Durability In The Built Environment And Sustainability In Developing Countries

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Summary: This paper discusses the relevance of sustainable construction and the role of durability and service life on sustainability. It summarizes the concept of service life planning, in accordance with ISO 15686, and investigates the applicability of this concept to the construction industry in developing countries. Examples and statistical data are given. Conclusions are presented.

Durability and service life have very important environmental dimensions. In some languages sustainable construction is translated as durable construction. Durability is much more knowledge-based than resource-based, because it is possible to improve service life without increasing environmental loads during the production phase.

Service life planning implies using of estimated service life of components as additional design criteria. The concept offers a logical scheme to make rational decisions based on economical (life cycle costs) and environmental (life cycle assessment) aspects.

More than 82% of the world’s population lives in so-called developing countries. These countries still need to construct a great number of houses and infrastructure. In other words, the developing world is still under construction and, potentially, can benefit very much from service life planning tools. However, several constraints like low environmental concern, the self-help construction scheme, higher interest rates and a lack of technical data and experts constitute barriers.

Keywords: Sustainability, service life planning, developing countries, durability

1 SUSTAINABILITY AND CONSTRUCTION

Sustainability has many definitions, but most people agree that it implies producing goods with a lower environmental load, thereby helping to preserve the environment for future generations. The Rio Summit 1992 definition includes additional dimensions to the concept, aside from the purely environmental one. First, the social dimension, which implies a more equal distribution of the results of development, within a country and between all countries, and second, the democratic dimension that demands increasing the direct participation of the public in the decision making process (John, 2001). All these dimensions are equal in importance.

1.1 Sustainability and construction

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The construction business is the biggest raw material consumer of any society. Kasai (1998) estimates that construction consumes about 50% of the total material consumption in Japan. Matos & Wagner (1999) estimate that in the USA construction is responsible for 75% of the total consumption of materials. The transformation of these raw materials into goods and the frequently long transportation distances require an extensive amount of additional resources and results in significant environmental loads. Additional resources are consumed during usage of the built facilities, plus those required by maintenance and decommissioning activities.

As a result, the sector is also responsible for consuming a significant part of the energy water and for the generation of pollution (John, Agopyan & Sjöström, 2001). For example, the decomposition of limestone during the production of the clinker Portland is solely responsible for generating about 3% of the world’s CO₂ generation.

Construction and demolition are also major sources of waste. Estimates of construction and demolition wastes vary worldwide from a mere 163 kg per capita to 3 658 kg per capita, with typical values surpassing 400kg per capita, which are typical values for domestic solid waste generation (John, 2000). To this total it is necessary to add all residues generated during building materials production.
Buildings are also important consumers of energy. WRI (2000) estimates that the residential, commercial and public sectors are responsible for 34.5% of the world’s total energy consumption.

1.2 Increasing sustainability of the industry

Sustainability certainly implies a delinking development from environmental loads (Janseen; Van Der Bergh, 1999). One specific tool for delinking is dematerialization. This implies delivering the same performance with smaller amounts of materials, which in turn means a reduction in pollution generation, transportation and decommissioning, and a reduction of the consumption of raw materials.

Dematerialization can also be achieved by replacing the linear model of production, where natural raw materials are extracted from nature, industrially transformed into products which are used and, after the end of service life are discharged as waste along with the residues of the production process. The new production paradigm is often called closed loop (Curwell & Cooper, 1998) or cyclical production (Craven et al., 1996). Within the building sector this implies that the production of buildings be maintained and operated with a minimum of resources, easily upgraded and/or refurbished. When the building becomes obsolete it will be disassembled and the resulting building components reused in a “new” building or, if they have already reached the end of their service life, recycled (John, 2000.). The amount of raw materials consumed and waste generated would be greatly minimized. Maximizing the use of renewable energy and renewable materials are, perhaps, the most commonly known other tools for reducing environmental load. Moving from carbon-based energy to a clean and renewable energy source will clearly solve global warming and acid rain problems. But the only source for renewable building materials is vegetable: wood, lignocellulosic fibres, etc. It is possible to expand the use of vegetable materials in construction, but obviously they cannot replace all other building materials, at least not without major industrial transformations. Additionally, even all the cultivable land available on Earth would not be enough to supply wood for the construction industry (Curwell; Cooper, 1998).

Recycling waste as raw material is also an important tool for preserving natural resources, and very frequently, reduces energy consumption (John & Zordan, 2001). Making the new products easily recyclable after the end of their service life is also very important.

Increasing durability is also an option for disconnecting materials consumption from development and, therefore, reducing environmental loads.

2 DURABILITY AND SUSTAINABILITY

Durability, measured as the in use service life distribution of a population of components, plays a very important role in achieving sustainable construction. Bordeau (1999), when reporting different concepts of sustainable construction collected by the CIB W82 among different countries, observes that in some languages like Dutch, Finnish, Romanian or French “sustainable” is translated as “durable”.

This confusion between sustainability and durability makes sense, because “one way of extending resource productivity is by extending the useful life of products” (DeSimone & Popoff, 1998). Increasing the service life can also reduce the amount of construction and demolition waste. Equation (a) describes the relationship between the environmental dimension of sustainability and service life:

\[ S = \frac{\sum E_l}{ESL} \]  

where \( S \) is the environmental sustainability index; \( E_l \) is the sum of all environmental loads of the building, on a cradle-to-grave basis; and \( ESL \) the (estimated) service life of the building. When comparing two solutions, which have an equal environmental load, e.g. they use the same amount of a specific material; the more sustainable is the one that has the longer service life. So, solutions with short service lives can be environmentally sustainable.

Of course, the proposed equation does not take into consideration the social and democratic dimensions of sustainability. In the long run, shorter service lives imply using more resources in maintenance, decommissioning and in reconstruction instead of using those “limited resources” to enlarge the existing built environment. Even if the short service life solution is the more environmentally sustainable, it may not be socially sustainable because it hampers enlargement of the built environment, e.g. housing, roads and sanitation. In developing countries enlargement of the built environment is a condition for achieving social sustainability and also for increasing national productivity.

2.1 Durability, a knowledge based attribute

Durability is much more knowledge-based than resource-based. Very frequently most of the environmental load is originated by the production of the component and service life can be increased or reduced without affecting the environmental loads proportionally. Some examples and evidence support this concept.
Let’s consider a reinforced concrete structure in an urban environment. The most common degradation mechanism will be corrosion of the steel bars due to carbonation of the concrete (CEB, 1993). Carbonation depth is a function of the square root of time and mechanical strength and a small increase of concrete cover from 20 to 25 mm can result in an increase of the service life from 50 years to 78 years, an increase of 56%. Applying that to a concrete component with a cross-section of 25 x 25 cm, this increase of 56% on the service life will cause an increase of only 8.2% on the environmental load during construction. Sometimes an increase in the service life of reinforced concrete structures can be achieved while reducing the environmental loads. Durability on marine environments can be improved by replacing clinker Portland with residues like granulated blast furnace slag or fly ash (Bijen, 1999). The durability of plastic components frequently depends on very small changes in its formulation (Guillermo Martinez, 1996).

Durability is not an intrinsic quality of a material. Simple changes in design details that result in greater protection of component from degradation factors can increase its service life with little or no change of the environmental load.

Obsolescence is another durability problem (ISO, 1999). Obsolescence is not the result of a degradation process but from changes in the user needs. It can be seen as socially defined service life. Since it is impossible to forecast social changes in the long run, “durability” against obsolescence cannot be controlled. But the environmental loads associated with obsolescence can be minimized, making components more likely to be obsolete easy replaceable. Additionally, the entire building will eventually become obsolete. Design decisions can control the speed of the obsolescence of the building and make the disassembling process and the reuse of the components easy. Knowledge is the key factor to control obsolescence related durability problems.

3 SERVICE LIFE PLANNING ACCORDING TO ISO 15686

ISO 15686-1 defines service life planning as a “preparation of the brief and design for the building and its parts to achieve the desired design life e.g., in order to reduce the costs of building ownership and facilitate maintenance and refurbishment.” (Annex B – Alphabetical glossary of terms). Its introduction starts by saying “ Service life planning is a design process which seeks to ensure … that the service life of a building will equal or exceed its design life, while taking into account (and preferably optimising) the life cycle costs of the building”.

Assuring that the building will reach the designed service life, defined as the one “intended by the designer e.g., as stated by the designer to the client to support specification decisions” is an essential part of service life planning. The second part of the service life planning process is to optimise the life cycle costs. Life cycle costs (LCC) are defined as the total cost at present value of a building or its parts throughout its life, including the costs of planning, design, acquisition, operations, maintenance and disposal, less any residual value. It deals with the economic performance of a building.

Even though LCC concept is a major incentive to adopt service life planning practices, the environmental dimension of service life planning is introduced only on item 10 (Financial and environmental costs over time).

Service life planning introduces the forecasting of service life into the design phase. It includes the following steps: (a) definition of the design service life of the building; (b) forecasting the estimated service life of building components; (c) using the estimated service life as a decision criteria for selecting alternatives during the design, in order to minimize life cycle costs.

The forecasting of the estimated service life of the component (ESLC) is carried out multiplying the reference service life of the component (RSLC) by modifying factors (A to G).

\[ ESLC = RSLC \times A \times B \times C \times D \times E \times G \]

The modifying factors are those which to take into account the effect of the differences between the forecasted in-use conditions and those conditions observed during the evaluation of the RSLC. The considered differences are relative to (A) quality of components; (B) design level; (C) work execution level; (D) indoor environment; (E) outdoor environment; (F) in-use conditions; (G) maintenance level.

Ideally, the component’s manufacturer will provide the reference service life data of the component. Inside the European Union the availability of this data is enforced by the EU Construction Products Directive 89/106/EEC (The Council of the European Communities. 1998). Other sources can also be used to do service life forecasting, such as previous experience or observation of similar constructions or materials in similar conditions, assessments of durability in Technical Approval certificates, results published in books, building codes, etc. A generic methodology to assess the reference service life is also provided.

Service life planning is intended to make the building as durable as that desired by the owner. It will allow maintenance activities to be planned during the design phase, which makes room for design decisions that makes these activities easy to perform. Also it should make easy refurbishment activities, defined as modification and to an existing building or its parts to bring it up to an acceptable condition. Service life planning makes it possible to integrate LCC and LCA during the design stage.

Two conditions are essential for applying the service life planning concept. Knowledge and infrastructure for measuring the reference service life, as well as knowledge of the effect of each factor on the reference service life.
4 SERVICE LIFE PLANNING, SUSTAINABILITY AND CONSTRUCTION IN DEVELOPING COUNTRIES

4.1 Sustainability and the construction industry in developing countries

Sustainability is a global concept for answer global problems, but its application in societies or regions results in very diverse Agendas 21. CIB’s recent effort on developing a version of its Agenda 21 for Sustainable Construction adapted to developing countries is recognition of this fact. More than 82% of the world’s population lives in developing countries (World Bank, 2001).

Developing countries are under construction because they, lack an adequately built environment. In the 43 countries with highest income 90% of the roads are already paved. In Latin America and the Caribbean only 24.2% of the roads are paved (World Bank, 2000). The lack of adequate houses is another indicator. Brazil alone needs to build about 5 million houses to be able to offer suitable shelter for its own citizens. In other words, expansion of the construction activities aiming to create an adequately built environment for all citizens is one of the items on the national Agenda 21.

The impact of the construbusiness on the environment in third world countries is relatively more important than it is in the developed countries. For example, the liberation of CO$_2$ due to decomposition of calcium carbonated during the production of clinker Portland is responsible for more than 6% of the total CO$_2$ released in Brazil but only accounts for about 1% in developed countries like the USA and Canada (Fig 1).

![Figure 1. Participation of clinker decomposition of limestone during clinker Portland production in the total CO$_2$ released in Latin America and the Caribbean, Brazil, Worldwide, and the USA and Canada (original data from Marland, Boden & Andres, 2000). These figures do not include CO$_2$ due to combustion.](image)

Statistical data about construction and demolition waste generation is scarce in developing countries. In Brazil typical generation rates are around 486 kg/year per person, considerably higher than domestic solid waste generation (John, Agopyan & Sjöström, 2001). In Chile the estimates are 236 kg/year per person.

It seems accurate to conclude that sustainable construction is even more important in developing countries than in the developed parts of the world.

4.2 Constraints for service life planning and sustainable actions

4.2.1 Lower environmental concern

Large portions of the population in developing countries, are hard pressed by basic problems such as hunger, poverty, violence, financial problems and scarcity of infrastructure. As a result, the developing societies tend to be less concerned about the environment than those from developed countries (Ocampo, 1999). Due to a scarcity of public resources to improve the infrastructure, different groups compete to build more facilities as quickly as possible, without much concern about quality and sustainability.

Even the very basic tools for protecting the environment are not yet implemented. In all of Latin America and the Caribbean, only Brazil, Chile and Mexico are considered to already have an acceptable measuring network for the monitoring of urban air quality (Kork; Saénz, 1999). In addition, there is a lack of basic legislation for waste management and most of the existing landfills do not comply with sanitary standards (Acurio et al., 1997).
Ocampo (1999) pointed out a lack of effective authority among the environmental public agencies as an additional barrier to implementing sustainable policies in Latin America.

As a result, the Agenda 21 in Developing Countries tends to be very much focused on poverty, democracy, increasing infrastructure and preservation of natural resources.

![Figure 2. Effect of annual discount rate on the present value of $100 expense made in future](image)

**4.2.2 Scarcity of financial resources**

Governments and societies of developing countries do not have enough money to meet the demands of better built-environments. This applies to governments as well to individual consumers. Also, interest rates in developing world tend to be much higher than in the developing world. Interest rates for building and construction in Brazil have historically been above 10% a year and the government has been paying interest rates of around 20% a year for last few years. For life cycle costs based decisions (as well as all other decisions made from a financial point of view) the higher is the discount rate the less important future expenses will be (Fig 2), because the financial decisions are made considering present values\(^1\) (ASTM, 1999). Therefore they tend to emphasize the cost of construction and neglect long-term costs and even construction facility service life. Hence, service life planning tends to be discouraged due to financial reasons.

**4.2.3 The self-help housing**

In most developing countries the informal construction sector is very important. In Latin America and the Caribbean (LAC) a very significant portion of the houses are built by the family members themselves. In Bolivia, this kind of production scheme is responsible for 45 to 55% of the total urban houses produced every year (CLICHEVSKY, 2000). In Brazil, most of the building materials like masonry blocks, ceramic tiles, Portland cement and paint are sold directly to individual consumers and not to building contractors. This reality has profound consequences on the building materials market. Price is the major driving force because most consumers do not have the technical knowledge to demand quality, not to mention to judge the environmental impact of different alternatives.

The self-help houses are in most cases not designed in the traditional sense, since no engineers or architects are engaged. There is no of human resources training, nor quality control. Without technical support it is not possible to adopt sustainable practices, including service life planning, which requires specialized knowledge.

**4.2.4 Continuous upgrading**

Low cost houses produced by the government are as a rule small and very simple. However, most of the houses are upgraded by the owners (John et al. 1995, Du Plessis, 1999). This process starts as soon as the owner is able to divert some money to home improvement and continuous for the life of the house. Some low-cost housing projects clearly exploit this concept by producing so called building embryos, i.e. a very small house. This building embryo normally consists of a small multi-

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\(^1\) It is important to note that the environmental impact of an activity is not reduced because it is planned for future occasions. This is the essential difference between life cycle costs (LCC) and life cycle assessment (LCA) methodologies. Therefore, as emphasized by ISO/DIS 15686-1, LCC are not directly related to LCA.
functional room and a toilet and is supposed to be enlarged by the owner. The same upgrading process occurs with the houses produced by self-help schemes, whose construction almost never ends.

The typical upgrading process includes improving aesthetics of the buildings, either by changing the façade as described by Du Plessis (1999) or by applying on new and more sophisticated interior finishing. Enlarging the house is an essential characteristic of this process. New rooms or an extra bathroom, a garage, a second or even third floor are part of this process, which can also include improvements on building services. Eventually this continuous upgrading of each house results in improvement of the entire neighborhood making it attractive to wealthier people. These new and wealthier users then take the upgrading process a step further.

ISO 15686-1 does not define the term upgrading but uses it together with refurbishing: “Whether allowance has been made for replacement, maintenance and/or upgrading to avoid undue disruption to the use of the building.” item 6.2 Conceptual and initial design); and “Refurbishment and upgrading are the major strategies to counter obsolescence” (item 11.3 – Minimizing obsolescence). In both situations, upgrading and refurbishment are tools to prevent obsolescence. But the two terms are considered to be different in some way.

Upgrading as described here is results from an improvement in the economical situation of the owners. It is implicit in the definition that the user was not satisfied with the previous performance level of the house but was forced to accept it due to financial constraints. In this context the ISO 15686-1 definition of obsolescence “loss of ability of an item to perform satisfactorily due to changes in performance requirements” seems to not fully apply. Also, ISO 15686-1’s description of economic obsolescence is related to high running or maintenance costs, which is very different from the previously described upgrading situation.

4.2.5 Lack of technical data and experts

Developing countries do not invest in research and development to the same extent that developed countries do. The research community in LAC, for example, is small and the national investment in research below 0.8% of the GNP (Hill, 2000).

Finally, developing countries focus less research on durability of building materials and components. Less than 12% of the papers presented at the 8DBMC, Vancouver 1999, originated from developing countries, including Turkey, Kuwait, India, China, Brazil, Israel, Botswana and Eastern European countries. Consequently, within developing countries little is known about the durability of building materials or service life planning. Even in technical communities, knowledge about degradation mechanisms and service life forecasting is not widespread. In general, building materials manufacturers in developing countries lack incentives to deliver reference service life data.

5 CONCLUSIONS

Durability and service life have very important environmental dimensions. Achieving longer service lives is more dependent on knowledge than on resources.

Service life planning and service life forecasting, as proposed by ISO 15686 are important tools for integrating the durability concept during the design stage, thereby allowing for life cycle costs estimates and life cycle assessment.

Since developing countries are under construction, they can, potentially, benefit more from the concept of Service Life Planning than the developed ones. However some important constraints make the adoption of this concept difficult.

A very important part of the construction activity in developing countries is done through self-help housing, with no technical assistance. As a rule, there is a continuous process of upgrading low-cost housing.

A scarcity of financial resources places the emphasis on construction costs and not on long-term costs. High interest rates in developing countries make solutions with low initial costs and higher maintenance and running costs more economically attractive. Even solutions with very short service lives can be financially attractive.

Developing countries lack data on durability and the local building materials manufacturers have few incentives to deliver it.

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7 REFERENCES


