Total LCC and Sustainable Construction ©

Indoor environment/climate/air

Sisäilmastoseminaari
17 Mar 2010, Dipoli, Espoo FI

Olavi Tupamäki
Villa Real Ltd/SA

PO Box 100
FI-02321 Espoo Finland
www.villareal.fi
tel +358 9 802 3667
fax +358 9 802 3610
info@villareal.fi

VILLA REAL® for Sustainable Construction© (1)

- ***We offer engineering and consulting services to the international clientele of the Construction and Real Estate Cluster - CREC:***
  - *On **technological**, **economic** and **sustainability** topics in general*
  - *To advance energy efficiency towards "**zero energy houses**", in the stages 4…5 of the RTD&IDC chain "research ⇨technological development & ⇨innovation ⇨demonstration ⇨commercialisation"; design, software, equipment*
  - *Advanced **FutureConstruct®** **software** **and** **services** for investors, developers, designers, contractors and users:*

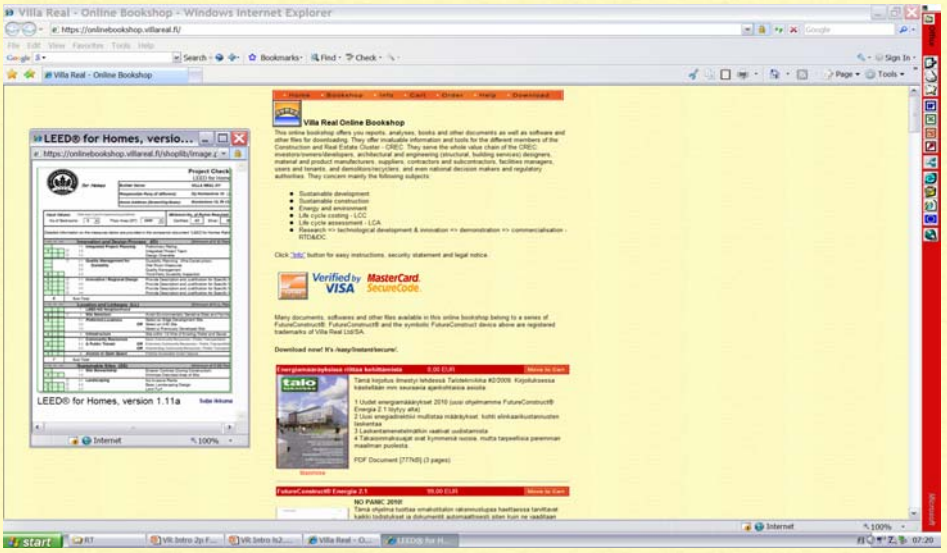
    *(1) to produce necessary **energy certificates and documents** to fulfill the EU directive of the energy performance of buildings in Finland (eg FutureConstruct® Energia 2.1 good for new regulations 2010 in Finland)*

    *(2) thru **Total LCC** calculations utilising the newest science to **monetarise externalities and intangibles** (occupational, mobility, environmental and societal impacts)*

    *(3) utilising the newest science and software to **replace deterministic singular values for costs and performance with a probabilistic approach - LCCP***
  - ***Post Occupation Evaluation – POE** using the **BUS** method licensed from the UK. This is to find out the suitability of the newly completed (office) building to it real use.*
- *We develop and sell related **software**, available in our **Online Bookshop***
- *We publish related **books, reports and analyses**, available in our **Online Bookshop***
- ***Keywords characterising our experience:** International • Strategic • Sustainable • Energy & Environment • Construction • IT & Robotics • RTD&IDC*
- *Our **clients** include several leading European contractors and manufacturers, Shimizu Corp. Japan, Singapore Ministry of National Development, the European Commission, and numerous European, Nordic and Finnish CREC organisations*

Further information available: www.villareal.fi

VILLA REAL®
for Sustainable Construction© (2)



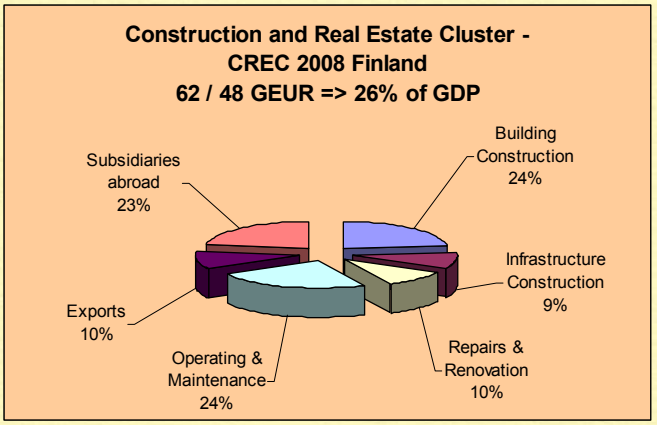
Contents

- *Construction and Real Estate Cluster – CREC for sustainability*
- *What are LCA and LCC - Standardisation?*
- *Total LCC & monetarisation – the ultimate solution*
  - *Indoor environment/climate/air*
- *Where are we today?*

***Low energy house at the Finnish National Housing Fair 2007**, completed by Villa Real Ltd.*

The Construction and Real Estate Cluster – CREC for sustainability

- *While in Finland construction represents 11% of GDP (or 14% if repairs & renovation are counted in), CREC represents 26% of the same GDP. The same total is true for the EC 15 / 27.*



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, an 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 facilities = 60-70% of the national wealth). Compared to the above, CREC covers the whole life of a building, hence additional activities concern operating and maintaining the building, which more often is done by facilities management.*
- *A reason to this approach is the fact that major contractors are moving from plain construction towards taking care of the building/facility for a certain period or its whole life. Also public-private partnership – PPP projects (BOOT, PFI; toll roads & bridges, schools, prisons etc) require this approach. All investors and property developers need this.*
- ***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!***

Could this be sustainable construction?

- *The ways in which built structures are procured and erected, used and operated, maintained and repaired, modernised and rehabilitated, 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**. (factor 4/10; NL: factor 20; Passive House, Zero Energy House etc)*
- *Building products should, as far as possible, 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 ease of **changeability** are necessary product properties, in particular for modular products and systems with different service lives.*

What are LCA and LCC? (1) Regulatory framework

- *It is good to realise that as an EU member state, Finland must comply with the generic EU administrative structure and procedures. For various CREC regulations the order is as follows:*
  - *EU Directive ⇨*
  - *CEN Standards: mostly in accordance with ISO standards ⇨*
  - *National regulations: must comply with the above ⇨*
  - *Voluntary Evaluation/Assessment/Calculation methods (such as LEED, BREEAM, PromisE, FC Environ etc for sustainable construction): must comply with the above*

What are LCA and LCC? (2)
ISO Standards

- *Derived from **ISO 14040**: In the Construction and Real Estate Cluster - 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 - **LCC** 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. It can be defined as the net present value - **NPV** of the total costs of an asset over the period of analysis.*

**ISO 15686-5 (2008) Buildings and constructed assets – Service life planning - Life cycle costing: life-cycle costing = methodology for systematic economic evaluation of life-cycle costs over a period of analysis.*

What are LCA and LCC? (3)
LCC & ISO 15686 (2009)

***This new standard covers 10 parts**: 8 parts are ready and the remaining parts advanced, and the first part "umbrella standard" already under revision. The proposed ten parts are as follows:*

- *ISO 15686-1 "General Principles" deals with issues and data needed to forecast service lives and gives a method for estimating the service lives of components and assemblies; umbrella standard; approved 2000, a revision to be approved soon.*
- *ISO 15686-2 "Service Life Prediction Procedures" describes a generic method for using testing of performance of components and assemblies to provide a service life prediction; approved 2001.*
- *ISO 15686-3 "Performance audits and reviews" provides tools for audits and reviews to ensure that relevant steps have been taken to achieve a service life that will match or exceed the design life; approved 2002.*
- *ISO 15686-4 "Data requirements" is a technical guide on methods of presenting data and evidence to support forecasts; under development*
- ***ISO 15686-5 (2008) "Life cycle costing" will provide guidance on life cycle costing; approved 15 Apr 2008.***
- *ISO 15686-6 "Procedure for considering environmental impacts" provides guidance on assessing environmental sustainability in the context of service life planning; approved 2004.*
- *ISO 15686-7 "Performance evaluation and feedback of service life data from practice" provides guidance on how to structure and use feedback data on in-use condition; approved 2006.*
- *ISO 15686-8 "Reference service life and service life estimation" will provide guidance on assessment of default service lives using available information; approved 2008.*
- *ISO 15686-9, "Inclusion of requirements of service life assessment and service life declaration in product standards"; approved 2008.*
- *ISO 15686-10, " When to assess functional performance"; to be approved soon.*

What are LCA and LCC? (4)
CEN and US (2010)

- *Also elsewhere standardisation is in a good progress:*
  - *"CEN/TC350 – prEN 15643 Sustainability of construction works - Assessment of buildings - Parts 1-4", and "ISO 21929-1 Building Construction - Sustainability in Building Construction - Sustainability Indicators".*
  - *In the USA new standards just approved, ahead of the EU: "ANSI ICC 700-2008 National Green Building Standard" (2009) and "ASHRAE Standard 189-2010 for the Design of High-Performance, Green Buildings" (2010).*

What are LCA and LCC? (5)
LCA Assessment methods

- *Some 100 national and other LCA methods and computer software in use. All are different by approach and criteria. Results are scorings and points and difficult to understand (the same building can get eg 4.2, 123 or 820 points depending on the method used).*
- ***LEED®** (The Leadership in Energy and Environmental Design by the US Green Building Council). Now used in 70 countries. In Finland there are 17 approved professionals, and 3 companies are members (Jul 2009).*
- ***BREEAM** (BRE Environmental Assessment Method; GB). Now used in 20 mostly EU states.*
- ***FutureConstruct® Sustain 1.0**, developed by 7 EU member states under EuroLifeForm project, and good for different periods of analysis(!).*
- ***PromisE** (FI), little used and yet now under revision.*
  - *For my low energy house in the National Housing Fair at Hämeenlinna, assessment was made using LEED® for Homes 1.11a. The project achieved 94 points, ie positioned in the highest class "Platinum". The software with instruction manual is available in https://onlinebookshop.villareal.fi/ free of charge.*
  - *The project was assessed also by FutureConstruct® Sustain, and it achieved scoring "Very Good" for the 25 (84 points) and 50 (88) year periods of analysis.*

What are LCA and LCC? (6)
How to calculate LCC = NPV (1)

How to calculate NPV

- *The **Net Present Value – NPV** procedure reduces a series of cash flows which occur at different times in the future to a single value at one point in time, the present. The technique which makes this transformation possible is called discounting. LCC is calculated as NPV of the accumulated future costs (C) over a period of analysis (t), eg 25 years (N), at an agreed discount rate (d), eg 2% (d =0.02) pa 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 easily...).*

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

- *It proved very difficult to get this fundamental formula into the standard. Yet, it is there now (but they changed the marking).*

What are LCA and LCC? (7)
How to calculate LCC = NPV (2)

Which discount rate?

- *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 and technology, 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.*

$$d_{real} = \frac{1+i}{1+a} - 1$$

Total LCC (1)
How to put LCA and LCC together?

- *To advance sustainable construction, we should be able to calculate LCC + LCA, ie money plus points! Eg, in the case of tenders, considering construction cost as usual plus LCC calculations plus LCA scoring, you should be able to calculate LCC + LCA ie a* ***total = money + points!*** *No existing related software gives you any proper consistent solution to this equation (3 apples + 2 oranges = 5 fruits, but 3 Euros + 2 points = nil).*

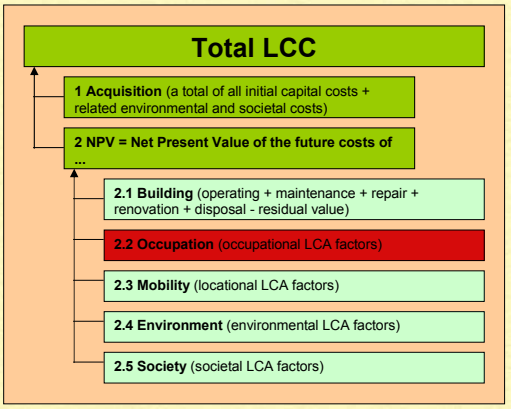
- *To overcome this LCC + LCA problem, I try to look at it purely arithmetically. In the book "****Construction Can!****" published by arrangement of ENCORD in 1998, I introduced a fresh approach to* ***LCC to cover*** ***not only the initial capital and direct future costs of a building or another constructed asset but also*** ***externalities*** ***and*** ***intangibles*** *(occupational, locational, environmental and societal impact costs).*

Total LCC (2)
ISO 15686-5

- ***6.5 Sustainable construction****: The objective of service-life planning should generally be to allow decision makers to include technical, environmental, economic and social (read: societal) aspects, all within a long-term context, in their decision making.* ***LCC analysis is a technique that should form part of an overall aim to balance the objectives of sustainable construction****.*
- ***6.2 Externalities****: Life cycle costing can help to ensure an optimized approach to asset selection, maintenance and use. However, judgments made on the basis of investment returns can be based purely on market efficiency, and can fail to recognize the wider implications economic decisions have on society. Market prices for construction might not value the social, environmental or business costs or benefits of production and consumption.*
- ***6.6 Intangibles****: Intangibles arise as a result of improvements in a constructed asset that can be difficult to quantify. These improvements can affect the user's comfort, amenity and efficiency, which can lead to increased satisfaction and efficiency, with associated financial implications (e.g. improvement in morale leading to reductions in absence through stress).*

Total LCC (3)
Monetarisation

- *To put it simply, **Total LCC** just tries to **convert all various LCA impacts to money**. After this **monetarisation** everything can be calculated mathematically as LCC = NPV of all effective costs over the period of analysis, as shown in the table below.*



Total LCC (4)
Indoor environment/climate/air (1)

- ***Occupational factors** refer to usability, ie indoor environment, climate and air related to health, comfort, productivity, safety and security of the building (eg office), as briefly listed below:*
  - *Hygrothermal performance: air temperature, thermal radiation, air velocity and relative humidity*
  - *Air quality*
  - *Acoustical performance: external and internal noise*
  - *Visual performance: natural and artificial lighting (luminance, glare), internal and external contacts*
  - *Design*
  - *Ergonomics*
  - *Tactile performance*
  - *Accessibility*
  - *Structural, fire etc safety*
  - *Security against intruders, utility supply interruptions etc*

Total LCC (5)
Indoor environment/climate/air (2)

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

Total LCC (6)
Indoor environment/climate/air (3)

- *Example Finland - Productive office 2005 (final report 2004):*
  ***High office temperatures**: 1 person per room; work value 50kEUR/a:*
  Before: Temp max = 32.7°C; 890°Ch >25°C [optimal 21…25°C = reference temp; productivity loss percentage = 2(t-25)%]*
  *Productivity loss before = **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 = 27.3°C; 51°Ch >25°C
  *Productivity loss after = **19EUR/a***
  *Improved productivity: **311EUR/a** (= 330-19; = 0.6%*50kEUR/a)*
  *Beneficial return: **208EUR/a** (= 311-68-35)*

  ⇨ ***Occupational impact monetarised**, and improvement profitable!*

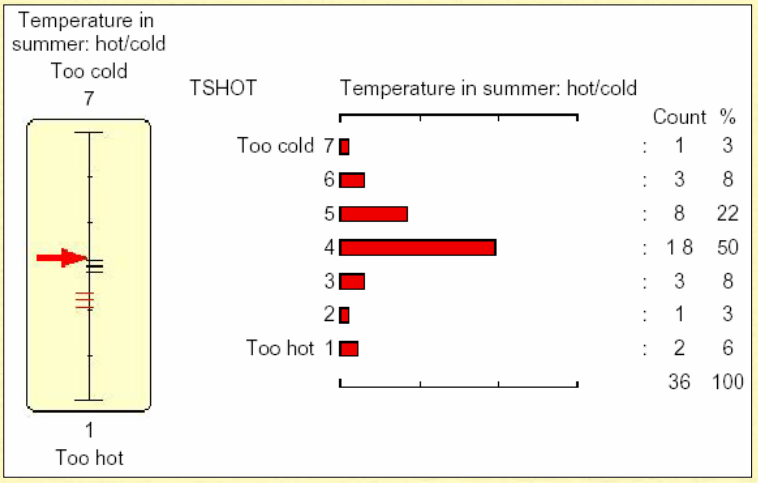
- *To further study the occupational factors, an assessment was made in Intentia HQ, Keilaranta 5 Espoo. There a **Post Occupancy Evaluation – POE** was performed utilising the **BUS method** from the UK, licensed by Villa Real; report is available free of charge in our online bookshop at www.villareal.fi/.*

Total LCC (7)
Indoor environment/climate/air (4)

- ***BUS*** *is a POE method (software and database) developed during the past 15…20 years in the UK. As detailed results it gives a range of quantitative and qualitative data usually including the following:*
  - *Background information about age, sex, time in the building, time at desk, time at VDU, workgroup size, window seats and other basic information about the sample and the respondents.*
  - *Ratings and feedback for design, needs, image, cleaning, storage, meeting facilities.*
  - *Response times for key variables.*
  - *Perceived productivity.*
  - *Perceived health.*
  - *Thermal comfort.*
  - *Ventilation.*
  - *Lighting, including glare.*
  - *Noise, including interruptions.*
  - *Furniture and space in the building.*
  - *Other workplace performance variables including e.g. perceived control.*
  - *Full ratings and benchmarks.*
  - *Comments organised alphabetically and by question category.*
  - *Web enabled graphics for 65 variables.*
  - *The ability to interrogate the database to answer more specific questions.*

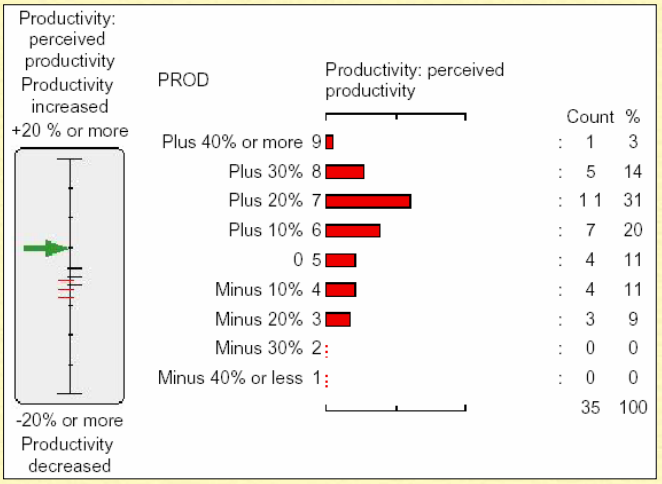
Total LCC (8)
Indoor environment/climate/air (5)

- *Temperature in summer; AC problem, fixed after!*



Total LCC (9)
Indoor environment/climate/air (6)

- *Productivity perceived; always can be improved*



Total LCC (10)
Indoor environment/climate/air (7)

- *In general, the POE proved that Intentia HQ is an excellent working place. As shown in the summary table below, the building achieved a rating "very good" with the **maximum scoring** of (60 ⇨ 100 ⇨) 7.*
- *Although control over heating generally seemed to be ok, yet there was a major number of occupants, who feel cold. These occupants are mainly women, feeling cold in the winter and summer time. The heating/cooling systems should be checked and adjusted to allow better control for the occupants. This was done after!*

- ***A value of different improvements proposed by this evaluation can be easily calculated via Total LCC approach** as NPV over the period of analysis. Through monetarisation the positive results can be seen at the bottom line of the company's financial statements.*

Where are we today?

***Where we are today**:*

- *Acquisition capital costs govern.*
- *LCC is up and coming; today mainly for future energy costs. In various PPP and similar projects LCC is a must.*
- *Total LCC gives valid answers easy to understand to support sustainable construction.*
- ***Total LCC gives tools to make the impact of indoor environment/ climate/air for comfort and better productivity easier to calculate**.*
- ***An EU directive on LCC is already under development**.*
- *This writer is confident that eventually the **Total LCC 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! What will be determined in the EU, will eventually come effectively to use in all the member states.*

***Total LCC is to be concluded in my doctoral dissertation now in its finalisation stage under prof Juhani KIIRAS, HUT/Aalto University**.*

Where to find more...

- *All the aforesaid and much more is available in Villa Real **Online Bookshop** www.villareal.fi or directly at the secured https://onlinebookshop.villareal.fi.*
- *Most of the documents, software etc are available free of charge. Our streamlined download process is **/easy/instant/secure/**. For payment, if any, MasterCard SecureCode and Verified by VISA double your security.*

Many thanks!

TOTAL LCC AND SUSTAINABLE CONSTRUCTION

Olavi TUPAMÄKI, MSc
VILLA REAL Ltd/SA

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). In particular occupational factors are discussed covering indoor environment, climate and air.

Keywords: Sustainable; LCC; Occupational indoor factors

1 SUSTAINABLE CONSTRUCTION IS IMPORTANT

In Finland construction represents 11% of GDP (or 14% if repairs & renovation are counted in). CREC represents 26% of the same GDP. In the EU the percentages are more or less the same.

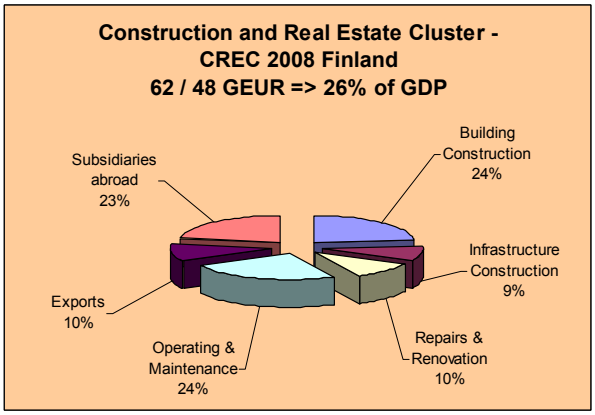


Figure 1. CREC, year 2008 Finland (source VTT)

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!

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 - LCC 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. It can be defined as the net present value (NPV) of the total costs of an asset over the period of analysis.

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. The final report *Life cycle costs in Construction* [1] was approved late 2003 in a tripartite meeting in Brussels, comprising representatives from the Commission, member states and industry (OT a member). The paper, 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 generic software for multi-criteria decision making (eg *Logical Decisions 6.0*) proved not to be successful.

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[1] 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 below.

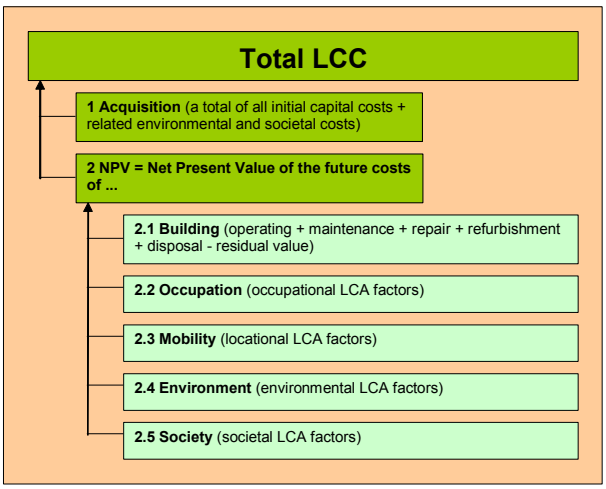


Figure 2. Total LCC – monetarising all impacts

[1] *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):

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

With support of my contribution this idea was already incorporated in the standard *ISO 15686-5 Life cycle costing* [4] approved in April 2008, as quoted in the following:

6.5 Sustainable construction: The objective of service-life planning should generally be to allow decision makers to include technical, environmental, economic and social (read: societal) aspects, all within a long-term context, in their decision making. LCC analysis is a technique that should form part of an overall aim to balance the objectives of sustainable construction.

6.2 Externalities: Life cycle costing can help to ensure an optimized approach to asset selection, maintenance and use. However, judgments made on the basis of investment returns can be based purely on market efficiency, and can fail to recognize the wider implications economic decisions have on society. Market prices for construction might not value the social, environmental or business costs or benefits of production and consumption.

6.6 Intangibles: Intangibles arise as a result of improvements in a constructed asset that can be difficult to quantify. These improvements can affect the user's comfort, amenity and efficiency, which can lead to increased satisfaction and efficiency, with associated financial implications (e.g. improvement in morale leading to reductions in absence through stress).

Also, CEN/TC350 is working on *prEN 15643-4 Sustainability of construction works - Sustainability assessment of buildings.* Their brand new draft *prEN 15643-4:2010 - Framework for the assessment of economic performance* [5] is dealing with the subject, yet with a conventional approach.

3.1 NPV - Occupation

Occupational factors refer to usability, ie indoor environment, climate and air related to health, comfort, productivity, safety and security of the building (eg office), as briefly listed below:

- Hygrothermal performance: air temperature, thermal radiation, air velocity and relative humidity
- Air quality
- Acoustical performance: external and internal noise
- Visual performance: natural and artificial lighting (luminance, glare), internal and external contacts
- Design

- Ergonomics
- Tactile performance
- Accessibility
- Structural, fire etc safety
- Security against intruders, utility supply interruptions etc

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 – calculated as per *Productive office 20050* [6] :

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 proved to be profitable! Then NPV over the period of analysis is easy to calculate.

To study the occupational factors, an assessment was made in Intentia HQ, Keilaranta 5 Espoo. There a *Post Occupancy Evaluation – POE* was performed utilising the BUS method from the UK, licensed by Villa Real; report [7] is available free of charge in our online bookshop at www.villareal.fi/.

The POE proved that Intentia HQ is an excellent working place; it achieved a rating "very good" and a very high scoring compared against the accumulated international benchmarks. In the following two graphics some results are shown:

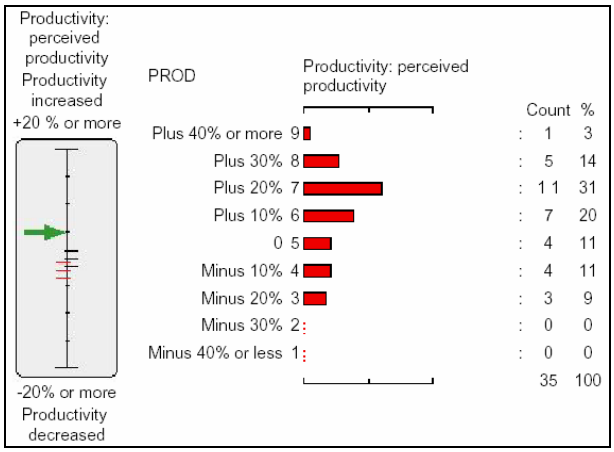


Figure 3. Productivity perceived

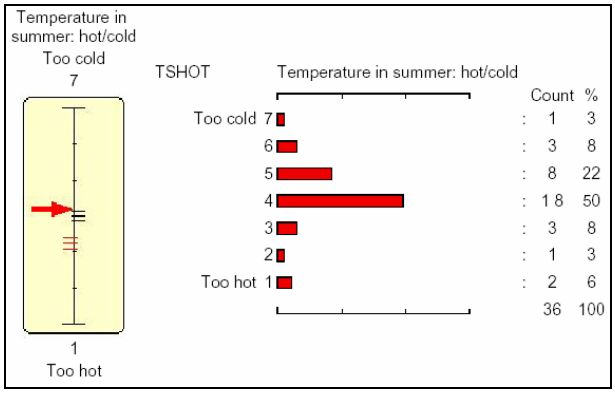


Figure 4. Temperature in summer; AC problem!

A value of different improvements proposed by this evaluation can be easily calculated via Total LCC approach as NPV over the period of analysis. Through monetarisation the positive results can be seen at the bottom line of the company's financial statements.

3.2 CEN/TC 350: Framework for the assessment of social performance

In the ongoing work programme of CEN/TC350 new standards on sustainable construction are being developed. In their latest draft *prEN 15643 Sustainability of Construction Works - Assessment of Buildings* sustainability is defined as ability of system to be maintained for the present and future generations. This suite of standards is concentrating in the "three pillars of sustainability" ie various impacts and aspects on environmental, social and economic domains.

The brand new draft *prEN 15643-3:2010 – Framework for the assessment of social performance* [8] actually tries to cover the above occupational factors. At the same time it tries to cover "loadings for neighbourhood", ie impact on surroundings and society as a whole. Yet, several occupational factors are missing, and most factors for societal impacts are left for future development. Also, the calculation methods to assess the social performance are left for the future.

3.3 Regulatory framework

It is good to realise that as an EU member state, Finland must comply with the generic EU administrative structure and procedures. For various CREC regulations the order is as follows:

- EU Directive ⇨
- CEN Standards: mostly in accordance with ISO standards ⇨
- National regulations: must comply with the above ⇨
- Voluntary Evaluation/Assessment/Calculation methods (such as LEED, BREEAM, PromisE, FC Environ etc for sustainable construction): must comply with the above

4 Conclusions

Where we are today:

- Acquisition capital costs govern.
- LCC is up and coming, today mainly for future energy costs.
- Total LCC gives valid answers easy to understand to support sustainable construction.
- Total LCC gives a tool to make the impact of indoor environment/climate/air for better productivity easier to calculate.
- I am confident that **eventually the Total LCC 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!

Total LCC is to be concluded in my doctoral dissertation now in its finalisation stage under prof Juhani KIIRAS, HUT/Aalto University.

Updated information, related publications plus some EU documents mentioned are available at http://www.villareal.fi and our easy/instant/secure online bookshop https://onlinebookshop.villareal.fi, all free of charge.

References

[1] Roger-France J-F et al, *Life Cycle Costs in Construction*, EC DG Enterprise, 2003/04.
[2] Davis Langdon Management Consulting, *Life cycle costing (LCC) as a contribution to sustainable construction: a common methodology,* 2007.
[3] Tupamäki O, *Construction Can!*, Villa Real Ltd/SA, ISBN 951-97676-1-4, 1998.
[4] *ISO 15686-5 Buildings and constructed assets - Service life planning - Life cycle costing*, 2008.
[5] CEN/TC350, *prEN 15643-4 Sustainability of Construction Works - Assessment of Buildings - Framework for the assessment of economic performance*, 2010.
[6] Seppänen O, *Tuottava toimisto 2005, Loppuraportti*, Helsinki University of Technology, ISBN 951-22-7286-5, 2004.
[7] Tupamäki O, *Post Occupation Evaluation - POE*, Villa Real Ltd/SA, ISBN 952-5545-02-4, 2004.
[8] CEN/TC350, prEN 15643-3 Sustainability of Construction Works - Assessment of Buildings - Framework for the assessment of social performance, 2010.