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INTEGRATION OF SERVICE LIFE IN THE PROCESS OF MANAGEMENT AND DESIGN OF BUILDINGS

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Abstract
This article approaches the regulatory framework on the service life of constructed assets and its integration into the management and design process of sustainable buildings. The importance of this study is to be found on the fact that currently, most of the building designers do not apply the integration and planning of service life into the process of management and design of constructions. Because of this, ISO (International Standard Organization) regulations are approached; said regulations are referred to the planning of service life of buildings, explaining and describing their relevance in the process of design. Basic principles of the sustainable planning, derived from *Leadership in Energy and Environmental Design®* method in the United States and Canada, are presented as well as the relation with the aforementioned *International Standard Organization* regulations on the service life of buildings, specifically that of ISO 15686.

Keywords: Design process, Regulations, Service life, Sustainable building, Sustainable management.

1. INTRODUCTION

In the last two decades there has been an increment in the use of models, certification systems and methodologies of environmental and sustainable design of buildings, including numerous online tools have been created to assist sustainable development in Engineering and Construction that provide a solution to several problems linked to sustainable design (Pearce et al., 2008), mainly in countries such as the United States, Japan, Australia, Canada and almost every country in Europe (Leadership in Energy and Environmental Design [LEED], 2003). In Latin American countries, Mexico for instance, in recent years the topic has just started to be discussed, however with no applications in the industry of architecture and construction that avoid and mitigate the main environmental impacts caused by buildings along their service life. When the service life of buildings is referred to, by designers, urbanists, developers of city infrastructure and equipment and real estate agents, it is normally related to the durability of the building, and in general other factors are not taken into account as part of the whole building life cycle; moreover, when we apply some model of environmental design such as LEED® or BREEAM®, this creates the impression that the only way to be successful at building is when the building has a programmed life of 100 years at least (Building Industry Authority [BIA], 1992). Although durability is important, it is not the only factor to consider.

Nonetheless, in practice certain buildings have a relatively short service life, for instance around 50 years, because of diverse reasons, to name a few: the cities evolve and so does the value of ground, also because of urban development and modifications to the cities, and even because of the very deterioration of the components of the building, material selection and constructive systems, or even because of the inadequate maintenance, operation and use of the building by the users or managers of the building. In the case of demolition of buildings, the reason to "finish them" occurs because of the adaptability of the building and its location in the place rather than because of the selection of systems and construction materials. In sustainable architecture, we have to avoid designing a building to be demolished and we have to search for other options such as deconstruction, dismantling, reuse, rehabilitation, and recycling their components (Building Research Establishment´s Environmental Assessment Method [BREEAM], 2005). These problems arise generally because *design by service life cycle in buildings* is not considered; thereby there is not any *service life planning of the building* being carried out from its pre-design and design until its construction, occupation, maintenance and end of service life. On the other hand, it is important to note that cities also require sustainable development and sustainability into its components for instance in cities as large and as important as Los Angeles, California, U.S., the integration of technologies into the policies of urban planning have achieved improving many of the main problems of the city, working in an integral and systemic manner, (Chen, 2009), including the planning of the service life into the equipment and infrastructure of the city. Another example in urban sustainable development is the need for promote massive and rapid implementation of sustainable energy technologies at decentralized sub-national urban regions based on to proven model of distributed generation and supply of energy (Ingwe et al., 2009), This would help a lot in the functioning and service life of cities.

Figure 1 shows the main stages or phases of the life cycle of the building, also including the life cycle of the construction materials, which is integrated to the whole life cycle of the building.

The ideal is, of course, that the building has a service life as long as possible and at the same time that it saves resources utilized in construction, operation, use and maintenance (Hernández-Moreno, 2008); this allows mitigating damage from noxious impacts on the environment. The key is found in sustainable development with characteristics of adaptability and flexibility, and equally important it is to design to de-construct buildings not to demolish them, and to propose the re-use and recycling of materials and components of a building in the case that it is not programmed to have a lengthy service life (about 100 years), where other criteria equally sustainable would be used.

In figure 1 the first phase of the life cycle is the pre-designing of the building and it is where the first lines and general ideas are performed, giving as a result an ante-project; the second phase is where the building is designed at all and an executive design of the project is produced; which can be constructed; in the third phase, the building is constructed; in the fourth phase, the building is operated and used and it is the phase that impacts on the environment the most; the fifth phase is the end of the building service life, where previously in the design phase, it had to be determined how the building is going to end (dismantling, de-construction, demolition, reuse, recycling, etc.) It is important to mention that the 4th and 5th phases are the period of life of the building, the time for which the building is designed to work, for instance 50 or 100 years of service life.

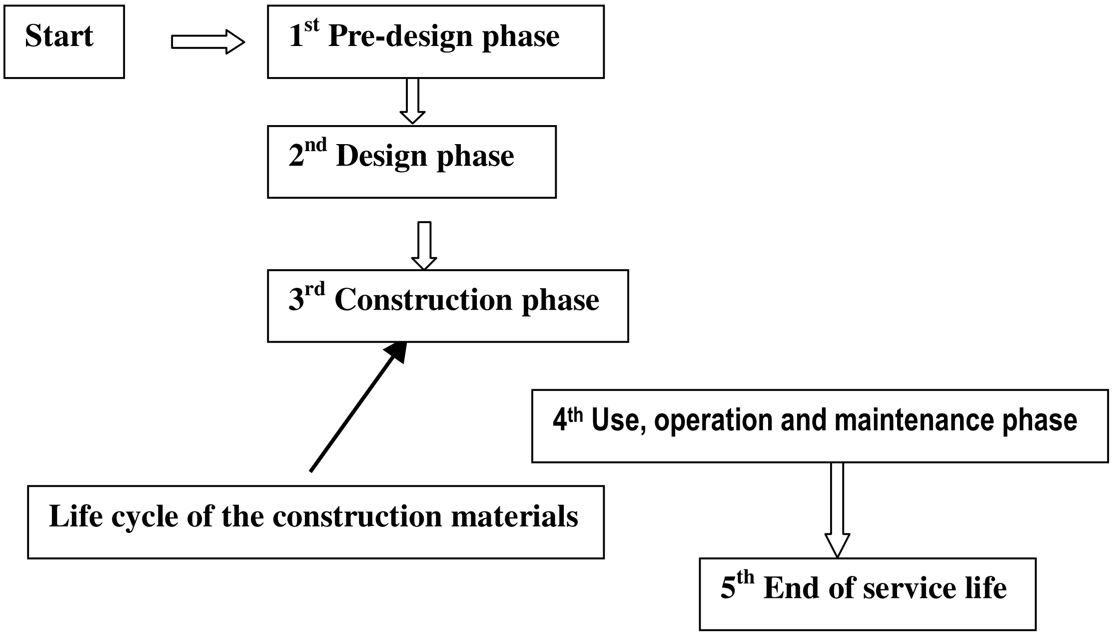

FIGURE 1 - PHASES OF THE LIFE CYCLE OF THE BUILDING

Finally when we speak of durability, in many cases it only refers to the maintenance of some parts or materials of the building; we have to take into consideration that there are components of the building that even though they are given less maintenance, they are going to last the same as other similar, and it is here where important benefits are offered for the whole system of the building (Frohnsdorff and Martin, 1996).

2. INTERNATIONAL REGULATION ON SERVICE LIFE PLANNING IN CONSTRUCTION

At international level there are several organizations in charge of regulating the activity of the construction industry as for design, management of construction projects, such as *International Standardization Organization* (ISO), la *European Union Construction Product Directive* (PeBBu), as well as *Canadian Standards Association* (CSA). Each of these organisms have developed norms to specifically regulate *service life planning in construction*; these norms are very useful in the processes of design and construction of buildings, nevertheless they are not completely carried out because of a lack of experts who intervene in the process of design, to particularly assist said planning, so generally these criteria are not applied and too frequently the building is designed on the basis of the designer's experience in the construction of buildings similar in their components and parts, as well as on the needs of the user and functions and sort of building; which is very important, but does not mean everything in designing and planning the service life of a property (Architectural Institute of Japan [AIJ], 1993).

The main regulations of these organisms in relation to service life planning in construction are:

- ISO 15686 (service life planning for buildings and constructed assets) is focused on regulating the implementation and integration of service life planning into the building; it describes the criteria and procedures to be taken into account in the process of design and construction of the building and its components in order to guarantee or ensure that every element or component of the building satisfactorily responds to durability and usefulness for which it was implemented (International Standards Organization [ISO], 2000:part 1). The costs of implementation of service life planning in the process of design are not contemplated in this norm however, it is in a complementary norm (International Standards Organization [ISO], 2000: part 3). Likewise, the criteria of sustainability in relation to durability are not included in ISO 15686.
- CSA S478-95 (Building Durability Plan) has as an objective to consider the agents and mechanisms related to the durability of the building, and also provides recommendations to incorporate the main requisites of service life and durability into the process of design, in the operation and maintenance of the building and its components (Canadian Standards Association [CSA], 2001: Q645). These lineaments include as well definitions of the basic concepts related to durability, such as: performance, failure, service life, among other; it also includes recommendations for the designers, builders, proprietors and operators of the building to attain the durability of the building and its parts, through design planning, construction, maintenance, repairing and renovation of the buildings. This norm also includes durability for the mechanical and electrical systems of the building. Even if it is not directly mentioned in the norm that durability and services of the building must be included in the integral design, these principles must be considered as any other component or element of the building, both in relation to architectural, structural or sustainable design of the constructed asset, as well as in the estimation of the analysis of the costs per life cycle of the building (Canadian Standards Association [CSA], 2001: S478).

Nowadays, building designers must take into account these regulations that are essential to determine the duration of the building and under which conditions and requirements, both physical and service-related, the building is going to function. The design requirements may refer to a number of aspects such as, costs per life cycle, requirements of technical nature at different scales on the performance of its components due to their use in its operation phase and maintenance, as well as environmental and sustainable considerations referred to durability along the whole life cycle of the building (International Standards Organization [ISO], 2004: part 6: 19-21). More often than not, designers consider these aspects in an intuitive manner in the phases of pre-design and design of the building, and because of the aforementioned reason that experts are required to implement the planning, these regulations are not adequately used; nonetheless, currently, the increase of regulations, quality control and the need for verification of service life planning activities in the projects of the buildings require their implementation and integration in the process of architectural design.

The principal technical limitation that hinders the implementation of these regulations in the design process of the buildings is that the complete system built (this is to say the very same constructed asset) comprises other subsystems with different scales (components and materials) for the greater system determines and decides the functionality of the smaller systems, as the greater system is substantially different, seen from the totality of the levels, from the smaller subsystems. Therefore, it is necessary to know from which point and how the solutions that respond to the requirements of service life design of said systems and subsystems will be approached. An adequate manner to do it would be through the disaggregation of the whole building, breaking it into components and materials, assuming that if every smaller subsystem works in good service conditions, then the greater system (i.e., the whole building.) is going to work adequately (Trinius, 1999), so it is necessary to evaluate in an inductive way each component or subsystem of the building in accordance with the requirements and specifications demanded by the sort and needs of the building.

Thereby, these lineaments regulate the requirements of performance and durability of the subsystems that compose the whole building, via the satisfaction of design requirements which fulfill a determinate period of life of the building where the values of performance and durability predesigned for a determinate system of building are covered, even being exceeded in time by every subsystem or component. In the case that the system is simple and with few subsystems, the prediction of service life will be carried out in a more reliable, precise and relatively simple manner based on said aggregation of components and specification of service life by component (Masters and Brandt, 1989: 92). Notwithstanding, in the case of a very complex system, the prediction of the service life of the building would have to be estimated by means of various scenarios where the designer must foresee a number of situations of design depending on several design factors (structural, environmental, architectural.) and being also aware of the approval of each component and each construction material taking into account both internal and external factors of degradation, durability and quality of each smaller subsystem (Masters and Brandt, 1989: 391).

ISO 15686 is a regulation that describes service life planning in buildings, as previously stated, and its main objective is to ensure a reasonable service life of a building on the basis of predictions and estimations included in the process of design of the building (system) and the subsystems (components, materials and installations and equipment;) this regulation is composed of the following parts, which are:

- ISO 15686-1, which refers to the general principles and basic concepts on the planning of the service life of the building.
- ISO 15686-2 refers to the procedures and methods of prediction of the service life of a building.
- ISO 15686-3, which refers to the securing and effectiveness of the implementation of service life planning in buildings; it describes all the procedures that must be applied in each of the phases of the life cycle of the building as for service life, in order to reasonably guarantee the performance and functionality of the construction components, materials and subsystems that compose the building within reasonable time and services. This part does not consider the cost per life cycle of the project.
- ISO 15686-5 describes the costs per life cycle of the building and its parts.
- ISO 15686-6 describes how to evaluate, during the phase of design, the potential of the environmental impacts of alternative or innovative designs of any constructed component or any subsystem. It identifies the interface between evaluation of the environmental life cycle and service life planning.
- ISO 15686-7 describes the process of evaluation of the service life performance of the building components in order to receive feedback from the information of service life from practical cases of similar existing projects.
- ISO 15686-8 provides a manual or guide on provision, selection and acquisition of information related to the estimation of service life that may be applied to proposals for the calculation of the project's service life using the *method per factor*; this norm does not contemplate the estimation of service life from changes or modification of the values of the factors that take part in the system.
- ISO/ TS 15686-9 provides a guide to derivate and present the information of the reference service life; it is applicable for the use of manufactures and producers of construction materials that provide technical information used in service life planning of the building in agreement with ISO 15686-1, ISO 15686-2, ISO 15686-3, ISO 15686-5, ISO 15686-6, ISO 15686-7 and ISO 15686-8.

The aforementioned regulations may be completed with ISO 14040, which describes the principles and general framework of the Evaluation of Life Cycle (ELC) of products, including definitions and objectives on (ELC), Analysis of Inventory of Life Cycle (AILC), Evaluation of the Impact of Life Cycle (EILC), the phase of interpretation of the life cycle and the limitations of ACV.

3. BASIC REQUIREMENTS FOR SERVICE LIFE PLANNING IN BUILDINGS

The basic requirements for service life planning in buildings are referred to three general aspects, as previously stated, and at different scales:

1. Performance of installed components in the buildings (construction elements and materials of structures and closings) also including installation services and services of the constructed asset (electric, mechanical, hydraulic, sanitary installations, etc.)
2. Costs per life cycle by component or subsystem (CLC).
3. Requirements of the whole system, this is to say, the building.
4. Considerations of sustainable design in construction, mainly on durability (Hernández-Moreno, 2008:20);

These three aspects are present along the entire life cycle of the building, mainly in the phase of use, operation and maintenance, which is the phase of the life cycle of the building that pollutes and impacts on the environment the most and are requirements of the design by service life that have to be covered and met in the process of design and construction of buildings (Leadership in Energy and Environmental [LEED], 2004: 75). Design In the design process of the building is where we are able to establish the duration or the service life of the building, which may be for instance of 50 or 100 years. In the phase of building design we can also avoid the main environmental impacts (International Standards Organization [ISO], 2004: part 6:9-25) which the buildings cause along their use, operation and maintenance, by means of a sustainable design, for instance using a model or method of environmental design in buildings such as LEED® (Leadership in Energy and Environmental Design) o BREEAM® (BRE Environmental Assessment Method), which are methods that solve problems of environmental impact through the architectonic design of the buildings, controlling and managing the main resources, both natural and financial, that intervene in the processes of design from selection and location of the site, sustainable management of energy, water, material, waste, to comfort inside the building.

Thereby, the requirements which will have to be fulfilled in order to plan the service life of the building are within the following aspects:

The building as a **complete** system:

- Subsystems which comprise components, materials and systems of installations and services, including construction and assembly system as well as installed equipment.
- Criteria of sustainable design of each of the previous subsystems, including environmental factors.

The following points are all factors that take part in the degradation of the building through time, according to ISO 15686-1 and CSA S478-95:

1. Quality of the materials
2. The degree or level of design of the components and their installation and assembly.
3. Technical expertise of the installer.
4. Environment inside the building.
5. External environment.
6. Conditions of use.
7. Maintenance level.

The following criteria considered in CSA S478-95 are added to this, as for three methods of service life prediction:

1. Effectiveness demonstrated on the basis of a historic registration of the performance of the system and its subsystems.
2. Modeling of the assembly, construction and installation of the components and/or subsystems.
3. Tests of assembly, construction and installation of the subsystems.

The regulation of CSA also underscores or highlights some topics that the designer must consider in the design process of a building.

- Conventional or innovative design.
- Material selection.
- Details of design and construction.
- Simplicity of constructive processes.
- Operation and maintenance.
- Functionality and obsolescence of the subsystems.
- Costs per life cycle.

Some other important points to consider, complementary to the previous are:

- Veracity of information in the quality of products or components.

- The expertise of the people in charge of executing and supervising the regulations and lineaments to be used in the processes of design, construction and maintenance (for instance the estimation of the climate and comfort inside the building and the needs for the correct functioning of the installations.)

4. BASICS PRINCIPLES OF SUSTAINABLE PLANNING IN BUILDINGS

In the models of environmental design such as LEED® and BREEAM®, except for LEED® Canada (Leadership in Energy and Environmental [LEED], 2004: 47)., do not contemplate the considerations and requirements for the integration and planning of service life in the process of design of the buildings, that is why it is important to utilize ISO 15686 or regulations such as the Canadian CSA S478-95 for said ends.

The LEED® model particularly points out criteria and recommendations of sustainable design in construction by means of 6 important entries, which work to sustainably manage and control natural, human and comfort resources during the process of design, and during the service life of the building, helping to decrease the environmental impact, sparing natural and financial resources and also improving quality and human comfort (Leadership in Energy and Environmental Design [LEED], 2008: 44); these entries are:

- Sustainable management of the place.
- Sustainable management of energy.
- Sustainable management of water.
- Sustainable management of construction materials and waste.
- Sustainable management of comfort inside the building
- Technological innovations applicable to the project.

If every entry of the LEED™ model was taken into account in an adequate manner along the service life of the building and in each of its phases (from pre-design to end of service life), then natural and human resources would be saved, the facilities and their correct functioning would be secured as well, including those of the whole system and the subsystems that compose the building, propitiating a lengthy service life with planned durability, estimated in the phases of design.

Some recommendations and requirements the designer must control or eliminate in the environmental design of the building are the following factors or design variables, these are basically *agents* that harm and make the components and materials of the system prematurely fail, and which are referred to the conditions of external environment of the degradation factors of ISO 15686:

- Water (which contributes to a biological degradation, corrosion, rusting in metals, contraction of materials by frosts, intake and absorption of water, condensation that creates humidity and deterioration to materials and finishes.)
- Air and air pollutants (they can also be agents of biological deterioration, yet also chemical, of the materials besides polluting the air inside the buildings and cause humidity in the components.)
- Wind (which damages the structural and closure components of the building, in addition to cause a variation in the air conditioning systems for instance, or other special installations where changes in air volumes are harmful.)
- Biological and ecological agents (which foster fungi, mold, parasites adhered to the materials, breakdowns caused by rodents, insects and/or birds are agents that damage the service life of the subsystems and the entire system.)
- Temperature (significant temperature variations might cause deterioration to some materials because of the movements and contractions that some materials may suffer in combination with other degradation factors.)
- Solar radiation (ultraviolet rays can cause severe damage to certain materials, mainly in the exterior of the building, because they can unleash chemical reactions and physical changes in the materials.)
- Incompatibility of materials (incompatibility of materials may cause different chemical reactions and propitiate degradation between components and construction systems, since said materials interact with one another.)

5. CONCLUSIONS

1. It is concluded that nowadays most of the building designers do not include service life planning in an adequate manner to the design processes because experts in the field are required as well as command of the regulations in order to implement them.
2. It is also concluded that it is necessary to know how the solutions are approached in the process of architectural design so that they meet the requirements of the design of service life of the different parts of the building. An adequate manner to do so would be through the disaggregation of the whole building by components and materials, assuming that if every subsystem is in good working conditions, then the greater system (this is to say the whole building) is going to work in an adequate manner.

3. The lineaments that are included in the mentioned regulation as for service life planning in buildings regulate the performance and durability requirements of the subsystems that compose the whole building, by means of the satisfaction of design requirements that fulfill a determinate service life where the values of performance and durability pre-designed for a determinate system are covered, even exceeded in relation to time by every subsystem or part of the building.
4. Planning the building by service life and life cycle would save natural and human resources used in the building; what is more, the facilities and their correct functioning would also be secured as well as the whole system and subsystems of the building, thus a lengthy service life with planned durability and estimated in the phases of the design would be propitiated.
5. It is also concluded that it is necessary to include models and methods of environmental design of buildings, into the process of integration and planning of service life in the design of buildings, in order to have better control of the environmental impact during the whole life cycle of the constructed asset.

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