As one of the most active actors of the built environment, in the discipline of architecture, several design approaches have been proposed for sustainable solutions. One of those approaches, “holism in architecture” aims to achieve sustainability in design responding the demands by the use of available or developing resources, technologies and methods. Similarly, “biomimesis”; learning from nature by studying natural systems and processes, have many potentials to develop new design solutions contributing the sustainability and sustainable development. This paper exemplifies and discusses how these two approaches together can be applied to buildings for better solutions in architecture by benchmark examples constructed recently.

Keywords: Holistic approach, biomimesis, sustainability, architecture.

1. Introduction

Sustainable development is “development which meets the needs of current generations without compromising the ability of future generations to meet their own needs”

*Brundtland Commission[1]*

18th century is accepted as a turning point in the history of mankind not only as the beginning of Industrial Revolution but also as the era when the scope and scale of the environmental problems started to change drastically. Today, excessive consumption of natural resources (even nature itself) and incessantly escalating severity of environmental problems force countries to take actions against environmental problems in a global level for sustainability and sustainable design.
Sustainability has become a very popular term in many disciplines and investors and researchers devote enormous time and money for related studies, implementations etc. to define their policies as well as initiatives on this subject. It is also seen that there is the danger for sustainability to become a branding or an issue for publicity. Today green washing becomes a powerful marketing tool which may easily shallow the concept of sustainability. However, the role sustainability in architecture is a strategic issue and one that will increasingly influence financial, social and environmental performances and thus stability. There are many researches showing that major energy consumers are “buildings”. Therefore the role of quality of built-environment and thus architecture in the realm of sustainability is unquestionable. Architecture, as one of the most active actors of built-environment has a substantial role in contributing sustainability. This role has been congealed, by naming it as sustainable or green architecture which is defined as the search for the best design options and systems for the building to economize the environment without sacrificing the human comfort.

In this regard, architecture has been seeking for proper methodologies and, several design approaches have been proposed for sustainable solutions/architecture [3]. One of those approaches “holism in architecture” aims to achieve sustainability in design, responding the demands by the use of available or developing resources, technologies and methods. The term holism has been used to describe the view that a whole system must be considered -as it is in nature-, rather than simply its individual components. Yales suggesting that a building should attempt to address all of the principles of green design in a holistic manner [4]. The principles of sustainability cannot be resolved in an isolated or compartmentalized way. According to Thomas holism in architectural design would need to be a comprehensive amalgam of three essential parameters: end user involvement in the design process; technological advance aimed at sustainability and the conservation of natural recourses; and, sound architectural principles in terms of aesthetics and construction efficiency [5]. What makes holistic approach more prominent in achieving sustainability than traditional architecture is the stimulus of understanding the environmental, social, cultural and economic factors as a whole- as all the processes that we encounter in nature.

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Biomimesis (also being used as Biomimicry or Biomimetics) is a term used to describe the act of developing different methodologies inspired by nature to innovate and provide solutions in various disciplines. Biomimesis in architecture has been mostly perceived as either a process of “form finding” inspired by countless forms, colors and details of nature, or as a way of imitating natural processes for sustainable/green designs. As is evident in Koelman’s comments [8] on the matter, Biomimicry can be applied to buildings in three fundamental ways; “by making stronger, tougher, self-assembling, and with self-healing materials; by using natural processes and forces to accomplish some comfort requirements of buildings such as heating and cooling; and finally by providing resources, rather than draining them, by using/applying the principles of Biomimesis for zero waste and co-evolution”.

The current examples seen in architecture which are related either with the imitation of nature by the generated forms for new challenging architectural designs [12], [13], [14], or through their functions for sustainable solutions. Yet these examples are not completely showing how Biomimesis can be more involved in the architectural design process and how this implementation/integration can be systematized.

In other disciplines, like mechanical and material engineering, robotics and medicine, Biomimesis has been successfully implemented with its own systematic and rules. Among the prominent way of implementing the principles of biomimicry, three levels namely form, process and ecosystem are plausible to be applied to any design problem.

In studying an organism or ecosystem, form and process are aspects of an organism. Ecosystem however is what could be studied to look for specific aspects to mimic [15]. For this reason Zari [9] has moved the discussion one step further and developed a framework to understand the various forms of biomimesis in architecture. (Table 1.) Although Zari argues that these varied approaches may lead to different outcomes in terms of sustainability in architecture, a more systematic approach should be discussed and proposed to achieve a holistic manner.

### 3. Case Studies: Biomimetic Architectures and Sustainable Solutions

From the theoretical framework explained above, Biomimesis can be considered as a way of learning to accomplish holistic approach in architectural design as in the other disciplines like engineering, agriculture, economics etc. In these disciplines researchers are exploring processes of nature through a systematic way of analysis and synthesis, to develop methodologies peculiar to their field in terms of innovative sustainable designs. Hence it is possible to claim that Biomimesis in architecture is a new platform/interface in which architects not only imitate or are inspired by nature, but learn from it to provide efficient designs that reveal the features of what they study/learn from animate or inanimate in nature.

#### 3.1. Eastgate Centre, Zimbabwe

As an early example how biomimesis can shape the design process, Eastgate Center in Zimbabwe can be given. Searching for environmental aspects, some biologists and environmentalists realized that, termites build their homes in the desert in extreme temperatures, and yet manage to keep the interior of the building cool and clean. A species of termites living in Zimbabwe build gigantic mounds and inside they farm a fungus which is their primary food source [16]. The fungus becomes fresh in exactly 30°C, while the temperatures outside range from 1.6°C at night to 40°C during the day. The termites maintain 30 degrees by constantly opening and closing a series of heating and cooling vents throughout the mound during the day time. With a system of carefully adjusted convection currents, air is sucked in at the lower part of the mound, down

<table>
<thead>
<tr>
<th>Level of Biomimicry</th>
<th>Example: A building that mimics termite</th>
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<tbody>
<tr>
<td>form</td>
<td>The building looks like a termite.</td>
</tr>
<tr>
<td>material</td>
<td>The building is made from the same material as a termite</td>
</tr>
<tr>
<td>construction</td>
<td>The building is made in the same way as a termite</td>
</tr>
<tr>
<td>process</td>
<td>The building works in the same way as an individual termite.</td>
</tr>
<tr>
<td>function</td>
<td>The building functions like a termite in a larger context; it recycles cellulose waste and creates soil for example.</td>
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</tbody>
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<tr>
<th>Ecosystem level Mimicry of an ecosystem</th>
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<tbody>
<tr>
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into enclosures with muddy walls, and up through a channel to the peak of the termite mound [17]. The mounds are cooled in a very clever way that uses the stable low temperatures under the ground. According to Koelman [11], from a whole-system perspective, the African termite mound might be the supreme example of advanced animal architecture, incorporating exquisite solutions to design problems (structural strength, elemental protection, ventilation, humidity control, etc.) that architects also face.

From this perspective the Eastgate building by Arup in Harare, Zimbabwe uses design methods inspired by indigenous Zimbabwean masonry and the self-cooling mounds of African termites as a source for innovation in the building’s HVAC design to keep the building cool, even on the hottest days, yet stays regulated year round with dramatically less energy consumption. Using nature-inspired designs for the ventilation and heating/cooling of buildings instead of high energy-consuming HVAC systems, as in this example, indicate potential for further innovative design solutions for more environmentally friendly, and yet efficient, building systems. (Figure 3).

System is quite simple and applicable; Fans suck fresh air in from the atrium, blow it upstairs through hollow spaces under the floors and from there into each office through baseboard vents. As it rises and warms, it is drawn out through ceiling vents. Finally, it exits through 48 round brick chimneys. During summer’s cool nights, big fans flush air through the building seven times an hour to chill the hollow floors. Ultimately it enters the exhaust section of the vertical ducts before it is flushed out of the building through chimneys. The Eastgate Centre uses less than 10% of the energy of a conventional building its size. These efficiencies translate directly to the bottom line: Eastgate’s owners have saved $3.5 million alone because of an air-conditioning system that did not have to be implemented. Beside of being eco-efficient and better for the environment, these savings also trickle down to the tenants whose rents are 20 percent lower than those of occupants in the surrounding buildings [17].

3.2. MMA Office Building, Qatar

Qatar is fairly barren, covered by desert, and receives an average annual rainfall of 8.13 centimeters [18]. Bangkok-based Aesthetics Architects GO Group decided to model the Minister of Municipal Affairs & Agriculture’s (MMAA) new office in Qatar upon the cactus inspired by the towering cactus successfully surviving in hot, dry environments. Taking inspiration from the way these plants deal with the scorching desert climate. The modern office and adjacent botanical dome are going to mimic the cactus in a way that they successfully survive in hot, dry environments [19]. (Figure 5)

Considered as a successful example of desert architecture, this building is designed to be the energy-efficient structure features sunshade panels that open and close according to the intensity of the sun at a particular moment. Depending on the intensity of the sun during the day, the sun shades can open or close to keep out the heat when it is too much. This is similar to how a cactus perform transpiration at night rather during the day in order to retain water.

3.3. Wuhan Energy Flower Building, China

Netherlands-based firm Grontmij, in collaboration with Soeters Van Eldonk architects, recently won the award to design and construct the new research center which will be both zero carbon and zero energy and include a slew of other green building strategies [20] claims that a flower, Calla Lily inspired research center for Wuhan University in China is a candidate for being one of the most sustainable buildings the world. the sustainable characteristics of the building was explained in competition report as follows "...The building will have zero carbon emissions and has zero-energy ambitions. The office building will be approximately 140m tall, surrounded by laboratories in the form of leaves. The building is designed so that it will be in its own shade in the hot
Chinese summer. The roof of the flower consists mainly of solar panels for generating energy. Rainwater is collected in the bowl and used as water supply in the building. The characteristic pistil consists of vertical wind turbines to generate wind energy. The edge of the bowl forms a sunroof designed for heating and cooling of the building. The building is the principle of natural ventilation. The central solar chimney of more than 120m in height is designed for natural air ventilation into the offices [18]. The center tower expands upwards into a bowl and is coated in a large solar array facing the sun, soaking up rays just like a real plant. A vertical axis wind turbine shoots up out of the center of the tower like a pistil. Rainwater is collected in the bowl and a solar chimney in the tower helps expel hot air from the building while pulling in cooler air below [19]. Jos van Eldonk, architect for the project said: We took our inspiration from nature itself for this innovative building design. The collective influence of sun, wind and water are integrated into the design of the flower-shaped building. Technical skill and creative imagination are perfectly combined in a sustainable way [21].

This innovative building is, after completion, assured of the highest award of Three Stars label in the China Green Building rating system and will also the first office building in the world that meets the standards for the highest sustainability class ‘Outstanding’ in the international BREEAM rating [22].
objectives (functionality, optimization, and cost effectiveness) aimed at both of these domains are very similar. Therefore, it is no surprise that mankind has always admired biological structures and has often been inspired by them, not only in their aesthetic attributes but also in their engineering and design qualities and efficiencies.

Examples discussed in this paper clearly shows that all attempted (and quite well-achieved) the requirement of being biomimetic in organism level, behavior level and ecosystem level. These examples encourage designers and researches to further study nature. In this context, biomimesis is a prominent approach to develop new and innovative solutions for forms, structural, mechanical systems, energy efficiency and more. It can also serve to develop processes and related systematics and methodologies for environmentally friendly structures/artifacts, as can be observed in structures/forms in nature.

Despite all the potentials of biomimesis in architecture, number of studies and designs inspired by the nature is still limited. Current examples in architecture, related with Biomimetic sustainability, are still quite individual and sporadic due to the lack of systematic designing criteria for architecture and that avoids being a discipline as in other research and implementation areas like engineering, medicine and agriculture. Architects, who want to be aware of “next technological wave” arising from advances in technology and science as a consequence of observing nature and its phenomena, and who want to design such advanced, high performance buildings manifesting the features of this era to which they belong, have the possibility to study the “nature-architecture” relationship using methodologies provided by the new discipline of Biomimesis.

5. References