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RESEARCH ARTICLE

Symbiotic architecture: Redefinition of recycling design principles

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Abstract
The study seeks to examine the possibility of implementing the biological concept of symbiosis into the field of architecture for redefining the design principles of architectural recycling. Through an in-depth analysis of the biological concept of symbiosis (i.e., a close and often long-term interaction between two or more different biological species and the criteria that govern the differentiation between symbiotic associations), three redefined design principles of recycling—commensalism, mutualism, and parasitism—have been described, which form the base for defining the "recycling model." Its value is in its multidisciplinary character and its systematic approach to the topic of recycling architecture. The principles embedded in this model relate to the aspects of structure, material, form, and spatial organization. The research methodology includes three case studies, which correspond to three redefined design principles and illustrate their basic characteristics. The research draws upon the biological concept of symbiosis, and its purpose is to elaborate possible structural, material, formal, and spatial relationships between the existing building and the new intervention in architectural recycling.

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1. Introduction

Architectural recycling is the process of altering the existing building using all of its available, useable material to make it suitable for new functions. The concept of recycling implies the notion of change, unlike many other terms that correspond to the intervention on the existing building. Thus, the original building is altered to accommodate a new function. However, most of the original buildings' materials are used, which offer a number of advantages, such as the increase of the working service life of existing buildings; profitability of the resources already applied (Cepinha et al., 2007); the absence of extraction, processing, and transport costs; and reduction of the need for manufacturing new components and products, which directly address the local economy and environment (Couto and Couto, 2007).

Sustainable architectural design includes the principles for the design of sustainable buildings but is inadequate in developing sustainable design principles only for new projects. The existing buildings must also be considered given that structural issues are usually not the reason buildings come to their end-of-life, but rather the shift of the building's original purpose, which makes the existing building unsuitable for new roles and functions (Lee et al., 2011; Baum and Christiaanse, 2012; Sijakovic, 2015).

The current literature on interventions upon existing buildings usually deals with the categorization and classification of projects according to subjective and vague criteria. The results of such studies are mainly catalogs forming a very useful database. Although consecutive, consistent studies have been made in the field of building construction and physics aimed at improving building performance, the lack of research on the recycling approach to existing buildings (beyond cataloging) is evident.

The research subject belongs to the domain of architectural recycling and is focused on elaborating environmentally sustainable design principles suitable for recycling existing building stock. Research in the field of architectural recycling lacks the precise identification of recycling design principles. Thus, the present research aims at the redefinition and creation of the "recycling model." The design principles of recycling elucidate possible relationships between the original building and new intervention. The research draws upon the implementation of biological concepts into the architectural field to redefine the design principles of recycling. This means that the extent of the analogy between the fields of biology and architecture is identified, which makes the firm multidisciplinary research background. Biological principles are also used to form the "recycling model." The concept of symbiosis serves for the definition of possible relationships between the existing building and new intervention in the process of architectural recycling. The terminology used in the field of biology, explaining different types of symbiotic associations between two organisms, has been transferred to the field of architecture. In the process of architectural recycling, original building and new intervention are compared with "symbionts," which are organisms closely associated with one another that take part in symbiotic associations. Three redefined recycling design principles are derived from the concept of symbiosis: commensalism, mutualism, and parasitism. Thus, the interconnections between different symbiotic associations and recycling design principles are elaborated, and new definitions are presented. Three case studies help illustrate the characteristics of redefined design principles.

After the introductory remarks, the correlations between the fields of biology and architecture are extensively explained by drawing on the contributions by architectural theorists and practitioners, such as Georges-Eugène Haussmann, Ildefons Cerdà, Frank Lloyd Wright, John Frazer, and Manuel de Solà-Morales. Such an informed review forms the basis for the redefinition of the recycling design principles. However, the biological concept of symbiosis is first elaborated by making the sound background for defining the recycling model of architectural design principles based on the inputs from the biological domain. The model is then tested in practice and illustrated through three cases of recycling industrial buildings. The conclusion proves the benefits of recycling as a method for environmentally sustainable architectural design.

2. Biological analogies in architecture

Cities have long been compared to living organisms. Plato, in his *Politeia*, written approximately 380 BCE, referred to the city as a "macro-anthropos" (in ancient Greek: *μακρο* - large; *ανθρωπος* - man), which highlights the analogy between the human body and the city. Plato also makes that correlation between the man and the city in terms of justice by stating that a just man is not different from a just city. Cerdà (1867) refers to a city as a body and a living organism and points to urban planners as both the diagnosticians and surgeons. Cerdá states that an urban planner should "first be able to distinguish sick areas of the city from those that are healthy, only then can he proceed with a true anatomical dissection of all of them and of all of their constituent parts" (Fraser, 2011:89). Choay (1969) explains that Georges-Eugène Haussmann transformed modern Paris and revolutionized its streets as arteries in the model of a "general circulation system." Fraser (2011) states that the application of the biological metaphors to city life was a practice that predated the work of 19th-century city planners and was even present in the 17th-century with the discovery of the blood circulation. Referring to the discoveries of the seventeenth-century, Sennett (2008: 204) writes,

> The scalpel had permitted anatomists to study the circulation of the blood; that knowledge, applied to circulation of movement in streets, suggested that streets worked like arteries and veins; this was thus the era in which planners began to incorporate one-way streets in their designs. Wren's circulatory city was commercial in intent, aiming to deal efficiently in particular to create streets that moved goods to and from the necklace of warehouses draped along the Thames. But this design lacked the equivalent of a human heart, one central, coordinating square.

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