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Flexible Design Processes to Reduce the Early Obsolescence of Buildings

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Abstract:- This work intends to analyze the processes of flexibility to improve the adaptability to the users and to define some strategies to delay building obsolescence. Some approaches that address the architectural flexibility processes are studied to understand the rapid transformation of user lifestyles and changes in needs and performance building requirements. Obsolescence is often characterized by the lack of flexibility in the structure and walls, as well as services that change rapidly according to the different uses of buildings. This poses a threat to the built environment, since a large number of buildings are demolished having still years of useful life. In this way, different types of obsolescence are analyzed, focusing on some structural, economic, functional and social aspects of the construction and the use of buildings, seeking the capacity to design and produce adaptive buildings that are more resilient to obsolescence. Thus, some concepts of flexibility and flexible process are presented to promote adaptability in buildings. However, flexibility is a complex process, a long way to achieve adaptability to the built environment and the changing needs of users. The method used in this analysis takes into account the diversity of the design process, making some considerations about the interrelation of the social, functional and technical aspects. Finally, some conclusions about the design methods faced by a flexible approach process can lead to more useful and adaptable spaces for future transformations in order to extend the life cycle and prevent early obsolescence of buildings.

Keywords: obsolescence, architecture, flexibility, adaptability, building.

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I. INTRODUCTION TO THE CONCEPT OF BUILDING OBSOLESCENCE

The fast transformation of users' lifestyles, changing user needs and building requirements performance, have influenced the capacity to use and adapt to the specific requirements of users The obsolescence of buildings is often characterized by a lack of flexibility in the structure and support elements as well as by the services provision that change following the different uses of buildings over time. According to Thomsen and Van der Flier (2011), the time factor and the processes related to the aging of the building are not the only elements to understand the obsolescence, since many old buildings can be maintained for a long period, while more recent ones have achieved the early obsolescence. In this context, obsolescence can be defined as the situation where an item is no longer suited to current demands, neither is no longer available by manufacturers or it is not sustainable. The topic of obsolescence has changed the strategies and processes of industrialized production, whose development occurs at high speed in a very competitive market. In the industrial sector, obsolescence is the condition that makes a product or service no longer useful, losing the demand capacity. This can occur even if the product is in good condition but outdated due to technical and scientific development, getting overtaken by the provision of new advanced products. On the other hand, mass production led to excessive consumption, where innovative marketing strategies led to the fast consumption and disposal of products in a short time. In this situation, planned obsolescence seeks to develop, manufacture and distribute products to consumers to become obsolete or non-functional for a particular date, inducing the consumer to purchase a new product. Explicitly or subliminally, marketing strategies supported by the media seek to induce the consumption of new products, proposing or inspiring new habits of consumption of products, such as electric toothbrush, as well as modern bathtub equipped with Led lights synchronized with different tools of hydrotherapy massage. Most dealers have the ability to awaken and create new needs for users by deliberately introducing obsolescence into their product sales strategy with the goal of generating durable sales volume in a fleeting environment, reducing the time between successive purchases. Thus, planned obsolescence or programmed obsolescence in the industrial sector can be defined by a policy of planning or designing a product with an artificially limited useful life.

Planned obsolescence has begun as an intentional strategy of the American auto industry in the late 1940s that were followed by other manufacturers of other products like appliances and other hard goods. It was not until Japanese automobile manufacturers started manufacturing durable cars and soon afterwards the Toyota

Auto Line production that costumers realized that something was wrong in cars quality. A significant part of the American auto industry problems today can be attributed to this sort of costumers' education and short-sighted manufacturing strategies. Many manufacturers still continue to produce in a short period of planned obsolescence, not respecting the costumers needs and the environment. In a first approach, Packard (1960) presented two classification for obsolescence. The first one, called *Psychological Obsolescence,* refers to marketers' attempts to wear out a product in the costumers' mind. This type of obsolescence occurs when designers change the styling of products in the way that customers will purchase products more frequently due to the decrease in the perceived desirability of unfashionable items. That works efficiently because lots of products are primarily desirable for aesthetic rather than functional reasons. Pope (2017) emphasizes that the consumerism governed by the law of demand, trough the manipulation of desire continues to refer to the imperative of profitability, the need for massive production and the despoliation of natural resource. The European Economic and Social Committee, EESC (2013), announced that it is studying "a total ban on planned obsolescence" in order to control the waste of energy and resources and generated pollution due to the replacing products that are designed to stop working within two or three years of their purchase. This committee was also one of the first institutions to issue its views on the implementation of collective actions for consumers' rights. The international financial crisis of 2008 has boosted the interest in a new model as a driver in the economic growth to reduce, reuse and recycle the production, circulation and consumption processes. Specific legislation from different countries, as Japan, Germany and Netherlands, has used the *Circular Economy* concepts in order to cover the production, waste management and the market for secondary raw materials.

In cities like Tokyo or New York , products are discarded periodically on the streets or in appropriate places, because there is no space to accommodate the purchase of new products at home. Getting rid of bulky items like sofas, household appliances, mattresses and broken shelves can be a challenge in big cities. Many products are deliberately designed to cease operation three to five years after purchase, forcing consumers to buy new products in order to keep the industry running. This strategy feeds the manufacturers' competitiveness and the after-sales service of distributors and the technical support to the products. Many consumers consider the practice of planned obsolescence a sign of unethical behavior, but when it is practiced on a large scale by several producers in a regulated industry it is seen as a usual practice in the product market. Another negative aspect related to planned obsolescence is the volume of non-functional and useless products that increase the disposition of urban solid waste. Many of these products, besides contributing to the consumption of natural resources, cause environmental damages, especially those that contain toxic materials or can produce contamination when exposed in the natural environment. Another characteristic resulting from these processes is the perceived obsolescence, which manifests itself in the field of the psychology of the individual and in the social behavior of the great mass. The most notable form of this type of obsolescence is the fashion industry, which offers a large amount of elaborate and ephemeral design products. As a strategy, the user is convinced of the urgent need to purchase an upgrade product, even if the existing product is fully operational. For this, the concept of style is used, which overlaps with the concept of functionality. Advertising is constantly used by manufacturers to persuade potential customers that their products are outdated, inducing the perception of themselves as out of fashion, away from modern trends. Likewise, planned and perceived obsolescence can be observed in the field of building construction and lifecycle management. In the first analysis of the obsolescence of the buildings, the attention was placed on the physical decomposition of the construction parts and the constructive elements. (Nutt et.al. 1976, Prak and Priemus 1986, Priemus 1969). Currently, in a multidisciplinary approach, several studies seek to characterize different types of obsolescence, such as structural, economic, functional and social (Thomsen and Van der Flier, 2011, Thomsen et al, 2015). Through some models, it is possible to understand the inter-relational effects between the factors that contribute to the obsolescence of buildings. According to these authors, obsolescence can be analyzed according to causes and effects, in which different scales, types of construction, use and management modalities can explain the dysfunction and the deterioration of the buildings.

The technological evolution of the construction industry, which has successively incorporated technological innovation from other industries, has become more vulnerable to the obsolescence of products and systems used in building construction. Obsolescence poses a generalized risk to the built environment, since many buildings are demolished when they still have years of useful life, causing serious environmental impacts. According to Brandon et al(2016) some flexibility performance indicators can be characterized in product design, construction, as well as in the processes of the operating systems to increase the building's capacity to receive and accommodate the changes. Nieboer et al. (2014), characterizes obsolescence in two dimensions that emerge defining the cause-effect relationship: the physical dimension, related to the built environment and the behavioral dimension, related to the behavior and actions of the users. The endogenous obsolescence concerns the internal phenomena of the building itself and the exogenous deals with the external actions to the construction and how the building interacts with the environment. Interactively, these factors can be expressed through a matrix that defines four types of obsolescence, as shown in Figure 1. Thus, endogenous physical obsolescence is the result of the decline of building performance by physical processes within or directly related to the building itself, such as the lower initial quality of materials and the accelerated physical degradation. On the other hand, exogenous physical obsolescence corresponds to the decline of construction performance by external physical processes, such as earthquakes, rain, air pollution, etc. Although complex, the characterization of the physical aspects of obsolescence is often easier to determine than the behavioral aspects, which vary considerably over the life of the building. The endogenous behavioral obsolescence corresponds to the decline in performance caused by internal or directly related processes of the building itself, such as variations in user actions and lack of maintenance. In a broader context, exogenous behavioral obsolescence is related to the building decline due to behavioral processes external to construction, such as reduction of the neighborhood's quality of life, reduction of market value in the real estate market, and adverse or precarious public policies.

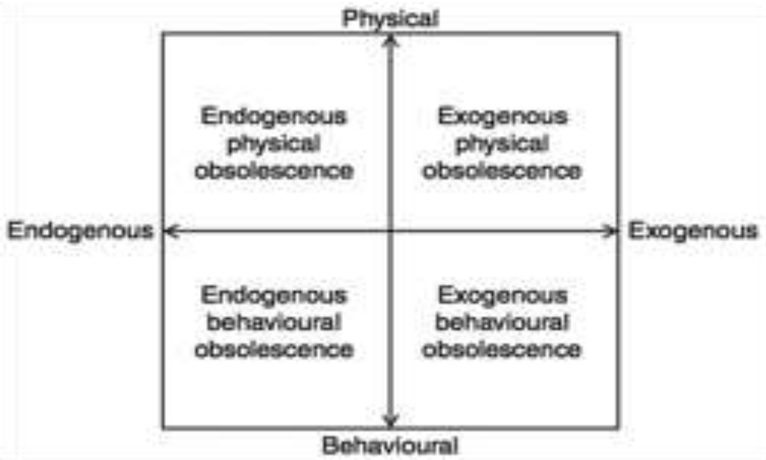

Fig. 1. Conceptual model of the obsolescence in buildings. Source: adapted from Thomsen and Van der Flier. (2011).

It should be noted that cause-effect mechanisms that operate in the obsolescence of buildings are often interrelated, making it difficult to identify if the deterioration process is due to lack of maintenance, characterizing a behavioral aspect or an inappropriate choice of material adopted in the design, characterizing a physical aspect. Other factors related to the buildings and their surroundings can cause decay and abandonment, such as behavioral processes that can act in neighborhood conflicts, restrictions of public agents or actions of the real estate market. All these factors tend to occur in a diffused and accelerated way in large urban centers, as a result of the processes of industrialization and globalization of products and values.

II. FLEXIBILITY AND FUNCTIONALITY IN BUILDINGS

Contemporary architecture presents a life cycle according to the kind of use, level of exposition, materials and construction systems employed. Project requirements are changing fast all over, mainly concerning building's performance and its operational phase (Bologna, 2002;; Sartoretti, 2013, Dodoo et al., 2010, Bologna et Barth, 2013, Barth et al 2017). It is well known that contemporaneous buildings must be adapted to this changing environment, but it also can be seen that most of the ephemeral buildings, after few years, disappear or are abandoned (Falasca, 2012; Di Sivo and Cellucci, 2013). Many of temporary buildings use the concept of planned obsolescence in order to satisfy emergencial needs. However, a large amount of resources and energy are used to produce this ephemeral architecture, so that its life cycle must be extended as long as possible to achieve a balance between operational time and appropriated use. In general, ancient and traditional projects do not consider the change of everyday needs and the rapid transformation of social practices. According to Merrian-Webstern (2014), the term 'flexibility' derives from the Latin verb "flectere", which represents the property of a body to bend, and, in a figurative sense, to vary and to adapt to different situations or conditions. In the mechanics of solids, the term is linked to the ability of deformation of an element, such as the bending of a spring or a limb. In this sense, flexibility is a mechanical property that defines the behavior of the material as a response when subjected to an external load, representing the ability to withstand or transmit these forces without fracturing or presenting uncontrolled deformations. Thus, the terms flexible and flexibility display variations to define aspects of movement and deformation of bodies and structures.

Flexible processes can also be observed in abundance in nature. Since ancient times living organisms have used flexible processes of genetic permutation and variety of types to be able to adapt to environments in continuous transformation. There are many examples of flexible strategies that living organisms use to survive in nature. The ability of some organisms to maintain their large size in the presence of wind or ocean waves has been attributed to their flexibility and the capacity to move with the flow, a tendency that reduces the dynamic forces imposed on the plant. According to Denny et al (2012), the benefit accrued from going with the flow is related to the shape and the mechanical flexibility of the plant. Nature evolution of some plants have provided a right combination of stiffness and flexibility to resist natural forces like wind and water flow. One of the most impressive things about bamboo in the forest is how they sway in the wind. Their bodies are hard and firm, stand firmly on the ground below. The foundation is solid even if it moves and sits harmoniously with the wind. Even with the strongest wind, the bamboo remains tall and intact. Following the natural flow is one of the secrets to the success of this millennial plant. Another example of flexibility and adaptability in nature is the octopus. This intriguing and mythological animal can live in all oceans, where many species have adapted to different marine habitats. The skin consists of a thin outer epidermis with mucous cells and a connective tissues consisting largely of collagen fibers and other cells that allow color change. The body is made of soft tissue, allowing it to stretch, contract and squirm. It enables the octopus to squeeze through small gaps, where even larger species can pass through small openings. In the absence of skeletal support, the eight arms work with different muscles around a central axial nerve. Thus, the octopus can extend and contract, bending at any place in any direction. Another point of interest is the application of the term flexibility to the human body. In this context, flexibility can be defined as the ability of the body tissues to stretch without damage. Furthermore, the type of tissue plays an important role in the stiffness of a joint. With age, the tissues lose elasticity, reflecting in the loss of muscle elongation and the reduction of mobility. The movement ability of the human body depends on the development of muscle tissue, motor coordination and flexibility of the articulations between the various parts, that with age lose their effectiveness.

Figuratively, the term flexibility can also be used to describe the ability of an individual to adapt to the different circumstances of life, being able to define the way to react and to perform the ability to adapt to changes. Thus, flexibility can be seen as a complex process linked to various human and natural phenomena that can be utilized in architecture to achieve adaptability and adequacy to its use. In this context, adaptability concept corresponds to the character of those who are able to adjust to new conditions or are adaptable to the requirements for a particular use or purpose in a suitable or appropriate way. The origin of the term comes from the Latin word "ad aptum" or "aptus", which means convenient. Adaptability is a tribute, feature or characteristic of what can be adapted. This term can be associated with the concept of the Evolutionary Theory, that explains the survivability and the capacity of reproduction expressed by its specific and individual genotype. In the Theory of Darwin (1859), individuals of a population are continuously competing with each other for space and natural resources. The environment makes a natural selection, where the weakest or less “aptus” ones are eliminated, those who are less suitable for survival under certain environmental conditions. In other words, adaptability is the ability that an individual attempt to satisfy needs and situations. Someone expresses this capacity naturally, others have some difficulty dealing with changes, but everyone can develop and strengthen this ability. Therefore, adaptability determines how people are able to interact appropriately with different changes in various environments and it is directly related to the way people realize and react to such changes.

The terms flexibility and adaptability can be used in many different situations and meanings, often causing misunderstandings in their application. Flexible solutions are those able to adapt more easily and more quickly to the needs of users. The effectiveness of the architectural spaces is defined by its functionality or the ability to meet the needs of users with fewer restrictions. Sartoretti (2013) says that in housing design, the organization of use, the degree of privacy of space, and the relationship between interior and exterior should consider the possibilities of an evolutionary performance where spaces are designed to be expandable and adaptable to new functions according to user changes. In the building design, the functionalism is based on its main purpose: suitable to be used. It may be characterized by some feature requirements in order to be partially or fully satisfactory. So, a function can be defined as the set of activities or components to achieve a specific objective. Leite (2008) proposes the evaluation of functionality in a social housing, according to some criteria that tend to quantify and qualify the functionality of its spaces, being represented in a radar diagram. Even in a simplified way, this method can show the functional effectiveness of a house by a unique value. The method also serves to evaluate different layouts of the same space to know which configuration is most appropriate for the specific use. In this approach, it is possible to see how different configurations of a space can be achieved by flexible building elements. According to Esteves (2013), flexibility suggests movement and change in a very fast association, where contemporaneous networks bring an enormous amount of information. So, flexibility is focused on the satisfaction of the user needs and desires, where the individual wishes and buildings requirements change over time. To do that, is necessary to increase the possibility of readjustment and adaption of parts of the building, ensuring the architectural quality and extending the performance over its lifetime.

Flexibility has been classified in different ways according to some authors (Groak, 1992; Albostan, 2009; Esteves, 2013). However, two categories are outstanding: *Intrinsic flexibility* corresponds to the initial design phase. This initial condition allows for some different uses, in which space is adapted by users to their needs and current desires. The second category is the *Continuous Flexibility*, that regards the period of use and the possibility of modifying the space and the configurations for various uses over time. Although it seems clear, there are some misunderstandings regarding the concepts of flexibility and adaptability. Sheppard and Town (1974) define flexibility as a property related to construction techniques and the configuration of the spaces. According to these authors, adaptable housing corresponds to the internal organization of units in order to provide a minimum determination of living standards of the users. In a different approach, Groak (1998) defines flexibility as the capacity of a space to allow different compositions and physical arrangements. For him, the adaptability is the ability to allow different social uses and it can be reached through the organization mode and the use of space, while the flexibility is achieved by alteration of the elements of the construction. On the other hand, Hertzberger (1996) conceptualizes flexibility of architectural spaces introducing the concept of functional versatility, referring to the capacity of a shape or a configuration to meet different uses without having to undergo physical changes. According to Schneider & Till (2007), housing is volatile, subject to the full range of cyclical changes and trends. When the building is not able to respond to these changes, it becomes unsatisfactory or even obsolescent. Douglas (2006) outstands the relevance of the building adaptation in order to avoid obsolescence and deterioration, establishing four levels of intervention: maintenance, stabilization, consolidation and reconstruction. The maintenance includes protection and conservation of building elements to avoid decay. The stabilization embraces rehabilitation and renovation actions and the consolidation includes restoration and also renovation of the building in order to improve or extend functionalities. At last, the reconstruction level can comprise the deconstruction or demolition of the parts or of the entire building.

Also noteworthy, it is the concept of flexible production proposed by the “Open Building” theory. For the first time, Habraken (1961) presented a specific definition of flexibility in the design of the support structures and dwellings to be produced by industry. The author introduces the industrial design concept into building construction, where the new construction system and the need for mass housing promote the design of building components to be manufactured industrially. The author suggests that different levels of decision making can be introduced in the building process: tissue, support and infill. This concept was the base of the architeture movement called *Open Building*, develeped by Habraken and later formulated in other publications (Habraken, 1998; Kendal and Teicher, 2002; Kendal, 2006). In that context, *Open Building* practice points out the emergence of a changeable user responsive infill level. Infill represents a relatively mutable part of the building that can be changed by the user without modifying the base building. Infill devices are more durable than finishes and furniture, although less durable than the base building. The application of the *Open Space* concepts was facilitated by the new constructional systems available in the Modern Architecture, which allowed larger span structures and light infill partitions.

III. USING FLEXIBLE PROCESS IN THE DESIGN OF BUILDINGS

Using similar concepts of *The Open Building* theory, Till and Schneider (2005) define *Flexible Housing* as a construction system that can adapt to the changing needs of users. This definition includes the possibility of choosing different housing layouts prior to occupation as well as the ability to adjust it over time. It also has the potential to incorporate new technologies as time goes on, adjusting to demographic changes or even to the complete change of the building use. These authors have classified Flexible Housing as a broader category than that of adaptive housing, which is the generic term used to denote housing that can be adapted to the changing physical needs of users, particularly those who are aging or losing their full mobility. So, the main principle of the *Flexible Housing* is very close to the *Open Building* theory, because it is based on the idea of an incomplete building, where a basic frame leaves space for the interpretation of personal uses. The occupants can decide how to divide the space and how they will live in it. If the composition of the family changes, the house can be adjusted and even expanded.

In this framework, the structural skeleton is a product of the building where the users can complete and improve the quality of the space according to their own needs. On the other hand, Hertzberger (1996) defines flexible housing as the capacity of proposing different solutions for diverse uses with no certain single solution but most appropriate response. He discussed flexibility in a different perspective by introducing the term polyvalence. Albostan (2009) points out that polyvalence refers to a characteristic of a static form that can be placed in different uses without having to undergo physical changes so that a minimum flexibility can still produce an optimal solution. Thus, the concept of polyvalence can be added to the one proposed by Habraken (1972), that includes flexibility and adaptability, terms used in multiple and overlapping meanings. Therefore, a building can change over time, expressing the user’s life style and showing also its *Modus Operandi*. It should be considered that contemporary cultural diversity and the specificity of environments and activities make architectures increasingly complex. Changing needs and requirements affect the use and the adequacy of space throughout long periods. In order to facilitate the transformations of the building, it is necessary to identify the layers of construction from structure, skin, services, internal partitions to finishes. This allows increasing control and flexibility as one goes through the layers. Till and Schneider (2005) point out that the disposition of services in building should be carefully considered to allow future changes and upgrading. Vertical services are deployed into easily accessible ducts, denominated shafts. Horizontally, raised floors and/or dropped ceilings allow endless permutations in the possible disposition of service outlets. In this context, it is also possible to develop a more comprehensive classification of methods by which flexibility may be achieved in housing. The classification can attempt to cover some conditions of flexibility, without intending to be prescriptive in setting out rules for the designers. At first, the classification works through investigating flexibility at different scales of housing, from the blocks, through the building and units, to the individual room. The authors point out that flexibility in housing can be obtained considering the use through design phases and also through innovative technologies. Technology flexibility deals with issues of construction and servicing and the way that these affect the potential for different kinds of uses. These two approaches are not mutually exclusive. The development of long span structures allows the elimination of load bearing partitions, which in turn allows the use of soft technology provided by construction innovations and new servicing and maintenance strategies.

The production of building elements is associated to a set of machines and equipment organization in order to produce a flow of materials and information for processing raw material into products. Thus, the variation in the mode of production can modify the design and construction process of the buildings significantly. In this way, Flexible Production can be seen as the ability to quickly change the manufacturing of one product to another, introducing an innovation in the standardized production system. The development of new technologies can create new business modalities and work organization to expand the possibilities of product offerings. Coperus (2001) notes that the construction sector is shifting from 'on-site construction' to a 'assembly process', from the use of basic materials to the use of more complex products and components produced at the factory and locally assembled. This change resulted in more efficient building processes, reducing construction time and increasing the quality of its parts. Although the building quality is not only determined by the quality of the its parts, but also by the way they have been put together. This means that it is not enough to have a flexible production of elements and parts, but it is necessary to meet the needs and performance requirements of the users to achieve the quality of the spaces and also to ensure the quality of the building throughout its lifecycle. Carbon and Naab (2010) note that flexibility is the degree to which a system supports future changes in its requirements. Thus, the concept of flexible design can promote the qualitative attributes of building and business information systems when applied to the construction industry, adding to the prevention of premature aging and obsolescence of buildings. A relevant consideration is that flexibility is not usually adequately addressed in today's architecture design methods. In this situation, some architectural mechanisms that support flexibility are introduced into the design process, and flexibility is expected to occur automatically. Greden (2005) developed a research aiming to embrace uncertainty as a guide to the design and economic evaluation of a building and its engineering systems. By addressing uncertainty through flexible design processes, one can achieve a project that can show the best technical and economical building performance.

IV. TYPES OF FLEXIBILITY IN ARCHITECTURE

As seen before, the complexity of architecture and its different configurations can induce conflicts between the inertia of the traditional building construction, the construction industry and the consumer’s demand constantly changing. Therefore, buildings designed with flexible strategies and built with separate systems can create conditions for the right choice to its transformation with responsibility and care. In this sense, the subdivision of the construction process must reflect the lines of decision and the definition of responsibilities among professional agents. Schneider & Till (2005) note that it is also important to consider the social aspects in the design of housing, in order to make it environmentally and economically viable. Thus, the first degree of flexibility responds to the building adaptability opportunity of that considers different social uses for construction. The second one is the flexibility opportunity that includes different physical arrangements and modifications over the life of the buildings. There is always some degree of uncertainty when managing a project. To succeed in an unsure environment, features such as robustness and flexibility in design are necessary to promote building adaptability.

Designers can increase the use of flexible processes by postponing irreversible decisions and focusing on collecting information that can improve decision making. Generally, information becomes available as projects are developed, facilitating the decision that benefit the company and the users of the building. In traditional project management, flexibility is not a very desirable feature, because it is seen as a uncertainty factor. However, a company needs to adapt to survive in changing environments with many uncertainties. The flexibilization of the processes related to building construction begins in the programming and organization phase of the company until the last phase that corresponds to the use and transformations of the building. Figure 2 shows the subdivision into stages, according to the evolutionary process that begins at conception and extends to all stages of the project, the production and the capacity to transform and adapt the buildings to different uses.

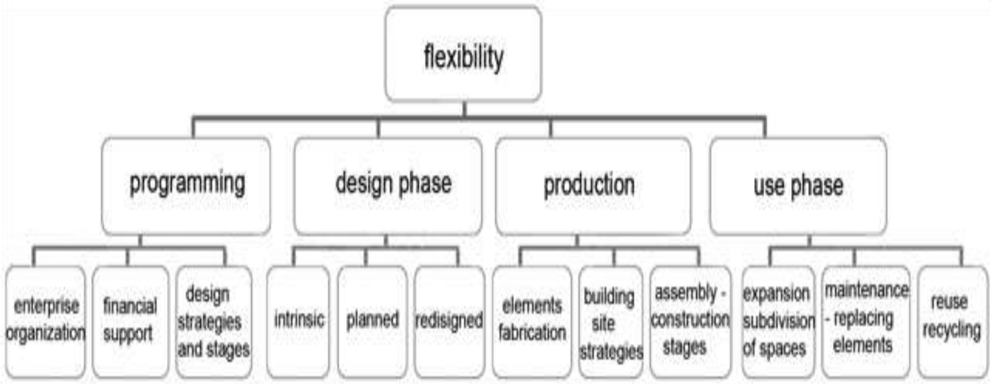

Fig. 2. Systematization of flexibility in buildings.

The flexible process can contribute to the deconstruction of buildings, allowing the reuse or recycling of their parts and elements. The first stage related to programming includes the organization of the company, the establishment of companies and partnerships for the feasibility of the project and the construction. This stage involves the companies incorporation, builders, manufacturers, projects and engineering companies that, in a coordinated way, establish financial and design strategies to meet the real requirements and the demands of the real estate market. The designer can settle the project needs program and the current regulatory requirements, in order to satisfy the users. Even if there is no concern at this stage with the future demands of users, the projected spaces and facilities have a certain degree of flexibility, called *Intrinsic Flexibility*, also called for some authors as the adaptability of the architectural space (Groak, 1992; Albostan, 2009; Esteves, 2013). The intrinsic flexibility in housing is defined as a property to promote a domain able to fulfill occupant's expectations. The adaptable approach, in contrast to the flexible process, emphasizes planning and layout rather than constructional technique and service distribution. It is based on considered variations in sizes, the relationship between spaces and openings and interactions between spaces. The capacity of adaptability can be considered as an intrinsic flexibility, because the users can adapt the space to their needs and desires without changing the parts that form the space. In a similar way, it is possible to change the use of a space without making changes in the setup of the parts. Different types of use can be proposed to the same room, for instance a round table meeting, a classroom, workshop groups or conference room. According to the spatial characteristics, the user can interact by modifying the furniture and the uses of the environment. In addition, some strategies can be designed to increase the possibilities of configurations, meet users demands and increase the attractiveness of the company. As an example of planned flexibility, the company can offer different models of the apartment with some variations of configurations. The optional room can be converted into a studio or vice versa. The dining room can be integrated with the kitchen or the living room and the social spaces can be integrated with movable walls or without any compartments. These possibilities can be offered in the variants of the apartments available on the various floors of the building.

Another type of planned flexibility is the one that allows the user to chose for some of the options offered in the basic design, which it may be modify and appropriate during the detailing phase to produce the customization of the project in the plan. Although very flexible, this modality is limited to the offer of some options compatible with the design of the structure of the buildings and the design of the electrical and hydro sanitary installations. Usually, projects are modified during the construction phase, causing design changes that should be represented in the *As-built* design. This representation seeks to show effectively the location of these modifications, in order to allow the user to know the final and true characteristics of the elements, equipment and installations that make up the architectural space. During the design, flexible strategies can be adopted to allow for dimensional and functional variations of spaces according to changing needs or through changes in the behavior and style of the users over time. In regards the flexibilization processes of the production of buildings, there is also a great complexity due to the various agents that usually interact in the different stages of production. The flexibilization of these processes can begin in the production plant of the elements and constituent parts. The product manufacturers can choose to produce various products that integrate elements and parts of the building. They can also use products from other manufacturers into their production line in order to reduce costs and increase production speed. This phenomenon shows how the building production sector is structured to increase efficiency and stimulate competition between different manufacturers. This diversification of the production organization can be seen at the construction site, where different builders share the same space to offer specialized services. Contemporary construction sites show diversification of the activities, which is modified according to spatial management of the construction site that changes constantly according to the construction stages. Several strategies can be incorporated into the planning work in order to increase the assemble of elements in a systematic way. This systematization can be subdivided, according to the stages and physical characteristics of the work. Different sub-systems are integrated to increase constructive efficiency, reduce waste and avoid rework. A compatibility process of the complementary projects can reduce errors and increase the dimensional control in the assembly process of the structure, construction and cladding elements. Different assembly possibilities can facilitate site management, increasing assembly productivity. *Just-in-time* delivery of industrial products on the construction site can reduce storage space, unnecessary transportation and non-productive operations. The assembly of prefabricated facades can be planned with the flexibilization of the assembly sequences, in order to facilitate the production process of the elements in the factory and their fast delivery. The building envelope and roof's assembly can be performed to progressively release the internal spaces in order to make faster the internal services of walls, ceilings, thermal and acoustic insulation and internal coverings. The flexible approach to these building processes can contribute significantly to environmental and economical efficiency work due to the ability to reduce the time and costs of the building construction.

In the building's use phase, it can be foreseen some processes that can facilitate interventions and modifications to be made by the users. A building may be more or less flexible for modifications, depending on the physical characteristics of the elements and processes adopted in the initial design and in the construction phases. The structure of the building consisting of columns, slabs, beams and support walls are the elements that present greater difficulties for later modifications. Facades of big buildings also tend to make modifications difficult because they depend on urban regulations and actions shared with other building users. Not withstanding these difficulties, balconies may be added, open spaces may be enclosed with glass panels and unprotected spaces may be covered. In apartments and commercial spaces, the internal spaces are often subdivided or expanded according to the changing needs of the users. The vertical subdivisions can be realized with light panels, movable elements and special furniture. Mezzanines or modular spatial elements can subdivide the space. Maintenance of the building's facilities and equipment can lead to changes and modifications of floors, ceilings and wall coverings. The user needs change faster than the building's transformation capacity. Thus, the user of the architectural space must, first of all, know the constraints to the transformation of spaces, the frequency of maintenance and the possibilities of replacing the parts of the building. Finally, after the use phase, reversible design strategies can be planned to easily separate the parts and elements of the building, so as to maintain its physical integrity for possible reuse in the same building or another user. Disassembly flexible strategies can facilitate the deconstruction and separation of the different materials in order to allow effective recycling of the materials used. A typological flexibility can be achieved by combining elements to provide different levels of functionality to users. The choice of basic products and customized products according to the requirements of the users can increase the performance of the building in terms of composition and function. Molinelli (2015) has performed a study with different layouts to an apartment keeping hydraulic system and sanitary installations. Even with fixed hydraulic and sanitary equipment it is possible to get a flexible use of space, offering layout options capable of meet the users' demands. According to Brandao and Heineck (2007), the customization and flexibility of projects is increasing real estate sales with made in plant marketing strategy. This expresses the possibility of user participation in the definition of the property. In the construction industry, traditional methods of developing and producing standardized housing for medium-sized families are becoming less and less offered. On the other hand, more buildings are being built to meet families with new lifestyles and specific needs for equipment and services.

The standards of life and work become more individualized in big cities, increasing the number of users who want customized projects. Spatial flexibility can be achieved through the physical transformation of the parts that make up the architectural spaces. It is defined as Constructive Flexibility because it makes necessary to change, move, exclude or transform components, elements or parts of the building to adapt spaces for new uses. Usually, contemporary buildings present light interior partitions and non-load bearing walls, which facilitate the transformation of the interior spaces. There is no doubt that flexible processes are more effective in the design phase in order to facilitate the user's transformation and to improve the adaptability of the architectural spaces. When the building is finished, the possibility of modifying its configuration is much more restricted, since it is implemented through framework solutions, service building, etc., which are laborious and expensive to change later. So it is much better to make decisions based on flexible attributes to optimize resources. According to Saara and Heikkila (2008), in a flexible construction process that takes into account modification when the project team analyzes user needs and together try to establish flexible goals. Thus, it is possible in the design process to design a project, proposing the principles of how flexibility can be implemented in different parts of the building. Finally, the implementation phase can detail the technical plans to start the solutions. The second phase corresponds to the design process when the designers work out a design-conception proposal, a modifiability concept, which describes the principles of how flexibility can be implemented in the different parts of a building. Lastly, the implementation phase where the technical plans are detailed to start up the solutions.

V. FLEXIBLE PROCESS IN DESIGN AND CONSTRUCTION OF BUILDINGS

The flexible design process and the capacity of transformation of the space are concepts related to flexibility in order to make buildings suitable to the changing environment. A distinction can be made between process flexibility and product flexibility. According to Geraedts (2001), Process Flexibility is the flexibility in a decision-making phase that occurs in an organization involving different agents in the activities of building construction. It may occur in the enterprise definitions, the project planning, design and construction processes or building operation. On the other hand, Product Flexibility is the ability of a product to be used or adapted in the construction process, according to its characteristics. An integrated production system, controlled by a complex of automated devices and numerically controlled machine tools, can offer a variety of products and types of parts to increase flexibility in the design of a building. This new technology is designed to achieve information and production efficiency, using flexible processes to get various types of parts and flexible products. Generally, the structural system composed by the permanent part of the building is relevant to determine whether the space configurations can be flexibilized or not. Flexible processes can be applied to the construction when the support and infill elements are easily separated and well interfaced in the building design. A flexible system of inner walls also contributes to overall flexibility of the building. Thus, the flexibility in the use of the internal spaces and in the construction of the envelope building can be increased significantly, reducing the amount of structural elements.

Facades, the most relevant feature in the envelope of skyscrapers, are the system that separates the inner space from the surrounding environment, causing a major impact on the inner space and also on the urban scale. Farjami (2015) shows that the structural systems, the service areas like other fixed elements, substantially affect the flexibility of the internal spaces. The envelope, especially the facades, is considered an immutable part when it comes to historic buildings, making it difficult to be changed in use. Granadero et al. (2013) emphasize that the envelope achieves a high compositional value in building design and is also crucial for its energy performance. Contemporaneous projects are taking more and more environmental aspects into account, but it is to be considered that only energy efficiency concerns can neglect other architectural features, such as aesthetic and functional quality. These authors reflect how the energy efficiency in a project approach can lead to inappropriate housing without considering any other requirements that a building is supposed to meet. In addition, there is a relationship between the users' needs, standards and urban restrictions, therefore making the environmental and social requirements more complex to a sustainable approach in the long run. The advanced methods of construction and other alternative approaches for the realization of the envelopes may be useful to adjust, interact and respond to changes in the internal conditions of the building. Some active building systems can be used for a new construction project, as well as be compatible with existing structures, in which elements may be flexible, active or even movable. Pan et al (2015) propose a self-diagnosis function of the building envelope sustained by a specific software device to allow the building system to respond to the changing environment, able to detect faults and to facilitate maintenance. Thus, new buildings can be more flexible to respond to changing conditions. Most modern buildings have large glass facades in different orientations. Retrofit these buildings can improve the efficiency of transparent facades, reducing the transfer of heat, maximizing the use of natural light by employing lighting control systems. Spectrally selective windows and dynamic elements can improve the building envelope performance. On the other hand, traditional masonry construction present very low flexibility to adapt to new uses and variable conditions. This type of building has, in general, low thermal resistance values that usually generate heat losses or intensive solar gains. Intervention in the inner walls can be done if the structural stability is provided by suitable reinforcements. However, the outer walls of ancient buildings have many difficulties for retrofitting because of the strict urban regulation.

The service spaces of a building correspond to the areas that have hot and cold water and sewage facilities, very often showing great complexity due to their specific characteristics. Access to service space is improved considerably when elevated floors, suspended ceilings, shafts are used to duct installation systems. The installation components are closely linked to the infill level, presenting as a general rule a short technical, functional and economic life. According to Saari and Heikkila (2008), service flexibility affects the fruition of the space and can be improved by movable partitions, flexible installations and adjustable facilities. A construction project requires programming and management control to ensure the safety of service areas such as bathrooms and kitchens. Issues relating to the use of flexible water and sewage facilities as a means of controlling access to the installation and its finishes and fixtures in a factory environment can reduce the costs associated with remedial works. Volumetric modules are often employed as an effective means of constructing highly serviced areas in buildings. Precast toilets and kitchens can improve construction processes and productivity, ensuring construction quality, reducing time and cost in the buildings.

The flexibility of buildings is inextricably linked with the flexibility of their installations, which more and more constitute an important element to the functionality of buildings. The design processes must distinguish two different decision-making levels: the support level and the infill level to ensure that buildings can be optimally modified to meet use changes in future. In short, support structures and their various components can be designed and implemented to fulfill various long-term functions as good as possible. Infill components can be designed and implemented to meet short-term changes in organizational and individual requirements. In design processes, the support and the infill levels must be matched to ensure that buildings can be modified optimally to meet changes in lifelong use. Infill components can be implemented to meet the short-term changes based in the organizational and individual requirements. The flexible design strategies can be used to produce multifunctional furniture in order to adapt different uses to the available space. Modular furniture can improve flexibility of use, because the design can consider flexible elements like joinery, inserts, connections making the manufacturing process more adaptive to different users, included disabled people, on a larger scale. Also there is less waste, financially and operationally, in terms of downtime when renovations occur, because facilities can easily relocate the product or even replace it. Multifunctional furniture pieces face the need and make more efficient use of the space, providing simultaneous and a sequence uses to one or more users. As it turns out, multifunctional furniture can also benefit from flexible designs that make the most of space, combining sleeping, storage and working spaces into one module in order to attend simultaneous and sequence uses, according to changing needs.

VI. CONCLUSION

This work aim to show the most relevant aspects of the obsolescence process of the buildings and some concepts regarding the ability of buildings to adapt to constant changes, needs and demands of users. The obsolescence of buildings poses a risk to the building environment, since many buildings are demolished when they still have years of useful life, causing considerable environmental impacts. Therefore, it is necessary to understand the various phenomena that contribute to the structural, economic, functional and social obsolescence of buildings. The flexible processes related to the construction and use of buildings can be used to investigate the ability to design and produce adaptive buildings more resistant to obsolescence. In addition, flexibility is characterized by the concept of adequacy involving projective and operational processes at different stages of design, planning, production and construction in order to meet the continuous changing needs of users.

On the other hand, adaptability seems to deal with the internal organization of housing units in order to accommodate change of use. Thus, flexibility is not only related to the structural system and the position of the service spaces of the building, but also to the physical changes that occur in the remaining spaces, such as adjustments related to the envelope and the interior space. In this respect, flexibility includes physical and social continuity in the building. This discussion can also provide a background for further researches on the issue of flexibility and adaptability in housing design in order to investigate strategies and methods to improve flexibility in contemporary projects and in the rehabilitation of old buildings as well. The potential of functional transformations of existing buildings can be explored and new strategies can be developed to meet the ever-changing needs of users with diverse lifestyles and different capabilities. So, the flexible approach to the structure, envelope, internal partitions, and equipment and installations carried out during the design phase can facilitate maintenance and change of use, as well as improving the capacity for intervention and adaptation of spaces. Access to service elements is another important concern to make the building capable of switching to a variety of unit types, giving the opportunity to make quick and easy adjustments in the future. Furthermore, flexible design can also increase the reversibility of building processes and extend future user interactions with the composing parts of buildings. Finally, these considerations on design methods faced by a flexible approach process can make spaces more useful and adaptable to future transformations in order to extend the life cycle and avoid the early obsolescence of buildings.

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