Total LCC and Sustainable Construction

Olavi Tupamäki MSc

Villa Real Ltd, Merivalkama 12, PO Box 100, FIN-00231 Espoo, Finland. Phone: +358 9 802 3667. Fax: +358 9 802 3610. E-mail: olavi.tupamaki@villareal.fi.

1. INTRODUCTION

This paper examines how to best achieve sustainable development in construction.

2. WHAT IS SUSTAINABLE DEVELOPMENT?

"Sustainable development is a matter of satisfying the needs of present generations without compromising the ability of future generations to fulfil their own needs" [Brundtland report, "Our Common Future", 1987]. Sustainable development means sustainability not only ecologically (= environmentally) and economically but also socially and culturally.

Lately in the EU and UN, an expression *the three pillars of sustainable development* is often used; the pillars are said to concern economic, environmental and social development. Yet, they *should read economic, environmental and societal* (= social, cultural, ethical etc) development. The importance of the omitted cultural issues is recognised eg in CIB's "Agenda 21 on sustainable construction", and numerous other documents and declarations.

As per Rio 1992, countries should prepare national strategies on sustainable development in 2002 latest. Only few countries have provided something meaningful (eg SE, DK, DE, AT, GB) with proper objectives (what, when) and action plan (how, who, financials, monitoring).

3. WHAT IS SUSTAINABLE CONSTRUCTION?

3.1 Recent development

For *sustainable construction* CIB W82 (OT a member) proposed the following definition in 1998: "The creation and responsible management of a healthy built environment based on resource-efficient and ecological principles". This *definition is not satisfactory, as it leaves out economic and societal issues* completely.

In its report "An Agenda for Sustainable Construction in Europe" completed in June 2001, an industry-led working group for Sustainable Construction with participants from the European Commission, Member States and Industry (OT a member) and working for the EC DG Enterprise's agenda on the Competitiveness of the Construction Industry recommends that "All member states and accession countries should be encouraged to draw up and publish plans and programmes for sustainable construction". Within the EU, Finland, Germany, Ireland, Luxembourg, the Netherlands and the UK have such papers of various qualities.

Last autumn, a new task group (OT a member) was established in the EC Enterprise to "Draw up recommendations and guidelines on Whole Life Costing - WLC of construction aimed at improving the sustainability of the built environment". The group tries to find models for practical application of sustainable construction based on Net Present Value – NPV of economic and environmental factors. Societal factors (social, cultural, ethical etc) were unfortunately left out.

3.2 Could this be sustainable construction?

The ways in which built structures are procured and erected, used and operated, maintained, repaired and refurbished, and finally dismantled (and reused) or demolished (and recycled), constitute the complete cycle of sustainable construction activities.

Minimise the use of materials, energy and water, and mobility. (NL: factor 20).

Building products should be reusable and materials recyclable. Design for long service life (and durability) is superior to design for reusability. Reusability is superior to recycling, and recycling is superior to waste disposal.

In sustainable construction, reusability and the ease of changeability are necessary product properties, in particular for modular products and systems with different service lives.

4. WHY SUSTAINABLE CONSTRUCTION IS IMPORTANT?

In advanced European vocabulary "construction" is considered to cover the entire value chain of develop/own, design, manufacture, construct, recycle a building, infrastructure or other constructed assets. Today in Finland and elsewhere, a new expression *Construction and Real Estate Cluster - CREC* has been taken to use to cover all activities directly related to construction and real estate (buildings, infrastructure and other constructed assets = 60-70% of the national wealth). Compared to the above, *CREC covers the whole life of a building*, hence additional activities concern running (or operating...) the building, which more often is done by facilities management. According to ISO 15686 “Buildings and constructed assets – Service life planning”, running a facility covers the following activities/costs:

Operating cost = The cost incurred during the normal operation of a building or structure, or a system or component including labour, materials, utilities and other related costs over the life cycle.

Maintenance cost = The cost incurred in conducting the combination of all technical and associated administrative actions during the service life to retain a building or its parts in a state in which it can perform its required functions.

Repair costs = The cost incurred in returning a building or its parts to an acceptable condition by the renewal, replacement or mending of worn, damaged or degraded parts.

Refurbishment cost = The cost incurred in rehabilitation (deprecated), renovation (deprecated) and modification and improvements to an existing building or its parts to bring it up to an acceptable condition.

A reason to this approach is the fact that major contractors are moving from plain construction towards taking care of the building/facility for its whole life. Also public-private partnership projects (BOOT, PFI; toll roads & bridges, schools, prisons etc) require this approach.

In 2001, VTT (a leading construction/CREC research centre in Europe) made a study about CREC in Finland[1]. Some interesting findings are repeated below for the year 2000:

[1] Different clusters have been studied in most EU countries during the past ten years. In Finland, cluster studies cover practically all the activities of society.

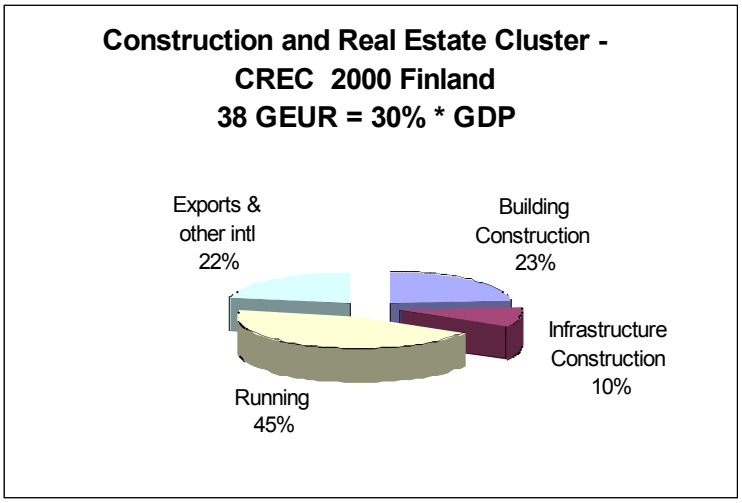

Figure 1 Construction and Real Estate Cluster - CREC, in Finland, year 2000.

While in Finland construction represents 10% of GDP (or 12% if repairs & refurbishment are counted in), CREC represents 30% of the same GDP. Accordingly, *in the EU construction represents 11% of the total GDP, and CREC nearly 30% of the same GDP!*

Figure 2 CREC Running Costs in Finland, year 2000.

Here it can be seen that in Finland heating (17%), repairs & refurbishment (16%), maintenance (15%) and cleaning & waste (14%) are the highest cost activities.

VTT also has written an initial definition for CREC: *CREC serves its customers through providing, developing and maintaining the built environment and related necessary services*. Also, as earlier said, CREC = develop/own, design, manufacture, construct, run/operate, recycle a building or other constructed assets.

All the aforesaid proves that *construction and CREC are big, thus their sustainability is most important for whole society!* Also their environmental impact is big: buildings consume about 40% of total energy and account for 30% of CO_2 emissions.

5. WHAT ARE LCA AND LCC (or WLC)?

Derived from ISO 14040: In construction, 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 other constructed facilities. LCA does not address the economic or social aspects.

Derived from ISO 15686: Life cycle costing - LCC is a technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial capital costs and future operational costs. [UK expression Whole life costing - WLC is gaining some support separating Life Cycle - LC from Whole Life - WL: WL can cover several different (usage etc) LCs of a building; also, the LCs of various replaceable components/systems are much shorter than the WL of a building.]

6. CAN LCA AND LCC BE PUT TOGETHER?

LCA has been very much studied. The results may be used to create regulatory requirements, offer incentives and determine rating/scoring systems to help decision-making. *LCA does not give you any figure in money*.

LCC gives you figures in money for any present and future costs as required. Thus, in the case of tenders, considering construction cost as usual plus LCC calculations together with scoring, you have to be able to calculate *a total = money + points!* No existing related software gives any proper solution to this equation. Thus, the initial result is no, *LCA and LCC cannot be put together*.

Yet, it is my intention to further study this equation on a case study project in Finland (a newly completed office building for adaptable rental use, 10,000 m^2 floor area) using LCC and some LCA-related method (perhaps including a proposed methodology that permits contract award to the Economically Most Advantageous Tender – EMAT, developed by a task group working for the EC DG Enterprise's agenda on the Competitiveness of the Construction Industry, and published in July 2001). It is also my intention to study the suitability of the newest software for multi-objectives and multi-criteria decision making using Monte-Carlo simulation (@Risk, Crystal Ball) and decision trees (Precision Tree, Logical Decisions).

7. TOTAL LCC & SUSTAINABLE CONSTRUCTION

7.1 Total LCC

To overcome this LCC+LCA problem, I try to look at it purely arithmetically. In the book "Construction Can!" published by arrangement of ENCORD in 1998, I introduced a fresh approach to LCC to cover not only the initial capital and (direct) future costs of a building/facility but also occupational, locational, environmental and societal factors, as shown below.

> *Total LCC = Acquisition (a total of all initial capital costs) + NPV [Building (operating + maintenance + repair + refurbishment + disposal - residual value) + Occupation (occupational LCA factors) + Mobility (locational LCA factors) + Environment (environmental LCA factors) + Society (societal LCA factors)]*

NPV = Net Present Value of the accumulated future costs (C) over a certain period of time (t), eg 30 years (N), at an agreed discount rate(s), eg 6% pa (i), dependant on prevailing interest

and inflation rates. NPV is calculated according to the following formula, and can be done with eg MS Excel (up to 29 years / 97 SR-2).

$$NPV = \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \quad (1)$$

Building (operating + maintenance + repair + refurbishment + disposal - residual value) refers to the future costs of all the different activities necessary to run the building or other constructed facility during a certain period of time, eg 30 years. The above-mentioned principal activities are as defined in ISO 15686. In the NPV formula, there are costs caused by these activities. Period is determined as per the planned/ongoing activity and can be whatever. This is also true for other factors below, of course.

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

1 : 5 : 200
1 = acquisition, 5 = building operating and maintenance, 200 = business operating costs → here the biggest benefits are easiest to achieve through better comfort and productivity → good indoor environment/climate/air.

Mobility, hence locational factors refer to 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 as well as to employees' daily commuting or school children's daily transport, ie the mobility the building is causing.

Environmental factors refer to different environmental impacts that various materials and actions cause; environmental profiles. Environmental factors are, however, hard to come by and need a lot of RTD at European and international levels to define their features and properties and, perhaps, to give them generally accepted values. Here the already existing LCA studies and environmental construction technology reports give a good starting point.

Societal factors finally need to be taken into account. This area is very little covered so far.

7.2 Can Total LCC Help Us towards Sustainable Construction?

In the Total LCC equation, acquisition cost plus NPV of building, occupation and mobility costs (case-dependant) are in direct interest of the owner and user. Thus we can look how much he/she can gain in investing for lower future costs.

Table 1 NPV calculations at different discount rates.

NPV = Net Present Value of accumulated constant 100EUR annual costs over a 40-year period and of the cost in the 40th year, at different discount rates (rounded figures)

Discount Rate	*NPV (40 a total)*	*NPV (40th a)*
9% "business economy"	*30% ¬ 1,100EUR*	*3% ¬ 3EUR*
6% "state economy"	*40% ¬ 1,500EUR*	*10% ¬ 10EUR*
3% "national economy"	*60% ¬ 2,300EUR*	*30% ¬ 30EUR*
0% "natural economy"	*100% ¬ 4,000EUR*	*100% ¬ 100EUR*

The rate of return available through LCC considerations is usually lower than that offered by alternative long-term investment: as annual return, 25% stock market (-90% for dot.coms ← high risk), 15% business ROI/ROC (risk), 6% bonds, 3% bank account. It may be claimed, however, that future LCC costs will be increasing due to higher energy prices and new environmental and other regulatory requirements. This development will rise the calculated return and *may enable market-driven LCC considerations*.

Where are we today: Acquisition cost governs! LCC is up and coming, yet today mainly for future energy costs only. The rest must be done!

This Total LCC approach I intend to study further theoretically and on two test cases, a newly completed office building for adaptable rental use, 10,000 m^2 floor area, Finland (mentioned earlier) and a newly completed hospital, 45,000 m^2 floor area, the UK.

8 EUROLIFEFORM

For LCC to become widely accepted, concerns about uncertainties in forecasting must be overcome: performance of building, products, systems; costs; occupational, locational, environmental and societal factors. A new European RTD project *EuroLifeForm is to advance a probabilistic approach on LCC* in construction, with a budget of 3.8 MEUR in 2001-04. Taylor Woodrow (GB) is the coordinator and Villa Real (FI) the originator and a major partner, plus partners from eight countries. The project aims to develop a design methodology and supporting data, using a probabilistic approach. It primarily addresses technological performance and cost issues but environmental impacts and other factors are also considered. The deliverable will be a generic model for LCC and Performance - LCCP, in a software format, good for developers and designers.

Here the newest theories and software are used; particularly multi-objectives and multi-criteria tools for decision making using Monte-Carlo simulation (@Risk, Crystal Ball) and decision trees (Precision Tree). These programmes are capable for complex decisions, where there can be trade-offs among competing objectives. They also include probability, risk and sensitivity analyses. And they are presented on MS Excel spreadsheet.

Data and information is collected in all eight member states; generic and on ten case studies. Studies carried out so far cover design decision mapping, performance data as per Unified Classification for the Construction Industry - Uniclass classification, cost data of acquisition/construction as per Uniclass, and environmental data.

Further information about EuroLifeForm is available on www.(...to be concluded).

REFERENCES

Bourdeau, L et al 1999. *Agenda 21 on sustainable construction*. CIB Report Publication 237, ISBN 90-6363-015-8.

Goodall, J et al 2001. *Competitiveness of the Construction Industry - An agenda For Sustainable Construction in Europe*. EC DG Enterprise / FIEC.

Tupamäki, O 1998. *Construction Can!*. European Network of Construction Companies for Research and Development – ENCORD, ISBN 951-97676-1-4.