IMPORTANCE OF SERVICE LIFE PLANNING IN SUSTAINABLE ARCHITECTURE

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Abstract

In most of the architecture and construction firms service life planning is not considered in the process of architectural design, and neither is life cycle assessment; and even on occasions, sustainable design is neither taken into account in the processes of building creation because it is complex and specialists are needed to implement it. The objective of the present document is to approach this topic from the sustainable design viewpoint and to regard it accordingly, analyzing several concepts related to service life and durability of the building and the strategies the architect or constructor must follow in order to create totally of partially sustainable buildings, which prolong its service life in optimal conditions of performance, functionality and comfort, thus decreasing costs and environmental impacts during its service life. It is concluded that it is of the utmost importance to apply these models, methods and strategies of environmental design to attain the efficacy of the building, mainly on the stage of life service related to use, operation and maintenance of the building, which is the stage that impacts and pollutes the environment the most.

Keywords: Service life, Sustainable Architecture, Planning, Durability, Life cycle.

1. INTRODUCTION

Nowadays the architectural design of buildings must gravitate around sustainable development criteria, using also tools and methods to control and mange the environmental impact caused by the construction along its service life. For said ends there are very useful methods, such as: Life Cycle Assessment (LCA), Service Life Planning (SLP), or models of environmental design such as LEED™ o BREEAM™, and some Software programs related to these models and methodologies, which are tools verified for such ends. Sustainable architectural design is defined as the process of creation of architectural projects where sustainability premises are used, namely: saving water and energy, better use of soil and natural resources both biotic and abiotic, the adequate use of construction materials and waste, as well as the improvement of the performance of all the subsystems which compose the building, providing besides a design that covers all of the requirements of comfort: thermal, acoustic, illumination and visual, including bad odors inside the building. To do so, in addition to produce a sustainable design, the service life of the building must be planned, the potential of the environmental impacts the building will create, from its inception until the end of its service life, shall be considered as well. This paper presents a proposal to integrate architectural design and planning and life cycle assessment; moreover, it summarizes the main requirements as for durability and service life of a project. Below, we approach the concepts we have to take into account to elaborate the aforementioned proposal.

2. IMPORTANCE OF LIFE CYCLE ASSESSMENT, DURABILITY AND SERVICE LIFE PLANNING IN SUSTAINABLE ARCHITECTURE

Nowadays it is very important to take into consideration the methodology of Life Cycle Assessment (LCA) along the process of sustainable architectural design; it is a technique or tool to compile, analyze, process and evaluate all the information referring to the potential of environmental impacts from a product (an instance: construction materials) or a system (buildings) along the phases or stages of the life cycle (ISO International Standards Organization, 2006). Basically, LCA is a procedure that associates environmental charges and damages to a system or product measuring and evaluating the environmental impacts in a quantitative manner, sometimes qualitative though, considering different natural resources, such as: energy, raw materials, water, diverse supplies and the pollution of air, water and soil, among other natural resources, both renewable and non-renewable, along the entire life cycle, this is to say, from the extraction of raw material to make a product to its application in the fabrication or construction of a product or a system. Currently, the efforts to regulate this methodology are summarized in ISO regulations, ISO 14040:2006, referring to Environmental Management Life Cycle Assessment Principles and Framework and ISO 14044:2006 referring to Environmental Management Life Cycle Assessment Requirements and Guidelines. The importance of applying these regulations while producing and constructing products and systems, is mainly based upon the careful observance of these procedures to reduce the environmental impacts provoked by the production, distribution and application of the products, which particularly referring to building construction, are considered along the entire life cycle, from the inception or pre-design of a building, design, construction, use, operation, maintenance to the end of its life cycle; as it is shown in table 1, which refers to the stages of the entire Life Cycle of a building.

TABLE 1 - STAGES OF THE LIFE CYCLE OF A BUILDING (SOURCE: HERNÁNDEZ-MORENO, 2010)

Phases of life cycle	Stages of the life cycle of a building
A) Pre-design	1. Preliminary information 2. Planning 3. Programming
B) Design	4. Draft (preliminary design) 5. Executive project (with specifications)
C) Post-design	1. Construction 2. Use, operation and maintenance 3. End of life cycle

Table 1 shows the stages of the life cycle of a building, which comprises 8 stages, from preliminary information to the conclusion of the life cycle, said stages are subdivided into three phases: pre-design, design and post-design.

In phase A) pre-design, particularly in the stage 1 of the life cycle referring to preliminary information, both the problem to solve and the needs of the project are identified; needs of the project include not only the building´s and client´s requirements but also the users' requirements and users must not only be consulted but directly must to be involved in the design process (Nichersu and Iacoboaea, 2011) through a checklist of specific needs. In second stage planning is carried out to develop the project defining and outlining all the requirements and objectives of the project, including an architectural program, as well as its main reaches; in stage 3, said requirements and activities are programmed to reach the goals of the project. In phase B) Design, particularly stage 4 of the life cycle, is when the preliminary design, also called draft, is produced where a first configuration of the project is identified, performed and outlined on the basis of a predefined architectural program; in stage 5, the plans and detailed specifications of the executive projects are developed, which will be ready to move to the next phase. In phase C) post-design, particularly in stage 6 (construction), the design is built and in this very phase the significant environmental impacts begin; they must be controlled and avoided from design, and even pre-design, by means of proposals that prevent environmental damages, mainly to air, soil and water, but also to different natural resources (flora, fauna and landscape) and the supplies (such as energy) of the place of the project and its area of influence.

The next life cycle stage (7) refers to the use, operation and maintenance of the building; it is the stage that impacts and pollutes the most, since it is the lengthiest stage of the life cycle, as a matter of fact this is the period called service life, as it comprehends from the beginning of the building use to the end of its “service life”. In order to lessen graver environmental impacts, as well as higher operation and maintenance expenses along the use of the building, diverse strategies are considered, including sustainable design, life cycle design, durability and life service planning, in order to lessen, avoid and mitigate the environmental impacts which the building will cause along its life cycle.

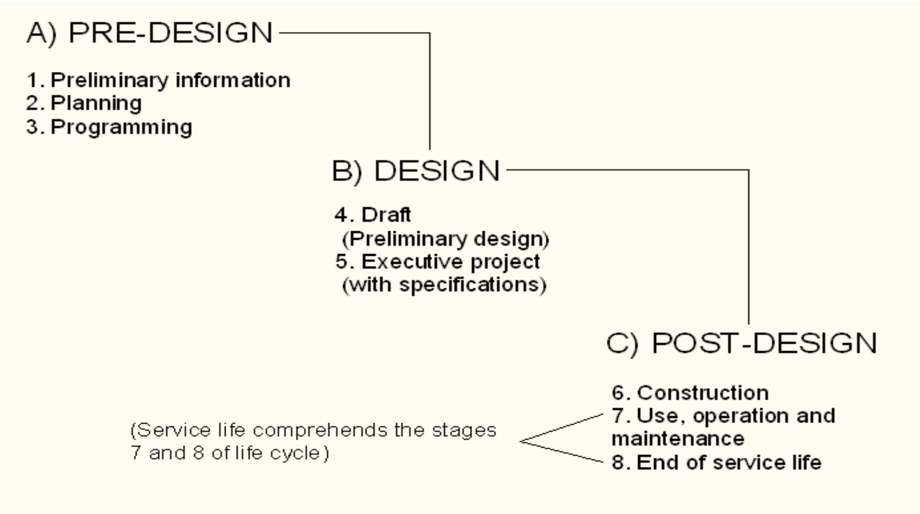

FIGURE 1 - LIFE CYCLE OF A BUILDING AND SERVICE LIFE PERIOD (HERNÁNDEZ-MORENO, 2010)

In the phases of Design and Construction, going through use, operation and maintenance, until the end of service life, the management of sustainable design by means several criteria and strategies can ameliorate and mitigate noxious environmental impacts along the entire life cycle of the building. These strategies of sustainable design applied to architectonic design are listed in table 2, and are divided into 5 sustainable design categories from which a number of strategies come out for each one, and at the same time, in the table the phase of design they belong to is specified. These design recommendations are based upon LEED™ methodology with some modifications and adaptations related to the architectural project.

TABLE 2 - SUSTAINABLE DESIGN STRATEGIES IN THE PROCESS OF ARCHITECTURAL DESIGN (SOURCE: USBC [UNITED STATES BUILDING COUNCIL], 2009)

Strategies of sustainable design in construction by environmental category	**Pre-design**	**Design**
Strategies of the site		
Avoid vulnerable or protected places, such as natural reserves	*	
Management plan of exterior works (pavements, passageways, streets)	*	
Erosion control and management plan for the landscape around the building		*
Transport alternatives	*	
Development of the site in its protection and restoration (it includes the biotic and abiotic relation of the place, increase the biological biodiversity of the site, create microclimates inside the place, use endemic vegetation)		*
Planning and control of the amount of rainwater in the site	*	*
Reduction of heat islands through walls		*
Reduction of heat islands in roofs		*
Reduction of illumination, acoustic and odor pollution		*
Water strategies		
Minimal piping and installations and efficiency in their connections		*
Measurement of the performance of water (in the whole building or by sections or in bulk).	*	
Additional installations both in piping and connections; to reduce water consumption between 10 % and 40 %		*
Reduction of water consumption via rainwater	*	
Use of water in cooling towers in warm weather		*
Application of systems to use grey waters for non-potable necessities (includes biological and chemical treatment)		*
Use of biologic systems in water treatment methods		*
Reduction of consumption of water from the municipal network (by means of minimizing consumption and saving devices)		*
Black water treatment		*
Energy strategies		
Passive control for the performance of energy in the building		
Orientate the building to take advantage of heat gain or loss	*	*
Optimize the building envelopment to improve its thermal performance		*
Supply natural illumination (skylights, domes, blinds, parasols)		*
Supply natural ventilation (Direct, crossed, windward and leeward ventilation, windows, vents, passive fans).		*
Supply eco-technologies for adequate heat transfers (gain or loss)	*	*
Humidity control inside the building		*

Strategies of sustainable design in construction by environmental category	Pre-design	Design
Active control for energy performance in the building		
Artificial illumination (reduce energy use via saving bulbs, intelligent sensors and actuators		*
Artificial ventilation (air conditioning systems and electric fans combined with intelligent sensors and actuators)		*
Artificial heat gain or loss (air conditioning and heating systems combined with intelligent systems)		*
Artificial and intelligent humidification and dehumidification		*
Efficient design of electro-mechanic systems		
Supply an adequate installation of artificial illumination		*
Maximize the performance of the electro-mechanic systems	*	*
Efficient use of equipment and apparatuses		*
Install electric devices to reduce energy use (capacitors)		*
Use low environmental impact energy		
Use renewable energies or other alternative sources (Photovoltaic, wind, biodiesel, passive water heating)		*
Simulate the total amount of energy that will be used		
Integrate the systems and reduce the total use of energy		*
Cut down energy use at least 30 %		*
Comfort strategies inside the building		
Air quality indoors		
Provide a clean and healthy indoor environment		*
Control humidity and prevent infectious agents		*
Provide good ventilation for a better thermal and pathogenic comfort		*
Tobacco control		*
Indoor air quality control (plan and monitoring, using passive and intelligent systems)		*
Human factors		
Provide good thermal conditions		*
Provide good illumination		*
Provide good ventilation		*
Provide good acoustic and vibration conditions		*
Provide good vibration conditions		*
Provide adequate outward visual relief		*
Control external bad odors		*
Control comfort from occupation		*
Control humidity conditions		*
Other factors		
Cleaning and maintenance of the building		*
Products and equipment used in cleaning and maintenance		*
Internal control of chemical and physical pollutants		*
Strategies in construction materials		
Evaluation of material properties and diminution of volumes in the work	*	
Raw material extraction		
Use of low environmental impact during the life cycle		*

Strategies of sustainable design in construction by environmental category	**Pre-design**	**Design**
Production		
Use of recovered and remanufactured materials		*
Use of material and products with recycled contents		*
Use of renewable materials		*
Distribution		
Use of locally produced materials		*
Installation and construction		
Use of materials of low emission of volatile substances		*
Use of durable materials		*
Reuse and recycling		
Use of reusable, recyclable and biodegradable materials		*
Strategies in construction wastes		
Reduction of rejects and wastes along the entire life cycle	*	
Appropriate handling of hazardous materials	*	
Elaborate a maintenance manual to reduce waste along the building life cycle	Post-design	
Conservation of resources		
Reuse of existing buildings	Post-design	
Design to use fewer materials		*
Design of pluri-functional or adaptable buildings		*
Design buildings to be dismantled not demolished		*
Waste management		
Save and recycle demolition remains	Post-design	
Reduce, reuse and recycle waste from construction	Post-design	
Reduce and recycle product containers	Post-design	
Reduce and recycle solid waste from the building users	Post-design	
Reduce and adequately manage hazardous waste	Post-design	

On the other side, along the entire life cycle of the building we must plan its service life from pre-design to the end of its service life; the concept referring to service life is basically related to the period of time after installation and construction during which a building or its parts fulfill or exceed the performance requirements they were designed for (ISO International Standards Organization, 2000). In figure 2 we present a schema referring to service life planning in the process of building design according to ISO 15686-1 (ISO, 2000), which describes the activities of service life planning in every stage of design. Another important definition as for service life in buildings is the real period along which the building, or any of its components, suddenly needs reparations and creates expenses (Canadian Standards Association [CSA], 2001). The importance of life service planning in buildings mainly lies in learning how long the building system (the whole building) and its subsystems (materials, components, equipment and installations) will last, which allows selecting and designing adequate construction systems, materials, architectural spaces; likewise, it allows foreseeing how the building will be used, operate, and maintain, therefore, it help us know how it will finish (stages 7 and 8 of the building service life).

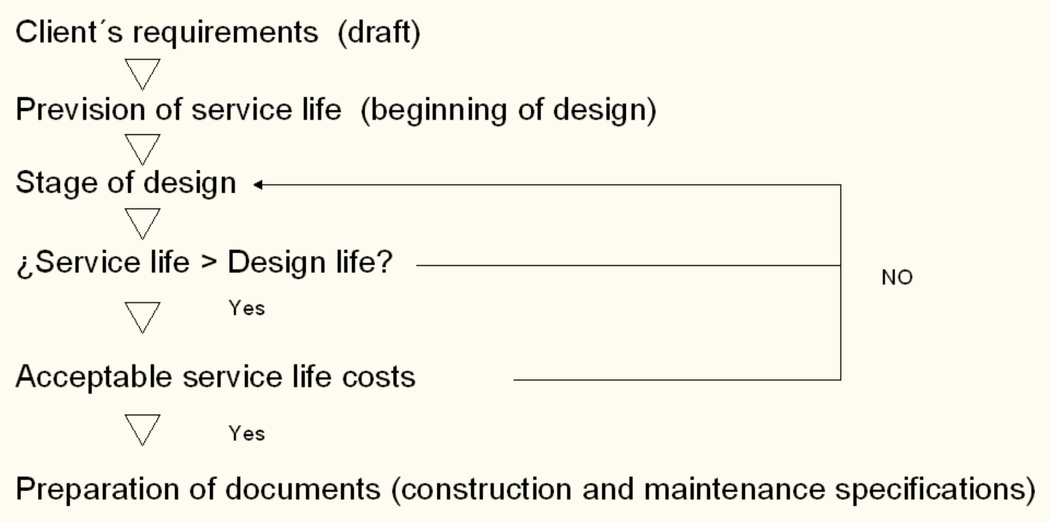

FIGURE 2 - INTEGRATION OF SERVICE LIFE PLANNING INTO PROCESS OF DESIGN ACCORDING TO ISO 15686-1 (SOURCE: ISO INTERNATIONAL STANDARDS ORGANIZATION, 2000)

Below we show the main factors that affect the durability of the building system and which must be taken into account when its service life is planned (ISO International Standards Organization, 2000). It is important to take into account the concept of durability, as it is an important factor in the sustainable design of buildings (Bourdeau, 1999); durability understood as the ability that a building, or any of its components, has to reach the optimal performance of its functions in a determinate environment or place, for a certain time without reparations or maintenance (Canadian Standards Association [CSA], 2001):

A) Quality of materials and components of the construction: in accordance with the corresponding BS/ISO regulations.
B) Design level: adequate use and application of regulations and lineaments of the process of creation, installation and construction.
C) Labor force: adequate execution of the works in the process of design and construction under the corresponding ISO and local regulations.
D) Building indoor environment: humidity and temperature regimes and chemical and physical agents.
E) Building outdoor environment: climate and its urban pollution.
F) Building use according to the specifications of builders and designers, adequate to its sort and operation conditions.
G) Adequate maintenance, according to the specification of the producers of the materials and components.

It is important to mention that to measure urban sustainability can be done using various indicators such as economic, social and environmental which involves making decisions based on multi criteria (Alpopi, Manole and Colesca, 2011). Also, one of these indicators relate to the *life expectancy*, not only related to population but also of buildings and urban infrastructure.

As a matter of fact, the aforementioned categories are the factors that are evaluated in the *method by factor*, one of the most commonly used methods to estimate the service life of construction materials and components (AIJ, 1993), ISO 1686 prescribes this method based on knowledge about materials and technologies to construct. The method by factor estimates service life by applying a series of factors related to determinate use conditions and specifications of the materials and components of the construction. The formula to estimate service life (ESL) using this method is.

$$ESL = RSL \times A \times B \times C \times D \times E \times F \times G$$

Where: RSL is the reference of service life of any material or component of the building, which may be taken from empirical information from laboratory tests of from the producers of the product (Masters and Brandt, 1989). RSL only a starting point, since it the key to estimate service life is given by means of the appropriate evaluation of the A, B, C, D, E, F and G factors.

The entries 4 and 5, see above, which refer to the environment both indoors and outdoors, bring along some agents that damage the materials and components of its service life and performance (Hernández-Moreno, 2010), these agents or degradation factors are mainly:

- Water (which contributes to biological degradation, corrosion, rusting, material contractions, water absorption, humidity and deterioration of surfaces).
- Wind and air and air pollutants (they can also be biological agents of deterioration, both physical and chemical, and causers of humidity and corrosion).
- Biological and ecological agents (such as fungi, bacteria and parasites, which adhere to the material causing deterioration, and other noxious agents created by rodents, birds, insects that damage the service life of materials and components).
- Temperature (it causes deterioration of materials).
- Solar radiation (UV rays cause severe damage to certain materials, mainly in the enveloping or insulation of the building).
- Incompatibility of some materials (which cause deterioration to one another and between subsystems, via noxious chemical and physical reactions).

To sum up, the following information on evidence of service life in buildings, provided by different associations of construction sector, is also a valid and appropriate resource to be taken into consideration (BRE [Building Research Establishment], 2007):

1. Evidence on the service life time of some installations and buildings supported on photographs and reliable technical data.
2. When evidence comes from other countries than the one where the project is carried out, the information must contain similar specifications.
3. References of proved and certified service life.
4. Evidence and physical tests in laboratories on accelerated exposure of materials and components (Sjöström and Brandt, 1991).
5. Verify that materials and components fulfill currently valid codes and regulations.
6. When the producers do not supply information, this may be obtained from other sources, as long as they are reliable.

Finally, stage 8 of service life, referring to the end of service life (see table 1), particularly refers to the demise of the building, previously referred through definitions from ISO and Canadian Standards Association, which basically state that the service life of a building ends when it or any of its components fulfills or exceeds the functioning and performance for which it was designed, thereby, it has to be replaced or substituted; besides it is no longer feasible, technically or economically, to sustain corrective maintenance (BRE [Building Research Establishment], 2007). Well now, there are several manners for a building to reach its end, regarding edification the main are: demolition, dismantling, or deconstruction, reuse and remodeling and reconstruction or it is simply leaving it in ruins. The most recommendable manner, ecologically speaking, would be the deconstruction of the building which could be dismantled or demounted, and make use of its parts separately to recycle or reuse. The unadvised manner, from the environmental viewpoint, would be demolition, as it is the most polluting way because it prevents the easy recovery of construction materials.

When in a complete system of a building some of its subsystems or components reach the end of their service life, it is useful to replace or substitute them by new ones in order to improve the system (Lacasse and Sjöström, 2003). The replacement of components is important, so taking it into account is important because on it depends, in the beginning of the design, the calculation of the amount of materials and components to be used to build any constructive element, which has to reach the expected performance, by regulation and design, to a determinate durability, this is to say, from pre-design and design we have to consider the prediction of how long a building will last and how we must maintain the whole building system in good operative and use conditions.

3. CONCLUSIONS

1. In order to reach sustainability in construction projects, it is necessary to utilize different methods, models and tools related into life cycle assessment and particularly, the integration of service life planning in the process of architectonic design of buildings; including, of course, environmental

design methods that involve sustainability criteria which have to be planned, designed and built in accordance with Life Cycle Analysis.

2. Life cycle design, besides evaluating the environmental impacts caused by constructions along their service life, also helps to improve the conditions of durability, functionality, performance and comfort of the building.
3. The stage of service life must be taken into account to carry out an adequate planning and control of the design, construction, use and maintenance processes along the service life of any building, in order to provide the optimal performance of all its parts and components.
4. Service life basically comprises the stages of use, operation, maintain and use of service life. This must be stated from the first stages of the life cycle of the building in order to estimate the time of service life the building will last, as well as its performance and functionality required in its design.
5. It is important to include in pre-design and design the main considerations and strategies of sustainable design in the architectonic project, as it will lead the way to a better design, thus providing a higher performance of the parts and components of the building, making it feasible not only from the construction viewpoint, but also economically and environmentally.
6. Service life planning in the process of architectonic design will depend on the requirements of the client and user of the building; in such manner that the expected service life has to be similar or longer than the designed service life. Then, the calculations of costs per life cycle can be carried out, as well as the preparation of documents and specifications of construction and maintenance, on the contrary one must return to the stage of design.
7. The factors that take part in the durability of buildings are mainly physical and chemical conditions, being also important the conditions of use, operation, maintenance, labor force in construction, quality of materials and constructive systems.
8. The most used method to estimate or predict service life in buildings is the method by factors, where not only a reference of service life from empirical information on similar projects is taken into account, but also the study of the environmental factors, weather, quality of materials, construction labor force and use conditions are utterly important for an adequate and correct prediction of a building service life.

REFERENCES

AIJ [Architectural Institute of Japan]. (1993). *The English edition of principal guide for service life planning of buildings*, AIJ, Japan.

Alpopi, C., Manole, C. and Colesca, S.E. (2011). Assessment of the sustainable urban development level through the use of indicators of sustainability, *Theoretical and Empirical Research in Urban Management*, Volume 6, Issue 2, pp. 78-87.

Bourdeau, L. (1999). Sustainable development and the future of construction: a comparison of visions from various countries, in *Building Research and Information*, 27(6), pp. 355-367.

BRE [Building Research Establishment]. (2007). *Methodology for environmental profiles of construction products*, Editorial BRE, UK.

Canadian Standards Association [CSA]. (2001). S478-95 (R2001), *Guideline on Durability in Buildings*, pp. 9-17, CSA, Canada.

Hernández-Moreno, S. (2010). *Diseño y manejo sustentable en edificación*, Editorial Universidad Autónoma del Estado de México, (UAEMEX), México.

Hernández-Moreno, S. (2010). Integration of service life in the process of management and design of buildings, in *Management Research and Practice*, N° 2(4), Retrieved December, 2010, from http://um.ase.ro/

ISO International Standards Organization. (2000). *Buildings and constructed assets-Service Life Planning*, part 1: General Principles, ISO 15686-1, pp. 18-49, ISO, Switzerland.

ISO International Standards Organization. (2006). *Environmental management-Life Cycle Assessment*; Principles and Framework, ISO 14040, ISO, Switzerland.

Lacasse, M.A. and Sjöström, C. (2003). *Methods for service life prediction of buildings materials and components* – recent activities of the CIB W80/ RILEM 175-LSM, Proceedings of the International Workshop on Management of Durability in the Building Process (Mila, Italy 06/25/2003), pp. 1-11, June 01, 2003 (NRCC-45691).

Masters, L.W. and Brandt, E. (1989). *Systematic methodology for service life prediction of building materials and components,* in Materials and Structures/ Matériaux et Construction, 22, pp. 385-392.

Nichersu, I. and Iacoboaea, C. (2011). Systematic spatial planning, *Theoretical and Empirical Researches in Urban Management*, Volume 6, Issue 2, pp. 67-77.

Sjöström, C. and Brandt, E. (1991). *Collection on In-service performance data: state-of-the-art* Approach by CIB W80/ RILEM 100-TSL Materials and Structures, Vol. 24, N° 139.

USBC [United States Building Council] (2009). *LEED™,* Guide of reference, Version: 3.0, Ed. USBC, Washington, D.C., U.S.A.