Value Oriented Product/Service Offerings for Sustainable Living Buildings

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Abstract

Current business offerings in construction assume that client needs remain fixed over the lifetime of a building. Buildings are therefore not fully capable of meeting changing user, social and environmental needs. The current cradle-to-grave thinking causes substantial waste, environmental damage and destruction of capital. Buildings underperform from an economical and ecological perspective. This paper presents a new business concept in the form of value oriented Product Service Offerings for Living Buildings. A provider of Living Building services adds value to the business of its clients and is rewarded for that. A provider is proactive and manages a portfolio of industrially produced, customizable solutions. During operation, user processes as well as social and environmental processes are closely monitored, and the building is kept fit-for-use during its entire functional life. Modules, components and materials that are released from a building after they have become dysfunctional, are remanufactured for reuse in the same or other buildings. This reduces waste, reduces the energy-intensive production of base materials for new buildings and saves construction costs. Living Buildings are expected to be less vulnerable for depreciation than traditional buildings and offer therefore an attractive alternative for investors. A first pilot project is currently realized for a school in Veenendaal, the Netherlands.

Keywords: Living Buildings, Business innovation, Value creation, Lifecycle management, Cradle-to-cradle, Remanufacturing, Product-Service System.

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Introduction

Current business models in construction, as well as current forms of contracting, assume that client-, market- and social needs remain fixed over the lifetime of a building. Requirements are pinned down in specifications and contracts. Deviations from an agreed specification often lead to time- and budget-overruns or, even worse, to legal disputes.

But in reality, user needs and social or environmental boundary conditions change continuously. Static infrastructures, buildings and servicing processes, such as maintenance, may therefore soon result in underperformance. Given the huge capital investments needed for the creation of new buildings and infrastructures, and given the often irreversible impact of building permissions on landscapes and townscapes, this causes high risks for investors, users and governments.

The current static approach often results in an over-specification of requirements, and in an over-dimensioning of built artifacts. After all, if a building is assumed to exist 30 years or more, the client cannot just define only present requirements, but has to predict also long term future requirements. Such requirements often depend on external factors that clients cannot control, such as social and environmental factors. And reversely, if a designer has to assure performance and quality for a long period of time, he or she will choose durable but costly materials and over-dimension the design. Planned maintenance procedures are intended to keep the artifact in its original state.

This makes no sense if user and societal requirements, as well as environmental conditions, change. For many building types, such as hospitals, schools, retail centres, office buildings, transfer centres and factories, requirements may change every 5 to 10 years. If the building cannot be modified adequately, three options exist: (a) users stay in the building but have to accept a sub-optimal solution, (b) the original users leave, so that the building gets a function for which it was not originally designed, or (c) the building will be demolished. In all cases the value of the building decreases, which poses a serious risk for the investor.

Figure 1. Many buildings are demolished and end up as landfill, because they do not meet today's standards for usage, and because they are not designed for disassembly and reuse.

The recent crash of the financial system has demonstrated these risks once more. Most construction projects are funded through loans from a bank. For a bank, the artifact is collateral for the loan. If the lender cannot meet his or her financial obligations, the bank is entitled to sell the collateral on the open market. But if such a market does not exist, the collateral has no value. Banks will perceive such loans as too risky. In the best case the bank will provide the credit but asks a high interest percentage in order to compensate the risk.

It is of course possible to produce buildings with a shorter lifetime. But the capital investments in buildings are usually so high that they cannot be written off in a short period of time. Moreover, the need to demolish a building after a short period worsens the already existing problem of excessive waste.

Dynamic thinking in construction is not new. Several initiatives have been taken in the past to realize buildings, often using industrial production techniques that can be changed if user requirements change. Probably the most well known concept in this respect is Open Building [Kendall 1999, Habraken 1988]. An Open Building has a fixed, durable, main structure, and a flexible infill. The Open building concept is primarily an architectural - and partially technical - answer to the problem.

More and more construction companies offer today mass-customized solutions, based on industrially manufactured building systems and production automation. Clearly, these are steps in the right direction to improve the efficiency and quality of construction.

But most industrial solutions are however positioned as alternatives for traditional contracting and rely therefore primarily on the reduction of initial (capital) costs, not on reduced Total Lifecycle Costs, reduced risks or increased client value. Furthermore, a building that is customized and made fit-for-use at the beginning of its lifecycle, may not remain fit-for-use at a later stage. Buildings that deviate from average market requirements are perceived as risky investments but will never be optimal solutions for users.

Objectives

This paper describes a new business model for construction that recognizes changing user demands as well as changing social and environmental demands. Not by trying to predict the future, but by realizing product/service combinations through which buildings can de adapted continuously, without destroying capital value and without causing waste and environmental damage. The research examines also the required change of contractual relationship between client and provider.

Background

In 2002, the national parliament of the Netherlands held an enquiry about fraud and cartel agreements in the Dutch construction sector. It was concluded that the sector had to reorganize itself. In order to support the transition process, a research and development programme called PSI Bouw was executed between 2004 and 2007. One of the most challenging concepts that came out of this programme was the Living Building Concept [de Ridder 2006]. A few companies now try to implement this concept in practice.

Chapter 1 presents a model of four levels of business efficiency. It clarifies the difference between the Living Building Concept as a Product Service system (PSS) and current business offerings in construction. Chapter 2 describes the lifecycle model of adaptable, sustainable buildings.

Chapter 3 discusses the processes of condition and performance monitoring, vitalization and remanufacturing. Chapter 4 addresses financing and value creation, and chapter 5 describes a pilot project in Veenendaal, the Netherlands.

1. The Business Model

1.1. Four Levels of Business Effectiveness

The type of business offering that is most appropriate for the new concept is a value oriented Product/Service combination. It differs fundamentally from existing business offerings in construction. The differences will be explained here.

The efficiency of a modern enterprise with respect to the delivery of client value can be expressed on a scale that has four distinctive levels [Gielingh, 2006]; see also figure 2.

a) An enterprise that offers capacity, such as human capacity, is paid based on time spent on a job. It does not sell the results or the way in which these results are obtained. Risks are minimal for the provider, but maximal for the client.

b) On the second level, enterprises offer processes, such as in the form of projects. They commit themselves to execute a project within time and budget. Results are variable and differ from project to project.

c) On the third level, enterprises offer products or services to their clients. They commit themselves to time, budget and results, but not to (end) user value. Most industrial enterprises, such as car manufacturers and producers of household appliances, belong to this category.

d) On the fourth level, providers commit themselves to the maximization of user value. They do this by means of integrated packages of products and services that are optimized for the user at any time of a contractual agreement. Usually they own the products so that these can be replaced by others in order to reduce the risks of the client. This offering, often called a Product/Service System (PSS), goes beyond pure leasing, as the latter is mainly restricted to financing. In a PSS, user value is optimized by an additional servicing package that ensures that the product remains fit-for-use, also if user requirements, client budget and other conditions change. Risks are minimal for the client, but maximal for the provider.

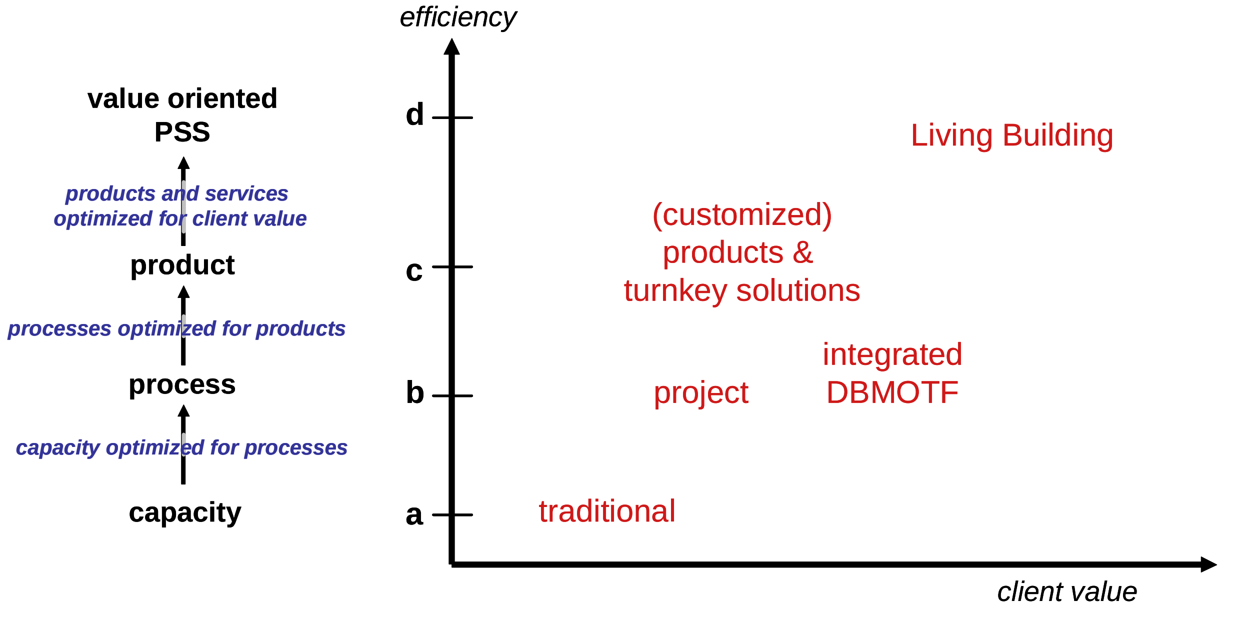

Figure 2. Four levels of business efficiency (left) versus client value.

The most widely applied business model in construction today is the offering of capacity. Competences are brought together and the risk is spread by forming consortia. Processes depend on client order. Business ICT is mainly restricted to Enterprise Resource Planning (ERP).

Some construction companies apply process orientation. Such companies are specialised in project- or process management. They run their businesses often without personnel doing the actual work; personnel is hired from capacity oriented companies. From an ICT point of view they apply workflow and document management systems. Well known applications in construction are the seamless team approach and integrated DB(MFO) projects.

Product orientation is characterised by the fact that enterprises have a portfolio of predetermined solutions that exist independent of client orders. These solutions can be configured and customized to comply with specific client needs. Processes do not depend on client order but are optimized for the product being delivered. Enterprises that offer products usually apply advanced 3D or nD (parametric) CAD systems that are integrated with Computer Numerically Controlled (CNC) production automation technology. They have fixed (order independent) supply chains that can be optimized for collaborative engineering and for logistics. Examples in construction are advanced suppliers of building systems and turnkey solution providers.

Value oriented product/service systems form the fourth level. A combination of products and services aims at the delivery of the highest client value for the lowest costs. In terms of ICT, enterprises use most - if not all - of the above mentioned applications as well as Customer Relationship Management systems. Value oriented PSS offerings are still rare in most industries as well as in construction. The concept will be described in more depth in section 2.2.

The four levels form essentially a stack: each level makes use of the efficiency gains at a lower level. Hence, the offering of value oriented product/service combinations is not possible without having products and services.

Figure 2 shows the four levels of business efficiency and effectiveness on the left. Current business offerings in construction can be placed in a diagram with two orthogonal axes: (a) business efficiency and (b) client value. Integrated DBM(FO) projects aim at offering high client value, but as they are not based on predefined and optimised products and services, they cannot do this efficiently. Such projects are at best process based. Turnkey solutions, using industrially produced (prefabricated) systems and components, apply more efficient processes which normally result in lower costs. But they do not necessarily result in higher client value, nor do they minimise client risks.

1.2 Product Service Systems

A Product Service System is defined by [Goedkoop et.al. 1999] as "a marketable set of products and services capable of jointly fulfilling a user’s need". Key factors of success are:

- to create value for clients, in economic sense or by adding quality and comfort,
- to customize solutions to meet specific client needs,
- to create new functions, or to make unique combinations of functions,
- to decrease the threshold and risk of capital investment by sharing, leasing or renting,
- to reduce environmental load and to deliver eco-benefits,
- to respond better to changing client needs.

Product Service Systems introduce a different way of doing business and require new kinds of contractual arrangements. They have the potential to decouple environmental pressure from economic growth [Mont 2002, Manzini and Vezzoli].

An example of a Product Service System is that offered by producers of printing and copying machines, such as Xerox and Océ [Kerr 2001, Steinhilper 1998]. In their PSS business models these companies do not sell machines, but a printing or copying function. Clients pay for the output of a machine and for quality and reliability. The combination of product and service is designed to deliver performance. If a machine runs out of toner, it automatically orders a new cartridge which may be delivered and installed by the provider. The condition of operational machines is monitored through sensors that record the number of copies made, paper jams, heat and/or other critical performance criteria. Before a machine breaks it can thus be repaired or replaced by a 'new', more reliable one. If the requirements of a client change, the provider replaces a machine by a new one. 'Old' machines are taken back and are disassembled. The parts are remanufactured and used again for the production of new machines. This reduces waste and the costs of making completely new machines from fresh natural resources.

Figure 3. Disassembly line of copying machines for the reuse of parts [Steinhilper 1999].

1.3 The Living Building Concept

The Living Building Concept [de Ridder 2006, de Ridder and Vrijhoef 2007] is an idea for a Product Service offering for construction. An LB provider takes full Extended Lifecycle responsibility for buildings and their parts. The provider is thus not hindered by the current fragmentation in the construction sector. Very much like common practice in other industries, LB providers have a supply chain which is strategic and thus independent of client orders.

Providers develop a portfolio of solutions for specific product/service - market combinations, such as for housing, education (schools), health care (hospitals), retail (shops, retail centres, airports), business (offices) or infrastructures (bridges, tunnels, roads). A solution consists of a building concept and a suite of services that both can be customized to specific client needs.

An LB contract aims at the delivery of maximum value for minimal money; it does not freeze user requirements or building performance. If user requirements or external conditions change such that the building no longer offers the best solution, it will be changed. The goal of the LB concept is therefore to keep a building fit-for-use, not just once, but always!

A provider does not wait until clients or users start to complain. The provider understands the type of processes that are facilitated by the building, and is proactive. User processes, social and environmental boundary conditions, as well as building performance, are continuously monitored. If any of these conditions change such that the building becomes sub-optimal, the provider may adapt the building and/or service. Depending on details in the service level agreement and impact on the agreed price, the provider can do this autonomously or by mutual agreement with client and/or user.

For each modification requirement, there may be zero, one or more solutions. Each solution will have its benefits and implications. These benefits and implications are considered in a broader context: change requirements can be addressed more economically by combining them into a single solution. Decisions about modifications are thus based on a rationale, in which integral benefits are weighed against integral implications.

An LB contract does not specify a fixed performance for a fixed price, but defines an agreed value-cost balance. Within such an arrangement, the process is dynamically controlled: clients can alter their initial demand and calculate the impact on the initial price, and vice versa. Providers are encouraged to propose new solutions that reduce costs or deliver additional value. An initial price will grow within this dynamic process in a controlled way to a final price. Instead of enforcing the initial planned value against a fixed price calculated in the first phase of the process, the price is based on actual delivered value during the process. The range between basic price and the client's financial budget can be considered as the client's "control budget". On the supply side, providers are enabled to reduce costs or increase value.

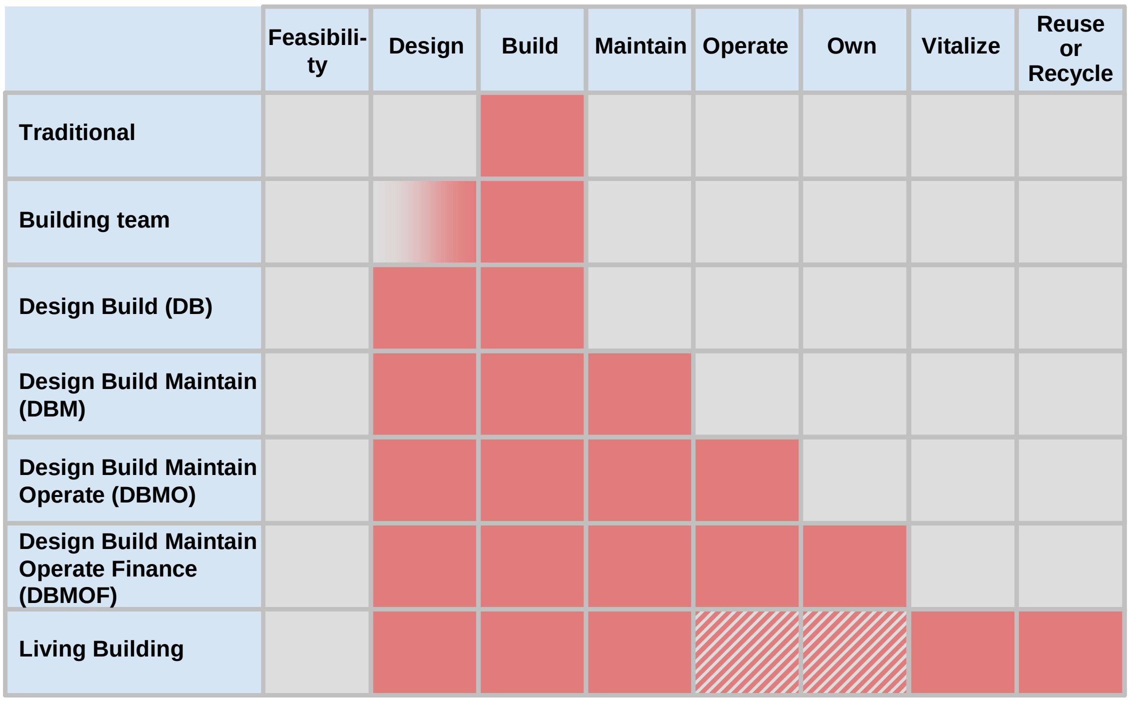

Figure 4. A comparison in lifecycle coverage of existing contract types and the Living Building concept. In the ideal situation, the provider also covers operation and ownership. In a minimal scenario, operation and ownership may remain the client's responsibility.

Given the possibility that buildings may change quite drastically during their life, it makes sense that the providers legally own the buildings; not the clients. However, providers do not rent or lease out buildings, but facilitate user processes. Hence, buildings may be multifunctional to facilitate the processes of multiple clients. This creates new business opportunities for clients and results in substantial cost efficiencies.

Figure 4 shows the lifecycle coverage of Living Building services compared with some well known contract types, where D=Design, B=Build, M=Maintain, O=Operate and F=Finance. Living Building services comprise in principle all of these stages plus vitalization and reuse or recycling. But the concept goes beyond mere lifecycle coverage and financing: it aims at the delivery of client value. Further, it can only be successful if a sufficiently large implementation base exists so that industrial production techniques can be used and a sufficiently large pool of interchangeable components can be built up.

1.4 Measuring Value

Values and costs are not limited to financial values and costs. Amongst the factors that can be incorporated in a value/cost model are social, cultural, environmental, ethical and aesthetical values, as well as risks, wellbeing and health.

A complicating factor is that economical values may have to be weighed against non-economical costs. Reversely, non-economical values may also have to be weighed against economical costs. The fact that 'costs' and 'values' of different kind have to be weighed against each other forms a special challenge for the concept. This problem is, however, not limited to the new business concept: clients in construction always have to weigh financial costs and environmental damage against economical, social and/or cultural benefits.

There exist a few concepts that try to tackle this problem, of which the best known is the Balanced Scorecard method [Kaplan and Norton 1996]. This method does however not project all different values and costs on a single scale. The consequence is that weighing between different types of values and costs, such as the financial value of the natural habitat of an endemic plant, or the costs of emitting one kg of CO_2, remains a subjective human task.

It is currently common practice to express all values and costs in terms of money. In the medical sector, even the value of a human life is expressed in terms of money. Money has however specific characteristics, such as interest, inflation, artificial scarcity and relationship with debt, that makes it less suited for the expression of non-commercial values. Central banks can simply print money if needed so that it is a highly elastic yardstick. This is especially important for products with a long lifetime such as buildings.

As an example: an investment in an installation for solar energy that gives an annual return of 3 % may be perceived as non-economical: the return on investment is seemingly lower than 3.5% annual interest that can be earned if the money is deposited in a bank. But money is subject to inflation (i.e. it loses value over time), while the price of energy is expected to increase over time, even faster than inflation.

The former banker Lietaer designed new kinds of money that are better suited for the expression and exchange of social and environmental values than current money [Lietaer 2001]. Amongst these types of new money are 'currencies' for the trading of care, education and energy. The Kyoto treaty has introduced the international trading of CO_2 emission rights. But again, these specialised currencies cannot be used for trading between values of different kind.

Another problem is the time-factor. Current values are determined by current trading. There is no trading between today and the future. This is why it seems 'economical' to exploit planet Earth today, and not to leave its resources untouched for use by future generations.

A very interesting solution for both problems may be the Terra Trade Reference Currency [Kiuchi 2004]. The Terra is not intended as a currency for direct usage, but as a reference currency against which the value of normal currencies, such as the dollar, euro, yen and pound can be measured. Although the Terra starts with a unit price, the value development as a factor of time differentiates based on the type of value being measured. The Terra is not created by banks but is coupled to real world values such as grain, rice, water, oil, copper, steel and human labour. It has no interest and is indifferent to inflation. Unfortunately, the Terra is still a concept and is not yet used in practice.

2. Sustainable Lifecycle Management

2.1 Three kinds of facility lifetime

We may distinguish three categories of lifetime that are relevant for buildings and any of its systems or components [Gielingh et al 2007]:

- *Usage lifetime*: the time in which there is a user need for the offered solution. Sometimes this is also called Functional lifetime.
- *Technological and fashion* lifetime: the time in which the offered solution is acceptable, compared with other alternatives. Technological innovation or changes in fashion may offer more attractive alternatives for the user.
- *Physical lifetime*: the time in which the physical properties of the solution remain within an acceptable tolerance-zone from its intended properties. If these properties deviate too much from intended properties, the facility may break or become less attractive. The physical lifetime of an artefact is usually determined by factors such as wear, tear, corrosion or accidental damage. Traditional maintenance activities focus primarily on the extension of physical lifetime.

The first two lifetimes determine the *value lifetime* [Tomiyama 1997, Umeda et al 2000]. An artefact has only value as long as there is a user need for it and as long as there are no better or more attractive alternatives for it.

These different kinds of lifetime do not just occur for a building as a whole, but for every component or (sub)system individually. The effective lifetime can be different on each level.

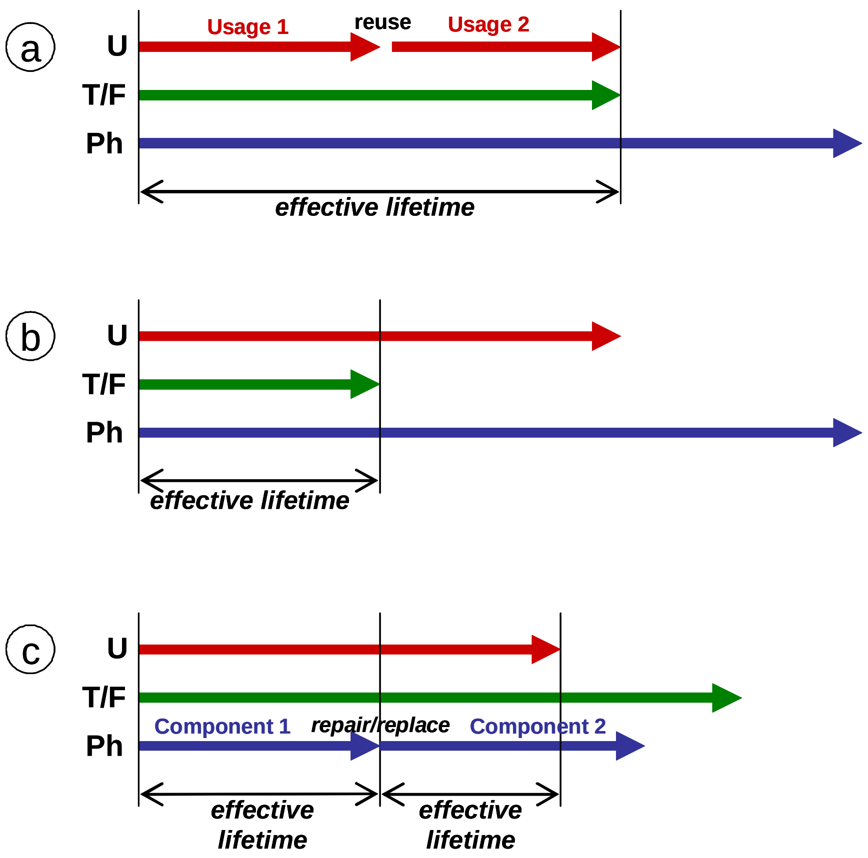

Figure 5. Combinations of Usage (U) Technology and Fashion (T/F) and Physical (Ph) lifetime determine the effective lifetime.

Figure 5 shows what happens if these kinds of lifetime are combined. Together, usage (U), technological and fashion (TF) and physical (Ph) lifetime determine the effective lifetime of a facility, component or (sub)system.

(a) On top a situation is depicted where physical and technological lifetimes are longer than usage lifetime. An example is a house that is bought by someone whose personal conditions change, for instance because of a divorce or because of new work in another part of the country. The user needs have changed, but the object itself is potentially reusable and can be sold to another person.

(b) The object in the middle has a long physical lifetime and a long usage lifetime, but a short technological or fashion lifetime. Although the user needs may not have changed after t=To, the component may be replaced because technologically superior or more fashionable alternatives have entered the marketplace. This is most prominent today for products such as mobile telephones, computers, cars and clothing.

(c) The component shown in (c) has a short physical lifetime. User needs and technology hardly change. The component will then be replaced during maintenance. Most current lifecycle models are based on this scenario. They assume - often incorrectly - that user needs and technologies do not seriously change

2.2 Sustainable Buildings and Lifecycle Differentiation.

Each (sub)system and each component of a facility has thus its own lifetime scenario. The primary function that is facilitated may exist considerably longer than the facility itself.

For example, the functional life of a hospital may span more than 200 years, while buildings normally have an estimated lifetime of 30 to 60 years. But sub-functions of a hospital have a considerable shorter lifetime than the main function. For hospitals we may refer to changing diagnostics technologies, such as the introduction of magnetic resonance (MRI) technologies during the last decades. An MRI scanner is a very heavy object that cannot be placed on a floor that is designed for regular loads. Also the recent policy to reduce the hospitalization time of patients and to increase the number of polyclinic treatments had an impact on the functional requirements for hospitals. Of even more importance can be changes in organization. For reasons of efficiency it can be decided that three existing hospitals merge into one, and that certain locations are no longer needed because of improved infrastructure. Such changes have a dramatic impact on the building. Does it have to be written off, even though it is still in good condition? Can it be given a new destination? Without any doubt, the future will bring more changes. But these are difficult to forecast.

Differences between the three types of lifetime require changes in the state or configuration of an artefact. Systems or components that need to be replaced but have not reached the end of their physical or technological life may be reused in the same or in another facility.

In case systems or components cannot be reused as such, the materials from which they are made can be reused. To trash components or materials, just because the user need has changed or disappeared, would be a waste of capital, and an abuse of scarce natural resources.

The Living Building Concept aims therefore at the reuse of components that have finished their usage lifetime but not their physical or technological lifetime. For components that have finished their physical and technological lifetime, it aims at the recycling of materials from which they are composed.

As a consequence, the Living Building Service Provider has to manage various lifecycles and a dynamic configuration structure. A reference model that can handle such configuration changes is published by [Gielingh 2008].

3. The business process that supports Living Buildings

3.1 Monitoring usage, environmental condition and building performance

The monitoring function of Living Buildings is an alternative for the current practice of trying to forecast the future.

A provider of Product/Service combinations for Living Buildings cannot assume that user requirements never change. In stead of waiting for users to complain, he must be proactive, so that new services can be developed. In order to keep the building fit-for-use he must understand the activities that are facilitated by the building, understand the conditions under which they take place, and understand trends. The provider must follow demographic trends of the community in which his building is located so that he can anticipate changes in required capacity. He must also understand trends in the processes that are facilitated, such as new teaching methods, new types of medical treatment, and new quality and comfort levels that users demand.

The appreciation of the performance of a building depends not only on the building itself, but also on the activities of the user and on environmental conditions. A room in which people are in motion requires a lower temperature than a room in which people are passive. Figure 6 (top) gives an example of five building related, two usage related and two environmental related parameters that may affect perceived thermal comfort in a room [Säteri 2004].

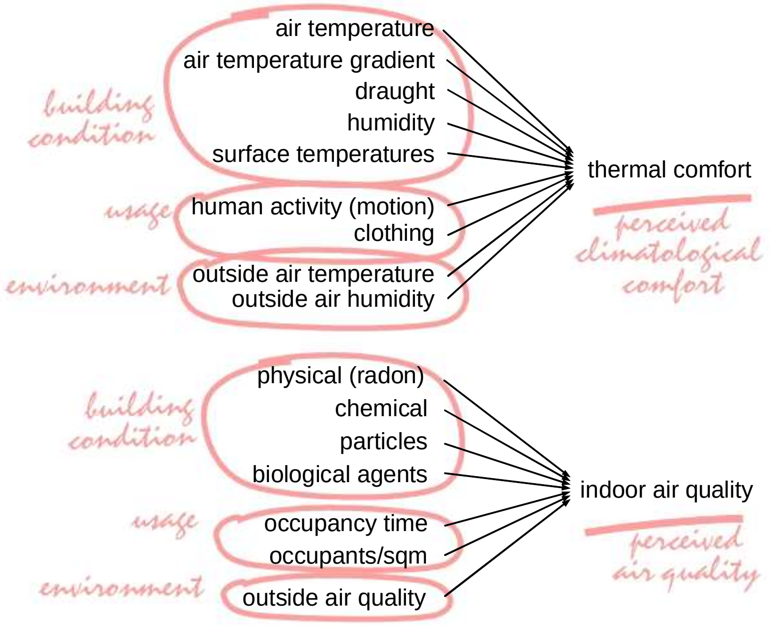

Figure 6. Two examples of the need to monitor room condition, room usage and environment for the determination of perceived room performance.

Hence, an essential part of providing adequate services and adequate performance is to monitor the building, its usage and its environment. Some of these monitoring functions can be done automatically with electronic equipment, but others require human action. Certain performance criteria cannot be met by the building alone, but require additional servicing. Cleaning, supply of consumables and light maintenance are well known examples. But also the optimization of health, safety and security conditions can be developed as a service by the provider.

3.2 Vitalization

The term 'maintenance' is used today for the servicing activity that keeps a facility in its original state. This term reflects the current static view on the functional needs for a facility. It assumes that these needs do not change.

The servicing activity that aims at the maximization of yield (= integral values divided by integral costs) is described by the term 'vitalization'. It incorporates not only traditional maintenance, but also modification of the facility to serve changing user needs and changing trends in technology and fashion.

Whereas most buildings meet only the user and community criteria that were defined at design stage, a living building aims at meeting actual criteria. This does not imply that the building is changed continuously, as the costs of change will have to be weighed against increased value. But, in principle, the building will be adapted on a regular basis in order to keep users satisfied and in order to meet changing standards such as for safety, health and energy. Vitalization of a building may mean that the building has to be made larger or smaller. In the latter case, building components will be released. If the Living Building concept would be applied according to traditional cradle-to-grave thinking, downscaling would be identical to (partial) demolition, which creates substantial waste. According to [Krutwagen et al 2004] construction is today responsible for 10.7% of the depletion of the Earth's natural resources.

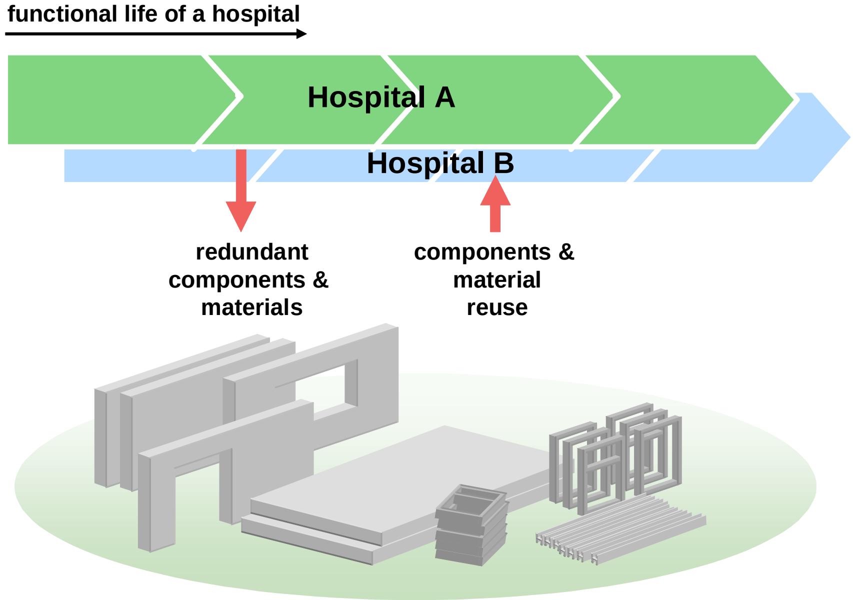

Figure 7. A Living Building, such as a hospital, will be continuously modified to satisfy user needs. This causes the release of redundant components and materials. Some of these components and materials may be reused for the vitalization of other Living Buildings.

The Living Building concept adopts therefore the cradle-to-cradle principle [Braungart et al 2007, McDonough et al 2002]. Modules or components that are released from a building, simply because their functional need has disappeared, will, as far as possible, be reused in another building. As these modules and components will not be as good as new, they may have to undergo a process of remanufacturing, such as cleaning, repainting, surface treatment or repair.

This approach is in line with future developments in construction. The European Parliament accepted in 2008 a directive on waste elimination which states that by 2020 measures shall be taken by all member states such that 70% of non-hazardous and non-natural construction materials will be reused or recycled [European Parliament 2008].

3.3 Remanufacturing

Recycling of construction materials, such as by the melting of metals and glass, or by the pulverization of stone and concrete, costs huge amounts of energy. The production of materials from fresh resources requires even more energy. Table 1 gives an example of the ‘cradle-to-gate’ embodied energy and embodied carbon of some popular construction materials [Hammond and Jones, 2008]. Cradle-to-gate refers to the energy use needed for the production of the base material itself; it does not include transportation, processing on site, maintenance and demolition. Total lifecycle energy and carbon will therefore be substantially higher. Especially the demolition of concrete requires huge amounts of energy, and may be of the same order as the energy needed for production. Given the fact that the cement industry alone contributes 5% to all global anthropogenic CO_2 emissions, it is clear that the carbon footprint of construction materials is huge. The middle column gives Embodied Energy in Mega Joules per kg of material, the right column Embodied Carbon as kg of CO_2 per kg of material.

Material	**Embodied Energy MJ/kg**	**Embodied Carbon $kgCO_2/kg$**
Aluminum (virgin)	218.0	11.46
Aluminum (recycled)	28.8	1.69
Bricks	3.0	0.22
Cement	4.6	0.83
Ceramics	10.0	0.65
Concrete (pure)	0.95	0.13
Concrete (reinforced, prefab)	2.0	0.22
Glass	15.0	0.85
Lime	5.3	0.74
Plastics (general)	80.5	2.53
Steel (virgin)	35.3	2.75
Steel (recycled)	9.5	0.43
Stone (general)	1.0	0.06
Timber (plywood)	15.0	0.81
Timber (sawn softwood)	7.4	0.45
Timber (veneer particleboard)	23.0	1.24
Vinyl flooring	65.6	2.29

Table 1 Embodied energy and carbon, cradle-to-gate, of some construction materials [Hammond and Jones, 2008]

A detailed study of the lifecycle energy of twenty Australian schools indicates that the total embodied energy in a building (for its full lifecycle, thus incorporating initial and recurrent embodied energy) can be as much as 37 years of operational energy [Ding 2007].

In addition, it should be realised that the production of materials such as cement, brick, steel and glass require very high temperatures that currently can only be realised through the burning of hydrocarbons. For the heating and electricity consumption of buildings there are other - more environment friendly - energy sources available.

Given the expected rise of energy costs in the far future, and the need to reduce CO_2 emissions, it makes sense to explore the possibilities for reuse. But as used components do not have the same ‘look and feel’ of new products, these components require some treatment, such as the repair of dents and scratches, surface finishing and coating. This principle is called remanufacturing.

The idea of remanufacturing originated in the automotive sector, where demolition firms started to disassemble cars, refurbish their components, and sell these as spare parts for similar types of cars. Remanufactured parts can be produced at around 50% of the costs, and can save up to 80% of the energy and CO_2 emissions as compared with the production of new parts [Steinhilper 1998]. Remanufacturing saves the Earth's limited resources and reduces the production of waste.

Up to now, take-back policies for certain products are implemented collectively, often through government interference. But [Webster and Mitra, 2007] found that individual take-back policies, enforced by law, will lead to a structural change of industry and will make reuse and remanufacturing a profitable business where today it is considered as non-profitable. In these cases, manufacturers design their products so that they are not just easy to assemble, but also easy to disassemble and remanufacture. Advanced manufacturing technologies used today for production can also be applied for disassembly and reuse.

Apart from cleaning, remanufacturing often includes surface treatment, such as the removal of corrosion and paint, repair of scratches and dents, and the addition of new coating layers. In some cases, remanufacturing may require shape modifications. In a few cases it includes melting or chemical processing, so that the base materials can still be reused. Reuse of components or modules, without melting or chemical processing, has the least environmental impact and is therefore preferred [Tomiyama 1997, Umeda 2000].

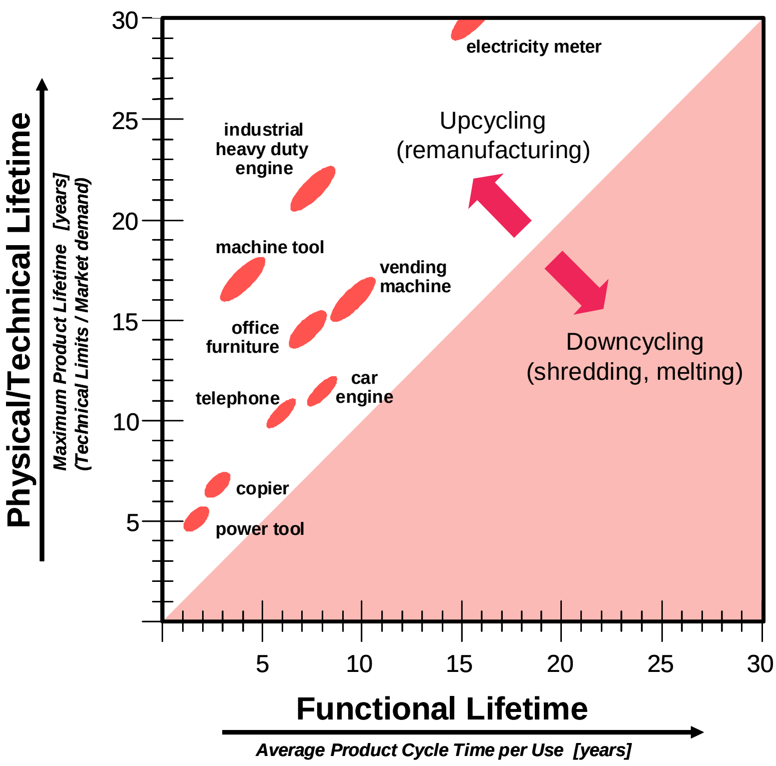

Figure 8. If the physical or technical lifetime of products or components is longer than their functional life, there is a case for remanufacturing (or 'upcycling') [Steinhilper 1998].

Given the increasing costs of raw materials and energy, companies that master this process well will have a leading edge over companies that apply cradle-to-grave thinking [Goedkoop et al 1999].

The business case for remanufacturing may even be greater for construction than for other sectors. This is because:

a) buildings and other constructed artefacts are massive relative to other products so that there is a higher incentive for reusing materials,

b) the technical and physical lifetime of components and materials used for construction is generally longer than their functional lifetime, and

c) remanufacturing, in combination with vitalization, extends the value lifetime of buildings and thus reduces the risks of capital investments.

3.4 Design for disassembly

An important prerequisite for vitalization, reuse and remanufacturing is that building structures can be (partially) disassembled without endangering the main structure of the building or any of its systems, and without damaging the components. In an ideal situation, it must be possible to vitalize a building without disrupting any of the activities that it facilitates.

A study of the technical implications of design for disassembly in construction was done by Durmisevic [Durmisevic and Brouwer 2002, Durmisevic 2006]. Guidelines for design include the separation of building functions, minimisation of the number of relations between assemblies in a building, a separation between main structure and infill, the connection of components of an assembly with a base part that connects the entire assembly with other assemblies, parallel assembly sequences, dry joining techniques and separation of components in different assemblies.

3.5 The Living Building Process

The envisioned process of a Living Building product/service provider is shown in figure 9. The left side of this diagram shows, from bottom to top, indicated with red arrows, the full construction process that starts traditionally with the extraction of raw materials from natural resources. Raw materials are chemically and often thermally processed for the production of base materials. Base materials are subsequently manufactured to become components for assembly.

In case changes of the building are needed during its operational life, the building will be partially disassembled and re-assembled. Removed modules may be reused for assembly in the same or another building. If modules cannot be reused as a whole, they will be disassembled into components. Disassembly can be drastically simplified if fixtures of components and modules are designed for that purpose. Further, given the fact that vitalization may take place in a fully operational building, main disassembly and reassembly should be designed such that ongoing activities in the building can continue with little or no disturbance.

Remanufactured components or modules are stored in a warehouse. As these components or modules are then readily available, the construction process can be very fast compared with traditional building processes.

Ultimately, all buildings produced by the provider will be a mixture of remanufactured and newly manufactured components and systems. Remanufacturing extends the technical lifetime of components so that overall construction costs and building lifecycle costs will reduce.

This concept even enables differentiated service offerings, such as luxury buildings made predominantly from new components, and 'economy class' buildings made from remanufactured components.

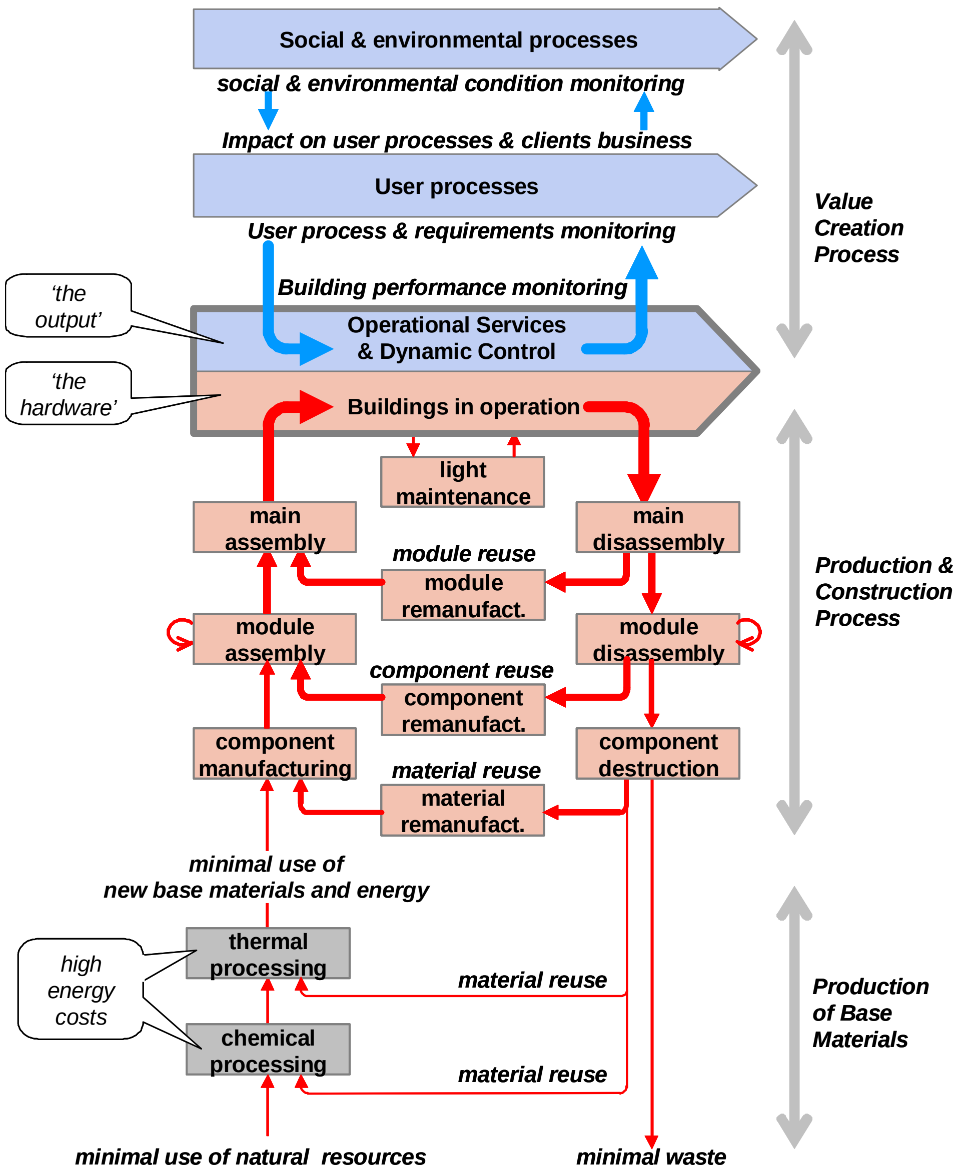

Figure 9. The process of a Living Building provider aims at reducing costs and use of natural resources in the construction process (red) and the increase of client value (blue).

The top of figure 9 shows, with blue arrows, the value creation process. The goal of this process is to anticipate changing client and user needs, so that adequate solutions can be developed as part of the product, the service, or both. This process is supported by three monitoring functions: (a) the monitoring of social and environmental conditions that may affect user processes and perceived building performance, (b) the monitoring of actual user processes, and (c) the monitoring of actual building characteristics and performance. A building can only be kept fit-for-use if its perceived performance remains high. Factors that affect perceived performance are fashion and market trends, new social insights and new technologies. Further, buildings such as schools, retail centres, airports, hospitals, hotels, offices and also houses support processes that may frequently change, perhaps even every 5 to 10 years.

4. Financing and Value Creation

The long term capital value of Living Buildings will be substantially higher than that of traditionally built buildings. Figure 10 shows the capital value of a building with an estimated lifetime of 50 years. Traditional buildings have to be demolished, so that they end up having negative value near the end of their life (figure 10 top). Remanufacturing turns 'waste' into a capital resource for the production of new buildings (figure 10 middle). If combined with regular vitalization, a Living Building will remain always fit-for-use, and thus retain a high capital value during its entire (indefinite) functional life.

This has two major implications for financing.

The first is that the risks of investments in Living Buildings are substantially lower than in traditional buildings. A Living Building can be modified according to changing user needs, it can be given a new function, and it can even be disassembled and rebuilt on another location if needed. Its sustained value is important because it serves as collateral for the creditor. If the long term value of the collateral is insecure, or if there is simply no market for it, the creditor risks a heavy loss on this loan in case the lender goes bankrupt. This risk is normally compensated by asking a high interest on the loan. As a Living Building may be perceived as a less risky investment, a lower interest rate on the loan may be negotiated with the creditor. This will reduce the lifecycle costs of the building.

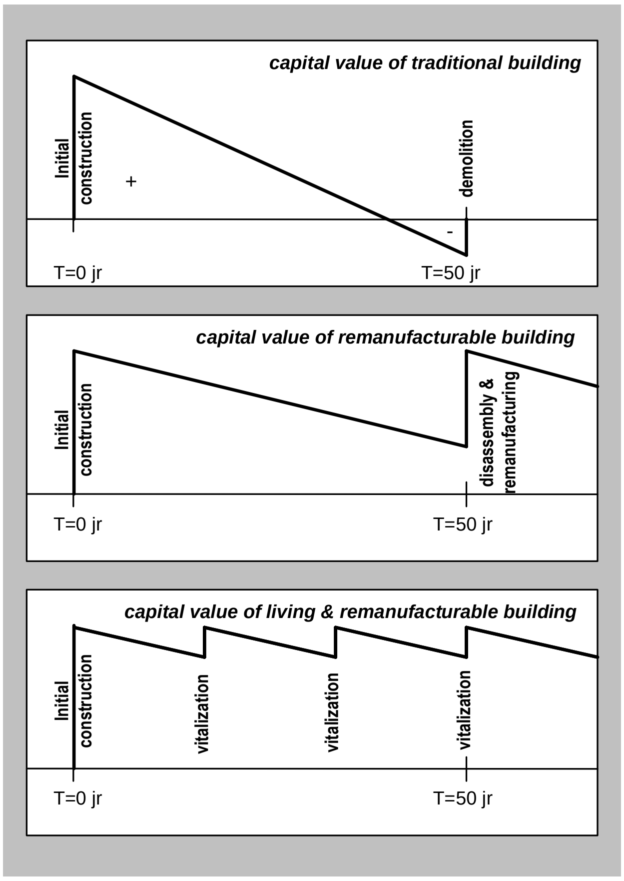

Figure 10. The capital value of a building as a function of time, (a) for a traditional building, (b) based on remanufacturing at the end of functional life, and (c) for a Living Building.

The second implication is that Living Buildings do not have to be written off, and that they may even rise in value compared to new but traditionally built buildings. The reason is that it is very likely that in the near and far future natural resources and energy will cost more than today. It has been mentioned in section 3.3 that the production of new materials from fresh resources, or the recycling of existing materials, requires much energy. This energy can be saved if materials and components are designed for reuse. Given the fact that material resources on planet Earth are finite, the long term value of such reusable materials and components will grow more rapidly than interest on a bank account. The amount of money in the two main economic zones, the US and Europe, grows on average between 8 and 10% per year. But only that what can be bought with money determines its real value, and the amount of available material resources does not grow at a similar rate.

Hence, the components of a Living Building do not have to be written off as quickly as a conventional building. They may even rise in value, similar to futures that relate to natural resources. An investment in a Living Building may thus be regarded as an inflation-proof investment.

5. Case studies

5.1. Pilot projects

Several construction projects were selected for experimentation with the Living Building Concept, all located in the Netherlands. The most prominent are:

- a secondary school in Veenendaal. Construction started in May 2009, and is expected to finish in August 2010.
- a hospital in Den Helder. A feasibility study is completed, but the project itself has not yet started because of a complication with financing.
- a canal and sluice valve complex in the province of Zeeland. This project is planned to start in 2010.

As the secondary school is currently the most advanced, more information will be given about it.

The idea of applying the Living Building concept to this school emerged when the concept was little more than a rough idea. Hence, there was no clear picture of the process and the contractual implications. M3V, a consultancy firm that advised the client, proposed the idea to the school board and the local government. The running process was traditional, with a design made by an architect, and a bidding, based on lowest initial cost. Just after winning the contract, the selected contractor went bankrupt for reasons that had nothing to do with the concept. A new bidding procedure started, this time covering integrated detailed design, construction, maintenance and vitalization, based on a number of possible scenarios that require future change. The provider that offered the best value/cost ratio was selected.

Although the Living Building concept is, by itself, new, there were several construction firms that already offered flexible solutions, and which had an interest in expanding their business by covering extended lifecycle services. Of these, the company Matrix Onderwijshuisvesting, a subsidiary of ASVB holdings, won the competition.

5.2. Technical aspects

The construction method applied is based on standardized and prefabricated concrete elements, for the exterior walls; standardized, prefabricated floor elements; and steel columns. The wall elements are load bearing. Wall elements that face the exterior of the building have holes for windows and have thermal isolation, and wall elements that face the interior are fire resistant. Both the wall elements and the floor elements contain cabling and piping for heating and ventilation. See also figure 11.

The only ‘fixed’ part of the structure is the core, where vertical transportation (elevator, stairs) and ‘wet functions’(lavatory, kitchen) are concentrated. For the rest, the entire structure is flexible. This means that floors can be added or removed, and that the building can be extended. The light interior walls needed for compartmentation can be placed anywhere on a 30 cm grid.

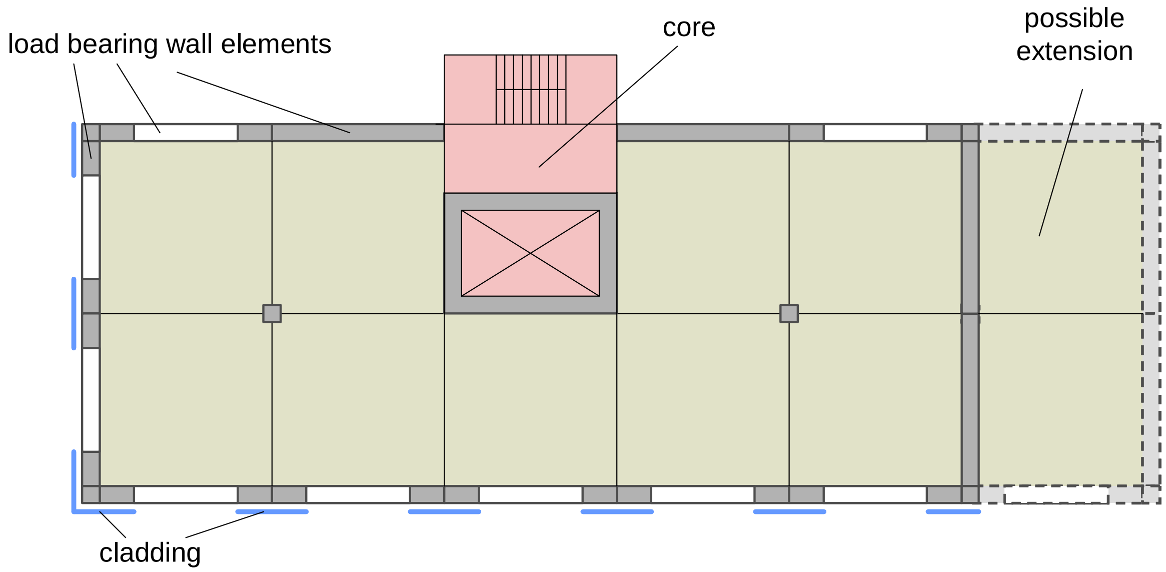

Figure 11. Schematic floor plan of one block of rooms, without infill.

The cladding, i.e. the visible part of the exterior wall, is mounted on the load bearing wall elements and can be replaced.

The building has two blocks of this kind, placed in an angle. The space between these blocks is used as an atrium. In the initial design, the building has four floors, but it is possible to add a few more or to remove some.

It is possible to change the function of the building as a whole, or any of its parts, such as a wing or one or two floors. Example designs exist for use as office and even condominiums. Hence, functionality can change.

All components and elements are joined with dry connections, and can thus be easily disassembled. The provider estimates that the main structural elements have a lifetime of more than 120 years. The cladding is estimated at 30 years, mainly for reasons of fashion. In other words, every 30 years (or sooner or later, whatever the client wants) the cladding can be replaced by another one, giving the building a more contemporary, 'new' appearance. Interior walls are estimated to be moved once every 10 years (on average) and have a lifetime of 30 years.

Thanks to the choice of using standardized prefabricated elements and components, the entire building can be erected in slightly more than one year.

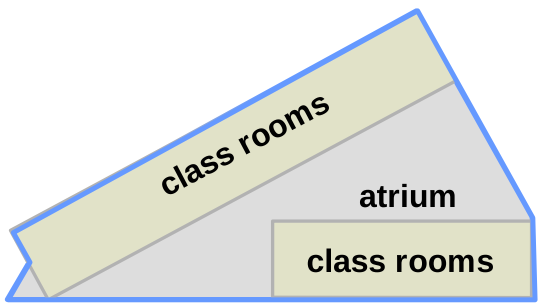

Figure 12. Plan of the school, with two blocks of class rooms. Between these blocks is meeting and circulation space.

Figure 13. Computer rendering of the exterior of the secondary school in Veenendaal; the first pilot project contracted according to the Living Building Concept.

Figure 14. Computer rendering of the interior of the secondary school in Veenendaal.

5.3 Financial and contractual aspects

There is little doubt about the feasibility of the concept from a technical/technological viewpoint. But the contractual and financial aspects appeared to be less easy to implement. The provider also offered the client a financial solution, in the sense that the provider remained owner of the physical building and the client pays for the performance of the building and related services; fully in line with the concept that is outlined in this paper.

This appeared to be ‘a bridge too far’ for the client. In the Netherlands, schools fall under the responsibility of local governments. They reserve separate budgets for school building, operation and maintenance, and this was also the case with this school. Further, the idea that a school building would be legally owned by a private (commercial) party felt risky. A factor that may have contributed to this perception was the bankruptcy of the former contractor. Hence, the building, once ready, will be owned and operated by the local government.

The consequence of this decision was that the initial costs had to be kept within the available (tight) budget, and that the provider cannot be rewarded for the offering of added value such as discussed in this paper. The provider, for instance, planned to install solar panels on the roof of the building, so that the school could become energy neutral. But this feature had to be dropped in order to stay within budget.

Another complication was that, because of ownership by the local government, the standard accounting rules used by this body applied. Consequently, the building as a whole will be written off in a period of 40 years, just as other public buildings. Although the users are happy with the new adaptable building, the specific advantages of the concept could not be made explicit.

Hence, it can be concluded that the new concept requires a drastic change in thinking by the clients.

Nonetheless, the provider, Matrix, has become very enthusiastic and plans to offer future clients the full package. It sees that clients need to be better informed about the concept, so that all parties will eventually reap the benefits. More work is also needed to express the added value through a leasing construction that includes a new form of financing and insurance.

Figure 15. Construction of the school, summer 2009 (almost same point of view as figure 14).

Results

A new business model for construction is described, based on a combination of products and services, in which – ideally – the provider owns the material building and is paid for the performance that the building provides to its users. The building is constructed from reusable components and materials that may have a lifetime which is considerably longer than the functional lifetime. The building can be adapted continuously to changing needs.

Several pilot projects are planned in the Netherlands. Of these, the project for a 'living school' in Veenendaal is currently (November 2009) in construction phase. In 2010 the realization of a 'living hospital' in Den Helder and a 'living canal and sluice complex' are expected to start.

The project in Veenendaal started as a unique experiment. But the company that built the school has now plans to form a joint venture with two consultancy firms and its main supplier that offers the integrated Product Service combination to the market. The ambition is to build a series of schools – which may all look different and unique from architectural perspective – all according to the same concept. It is expected that lifecycle costs can be reduced, while the risks for the local governments will diminish. This is contrary to the common belief that sustainable buildings cost more than traditional buildings. The concept is in particular interesting for regions that are faced with a shrinking population.

Conclusions

The Living Building concept seems to be a feasible and powerful business concept for the realization of sustainable buildings. An important advantage, as compared with other business models, is the extended lifetime of material components, resulting in considerable savings on embodied energy and CO_2 emissions. In addition, 'living buildings' can always be adapted to changing user needs and changing social and environmental insights and requirements. Hence, the lifecycle value will increase. As the continuous modification of buildings will require human effort, it can be stated that, from an economical point of view, the concept shifts the application of capital investments from energy and material resources to labour. The higher labour intensity should not be seen as a factor that increases costs, because building vitalization is always done to keep the building 'fit-for-use'. Decisions about change will always be backed up by a cost/value analysis.

The pilot in Veenendaal shows that the concept is technically feasible, although certain improvements remain always possible. Thanks to the use of prefabricated, standardized components, construction time is very short. If in the future remanufactured components will be used, construction time can be even shorter. However, clients and investors, as well as their advisors, need to get used to the idea. They tend to stick to old thinking patterns, which restrain the effectiveness of the concept. More work is needed to examine the financial implications, as well as the contractual and legal implications. Important risks such as bankruptcy of a provider and changing standards for reusable components need to be addressed.

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