our secured online bookshop https://onlinebookshop.villareal.fi.

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