BIO-TECH RETROFITTING TO CREATE A SMART-GREEN UNIVERSITY

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ABSTRACT

Over the past century, architects have been attempting to dominate nature with the aid of technological development, machines, and high consumption of energy; so the gap between nature and the built environment was expanded. During the last few decades, there was a dramatic change in the way of thinking, shifting from the information age to the knowledge society with new multidisciplinary sciences. Nature is continuously motivating human accomplishments and has led to efficacious materials, structures, and processes and the outcomes have made a great difference in the survival of future generations and proceeded to secure a sustainable future. So, what if nature, contemporary sciences, and technology are mixed creating new architecture designs and materials to achieve a sustainable green built environment and smart buildings that conform to the requirements of the 21st century? A comprehensive review of utilizing biotechnology in retrofitting universities' architectural design is discussed that reflects the modern worldwide technological movement to create an eco-friendly university with modern educational methods through the studying and analysis of biology and contemporary scientific technologies as significant tools for creating a sustainable bio-tech architectural design and construction for a university to create a smart educational environment.

Keywords: biomimicry, biotech architecture, sustainability, retrofitting, biomaterials, ecological architecture, bio-technology, smartness.

1 INTRODUCTION

The sustainability concept in universities has been a main concern in the last two decades. University is an important place for promoting sustainable concepts to improve environmental and moral understanding, values and attitudes, abilities, and habits toward sustainable development.

Biomimicry, biotechnology, and biomaterials are alternative solutions, in a way of seeing and esteeming nature, based not on what we can extract from nature, but on what we can learn from it. It may alter the way the architectural designer thinks of the external forms to design buildings and assist the earth to decrease pollution and reduce the global warming impacts.

2 BIO-TECH ARCHITECTURE

"The genius of the human may be able to make a lot of inventions and achievements, but it would neither be more beautiful nor simple than that of the nature because the nature does nothing that is not necessary or is not required" (Leonardo Da Vinci) [1].

Biotechnology is defined as any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for a specific use or solve problems and make useful products [2].

2.1 Biomimicry

Biomimicry from bios, meaning life, and mimesis, meaning to imitate, so "Biomimicry" means simulations of life means simulation of the environment and the living organisms surrounding us through mimicking the biology and ecology. Biomimicry is a path to a

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sustainable future [3]. It's defined as a new discipline considering nature's best thoughts and simulating these ideas and design processes to unravel human issues [4].

2.1.1 Biomimicry categories (levels)

Biomimicry was broken down into three different categories or "levels"; organism, behaviour, and ecosystem [5].

2.1.1.1 Organism level (natural form)

Alludes to simulating a specified organism; the whole living being or a parcel of it. This level of Biomimicry took the mechanism that's found within the creature itself and mimicked it to create a sustainable solution to a problem [5].

An example: The Hydrological Centre of Namibia University. As Namibia is a dry place; the design tried to mimic the same type of technology used by the Namibian beetle [5]. It lives in a derelict desert with rare rainfall so it tries to find another water source. There are bumps on the beetle's shell which are hydrophilic (water-attracting); they act as channels or groves for water and dampness. On a hot day, it's exposed to the sun and its dark shell retains a large parcel of the heat. When night falls, it comes out from underneath the ground and climbs high to a mound and holds up for the morning. When the morning haze rolls in, water beads from the haze are combined and collected on the dark shell; then the beetle tilts its back and the droplets run down into its mouth [6].

Figure 1: The Namibian beetle [6].

The building was designed to turn water droplets collected from the fog into usable water. It has a series of pods that are positioned behind a tall, slightly-curved nylon mesh screen-oriented towards the ocean which is used to collect as much moisture as possible from the fogs. By the mesh screen shape and its vertical position, the water runs down into the canal framework found at the bottom of the screens. The water at that point is transported into huge cisterns that keep it at a suitable cool temperature so that it wouldn't dissipate [5].

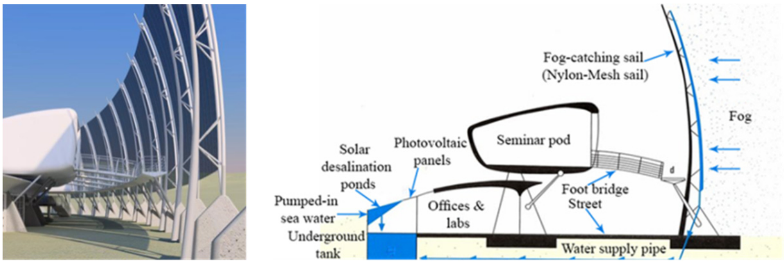


Figure 2: The fog-catcher, the University of Namibia [5].

2.1.1.2 Behavioural level (natural process)

Not mimicking the organism, itself, but its behaviour or act that is done by the creature to outlive or reproduce in connection with the large context [5]. It may be possible to mimic the relationships between organisms or species in a similar way [7].

An example: is adaptive fitting glass; a unique technology that simulates the skin of the Namaqua chameleon [8]. The Namaqua chameleon is found in the Namibian Desert. The average temperature from November to March is about 32°C but at night, the temperature drops to 7°C. The chameleon, to regulate its temperature, can alter its cover colour depending on the sun's position. Where ever the sun is shining, it changes that half of its covering skin to a darker colour to retain heat, whereas the other side turns to a lighter colour to prevent the heat from getting away from its body [5].

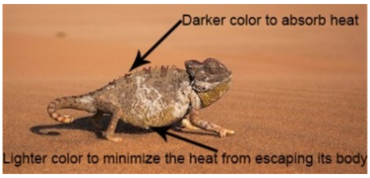


Figure 3: The Namaqua chameleon [9].

Adaptive fritting provides a surface of controllable transparency that can modulate between opaque and transparent states; by shifting a series of fritted glass layers so that the graphic pattern alternately aligns and diverges [9]. This is an innovative way to not only control transparency and light that enters a space but also can control heat gain [8].

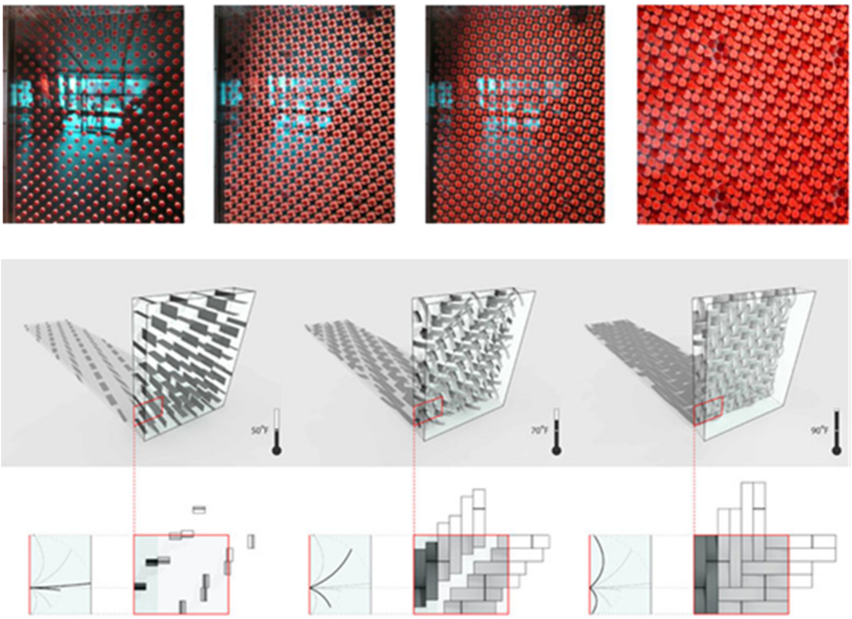


Figure 4: Shifting of adaptive fritted glass layers in different temperatures [8].

2.1.1.3 Ecosystem level (eco mimicry)

Refers to mimicking a specific ecosystem and how it works successfully as well as what elements and principles are required for it to work [5].

An example: The carbon-neutral Utopian Village (coral reef project), Haiti. Haiti was a victim of devastating earthquakes where homes and communities were destroyed by those natural disasters [5]. The architect Vincent Callebaut looked at nature and investigated the principles behind coral reefs. It is submerged structural formations from calcium carbonate, they are domestic to numerous marine creatures; conjointly offer assistance to adjust the underwater ecosystem, it grows in a dynamic shape, and each piece of coral is unlike the other. Callebaut was interested in the non-uniform shape and the arrangement of the reefs and utilized this as the base of his design [10].

Figure 5: Coral reefs [11].

The overall design is displayed as a living structure that can grow and house over a thousand Haitian families. The housing shows up as two waves that undulate all through the man-built pier, which was built on seismic piles to endure seismic impacts from the tremors. A valley of gorgeous green terraces and organic gardens is in between the two waves to form a space that embraces the community and culture of Haitian society. The module comprises two passive houses, with a metallic structure and tropical wood elevations, which interlock in a duplex around the horizontal circulation which joins every unit. When these houses, or modules, are collected together, they form the two waves shape of the coral reefs. Since they were planned in this way, the modules can cantilever out over one another which allows a natural cultivate-garden to present on every module to use the roof of the underneath unit as a planted surface that can serve each family to cultivate and grow their food, making them self-sufficient [10].

Figure 6: The two waves of the Coral Reef Project Haiti [10].

Figure 7: The passive units with the organic gardens [10].

Moreover; the project has hydro-turbines placed underneath the pier. The hydro-turbines transform the kinetic energy from the sea into electrical energy. Photovoltaic panel arrays are set on the top roofs to capture solar energy. These all are working together as one, to create a self-sufficient village [10].

Figure 8: Self-sufficient village [10].

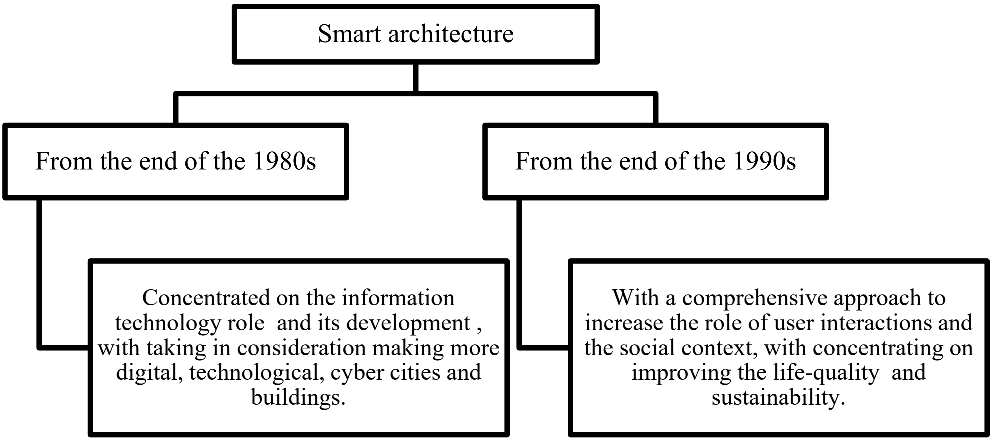
2.2 Smart/intelligent architecture

Smart building is the one that accommodates the latest technologies to respond to the demands of the user and adapts to the internal and external conditions. The smart building not only accommodates the latest existing technologies but is also capable to accommodate any new technology that appears later [12]. It ought to be sustainable, healthy, technologically aware, meet the requirements of inhabitants and businesses and must be flexible and versatile to deal with changes [13].

The concepts “smart city” and “smart building” appeared in the 1980s and were developed together. Smart buildings are the key block of smart cities [14], it depends on using computers and artificial intelligence, but in ancient civilizations, the buildings were based on pure and applied sciences like chemistry, physics, mathematics, geography and astronomy [12].

2.2.1 Smart architecture approaches

The approaches of smart can be grouped into two phases:



Concentrated on the information technology role and its development , with taking in consideration making more digital, technological, cyber cities and buildings.

With a comprehensive approach to increase the role of user interactions and the social context, with concentrating on improving the life-quality and sustainability.

Figure 9: Smart architecture approaches [16].

2.2.2 Development of smart buildings

A significant developing change has been seen in the smartness of buildings in the last years and a great development is predicted in the next buildings' generations that the future building can be a thinking building. Here is a comparison between old, recent, and future smart buildings through their bounds, as shown in Table 1.

Table 1: Development of smart building [14].

Building category	Intelligent buildings	Smart buildings	Thinking buildings
Control flow	Reactive	Adaptive	Predictive
Comfort and efficiency information input	Systems and data integration	Enterprise integration and building as a system approach	Undefined/ambiguous data
Occupant interaction and efficiency	More control, higher efficiency	Inherent control, higher efficiency	Predictive control, higher efficiency
Material and construction	IP backbone used to integrate building service systems	Further integration using middleware, and adaptive building structure with reactive features	Future technology, control hardware, software and materials
Interaction of operation with occupants	Ability to react to occupancy data in real-time	Building operation defined by and adapted to building occupants	Effective operation based upon predicted used by occupants for a specified function

2.2.3 Smart building basic elements

The smart building provides a productive and cost-effective environment through the optimization of the four basic elements: structure, systems, services, and the relationship between them [15].

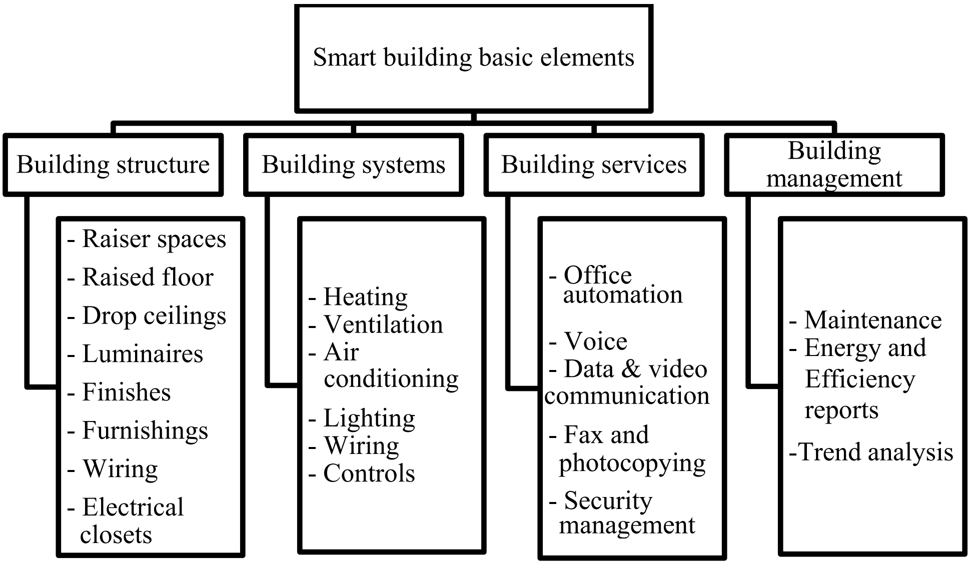


Figure 10: Smart building components [15].

2.2.4 Smart building components

The fundamental components of the smart building that affect its degree of intelligence are:

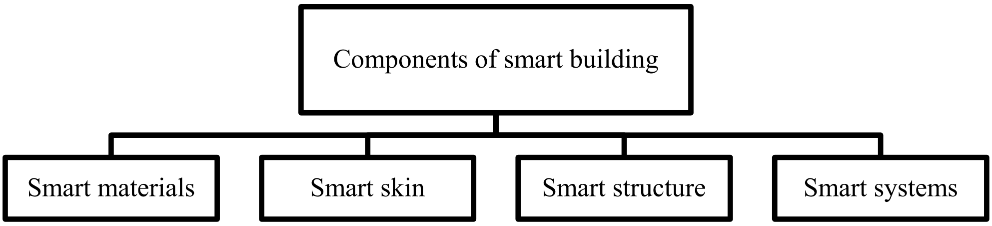


Figure 11: Smart building components.

2.2.4.1 Smart materials

Some actuators and electronic models are distributed through the material to develop its material properties; so it would be able to respond to the changes happening around them and interact with them [17].

Example: Self-healing polymer material; when a crack propagates through the material, one of the most effective approaches is to consolidate microcapsules that are filled with a healing agent fluid, polymerization of the healing agent is activated by contact with an embedded catalyst, so the crack faces are bonded [18].

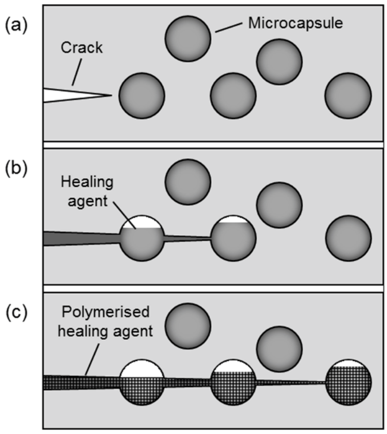


Figure 12: Schematic of the self-healing process using embedded microcapsules [18].

2.2.4.2 Smart skin

Can be applied by integrating sensors and controllers within the building's outer skin to control the climate change inside and outside the building (climate organizer skin) [19].

Example: Thermo bimetal. A strip of two metals with distinctive expansion coefficient (lamination of two different metals together), this technical term is called flexivity. When it is heated, one side will expand faster than the other as it has two different coefficients of expansion, and result in a curling action. So when the surface gets hot, the thin panels of the shade twist up to permit more air to pass through to the underneath space and when it cools down, it closes up once more [19]. The entire surface can react differently depending on how the sun moves across the building [20].

Figure 13: Thermo bimetal [19].

2.2.4.3 Smart structure

It can also be called intelligent structure, adaptive structure, and functional structure; is defined as a structure which can sense the outside boosts such as pressure, velocity, density and temperature changes and respond in a controlled manner in real-time. It consists of four key elements: actuators, sensors, control strategies, and power conditioning electronics [21].

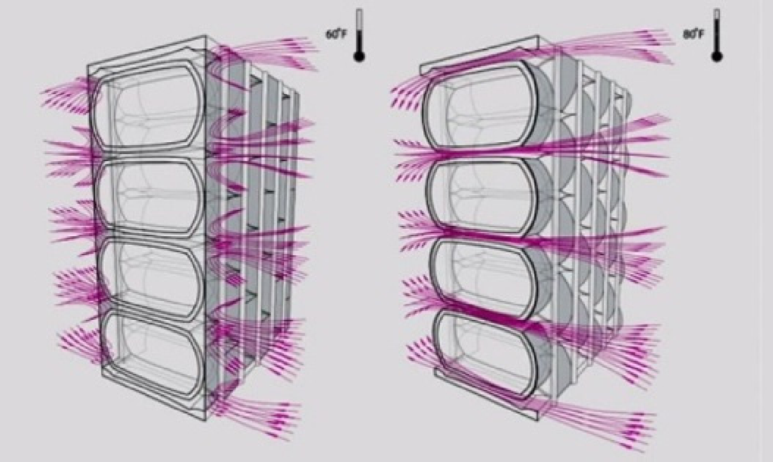


Figure 14: Thermo bimetal reacting with sun heat [20].

Example: SMA (shape memory alloys). Alloys which remember their authentic shapes. SMA have a couple of phases: austenite and martensite. In the austenite phase, SMA behaves like metals having higher Young modulus depending on the well-pressed crystalline structure; while in the martensite phase, SMA behaves like elastomers due to losing packed crystalline structures. When heat or force is applied to shape memory alloys they alter from austenite phase to martensite phase or vice versa through heating and cooling [22].

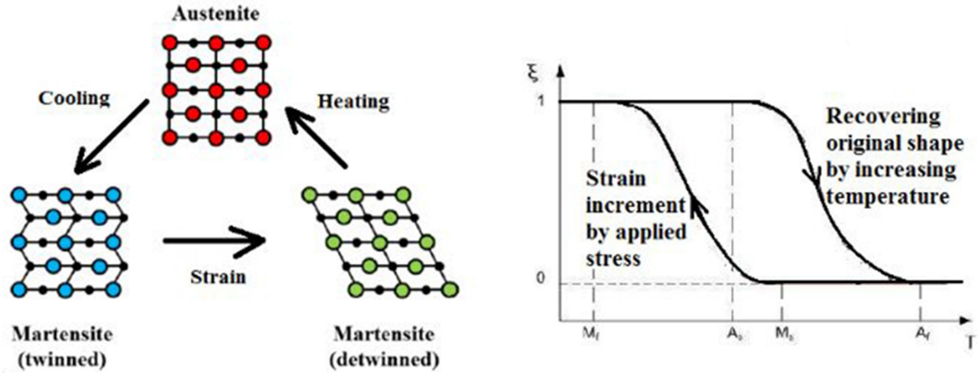


Figure 15: Shape memory effect of SMA materials [22].

SMA actuators were embedded in laminates (e.g., glass/epoxy and Kevlar®/epoxy prepreg) to obtain self-actuating structures [23].

2.2.4.4 Smart systems

To produce economic and environmental benefits for the building's proprietors by the combination of IT and building automation systems; these incorporate broad sensors and actuators systems, networking and communication systems, software platform systems, HVAC systems, and smart control gadgets [24].

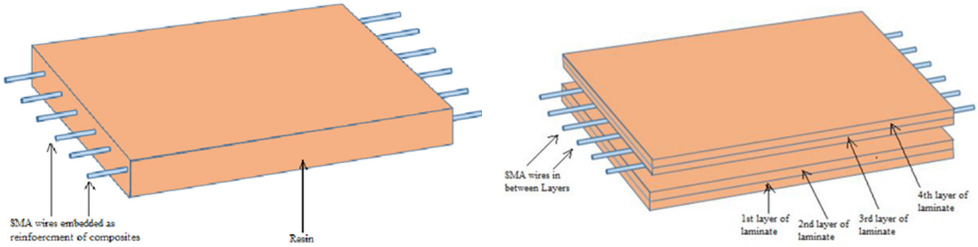


Figure 16: SMA wires embedded as reinforcement [23].

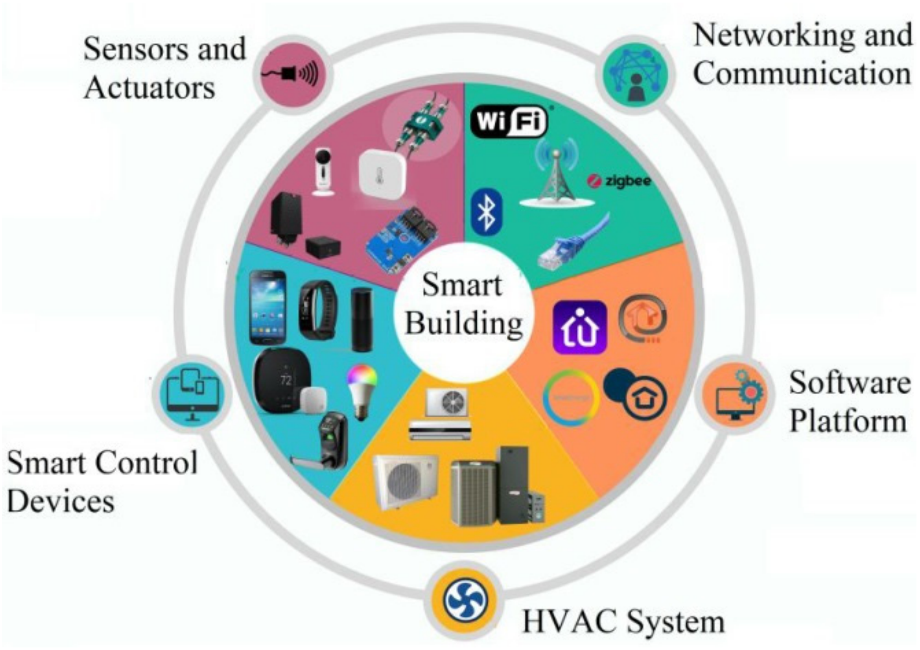


Figure 17: Smart systems in smart buildings [24].

3 SMART-GREEN UNIVERSITY

3.1 Objectives of creating a smart-green university

The desired results that are to be obtained [25]:

- To diminish the consumption of energy.
- To decrease the holding up times of taking advantage of campus facilities.
- To progress the staff efficiency.
- To increase the classroom education quality.
- To guarantee the contribution of all campus users to problem distinguishing and solutions.
- To analyse public resources utilization by analysing all data collected.

3.2 Smart-green university framework

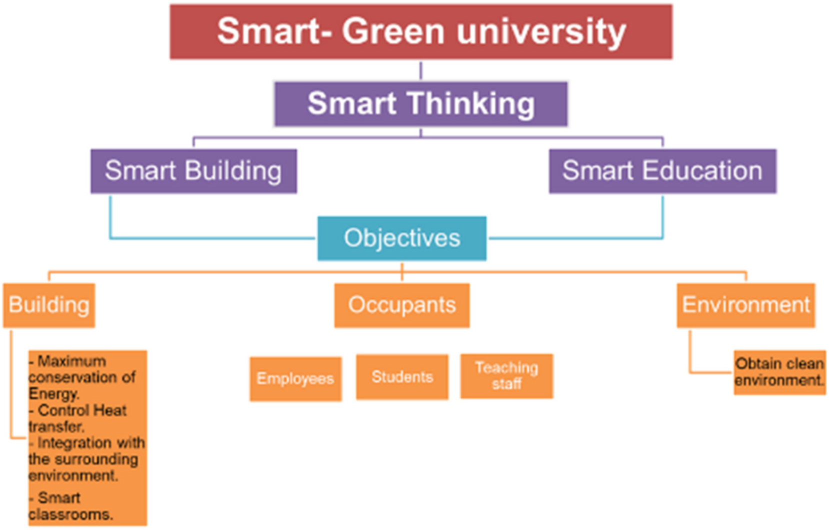


Figure 18: Smart-green university framework.

4 CONCLUSION

A strategy can be developed based on a more progressive approach toward sustainability. The green university campus Framework targets different levels of green campus development that are reasonable for the modern ages. Eventually, universities can work in an adaptable way to perform an adequate policy to attain the green, sustainable and smart concept based on their capabilities, needs and imperatives that are context; particularly; within a progressive scope.

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REFERENCES

[1] Pufendorf, B.S.V., *Of the Law of Mature and Nations*, Clarendon Press: Oxford, 1672, reprinted 1934 and 1995.
[2] Elsamny, M., Advanced technologies in architecture biological nanoarchitecture (BNA). PhD thesis, Department of Architecture, Faculty of Engineering, University of Alexandria, 2013.
[3] Faragallah, D.E.S., Biomimicry in interior design. MSc thesis, The Décor Department, Faculty of Fine Arts, Alexandria University, 2011.
[4] Benyus, J.M., *A Biomimicry Primer*, Biomimicry Institute, 2011.
[5] Maglic, M.J., Biomimicry: Using nature as a model for design. MSc thesis, Department of Art, Architecture and Art History, University of Massachusetts, Amherst, 2012.
[6] DeYoung, D. & Hobbs, D., *Discovery of Design: Searching Out the Creator's Secrets*, Master Books, 2009.

[7] El Ahmar, S.A.S., Biomimicry as a tool for sustainable architectural design towards morphogenetic architecture. MSc thesis, Architecture Department, Faculty of Engineering, Alexandria University, Egypt, 2011.

[8] Drozdowski, Z. & Gupta, S., *Adaptive Fritting as Case Exploration for Adaptivity in Architecture*, Hoberman Transformable Design, 2009.

[9] Carpenter, A.I., *Chamaeleo namaquensis, Namaqua chameleon*, The IUCN Red List of Threatened Species, 2015. https://www.iucnredlist.org/species/176311/7215782. Accessed on: 12 Apr. 2022.

[10] Callebaut, V., *Coral Reef, Matrix and Plug-In for 1,000 Passive Houses Port-Au-Prince Haiti*, 2011. http://vincent.callebaut.org. Accessed on: 25 Mar. 2022.

[11] National Geographic. https://www.nationalgeographic.com/. Accessed on: 21 Apr. 2022.

[12] Saad, B.S., Abou Al-Einen, E.B. & Abo El-Azm, F.M., The impact of using smart architecture on architectural creativity. *Port Said Engineering Research Journal*, **20**(1), 2016.

[13] Buckman, A.H., Mayfield, M. & Beck, S.B.M., Smart and sustainable built environment: What is a smart building? **3**(2), Emerald Insight, 2014.

[14] Beevor, M., Smart building initiatives are the building blocks of a smart city. IOT For All, 8 Apr. 2020.

[15] ELkiki, N.A.A., Smart architecture techniques for processing the optical environment in university spaces. MSc. thesis, Ain Shams University, 2015.

[16] Bašić, S., Strmo, N.V. & Sladoljev, M., *Smart Cities and Buildings*, Gradevinar, 2019.

[17] Frighi, V., *Smart Architecture: A Sustainable Approach for Transparent Building Components Design*, Springer, 2021.

[18] McDonald, S.A., Coban, S.B., Sottos N.R. & Withers, P.J., Tracking capsule activation and crack healing in a microcapsule-based self-healing polymer. Scientific reports, *Nature Research*, 28 Nov. 2019.

[19] Rajani, K., 8 Smart building skins that are revolutionary, 27 May 2017. https://khyatirajani.wordpress.com/2017/05/27/8-smart-building-skins-that-are-revolutionary/. Accessed on: 18 Dec. 2021.

[20] Huq, O., Breathing buildings. *Architecture Hacker*, 6 Oct. 2015.

[21] Chopra, I., Review of state of art of smart structures and integrated systems. *AIAA Journal*, **40**(11), 2012.

[22] Barbarino, S., Flores, E.I.S., Ajaj, R.M., Dayyani, I. & Friswell M.I., *A Review on Shape Memory Alloys with Applications to Morphing Aircraft, Smart Materials and Structures*, IOP Publishing, 2014.

[23] Baitab, D.M., Abdul Majid, D.L.A.H., Abdullah, E.J. & Abdul Hamid, M.F., A review of techniques for embedding shape memory alloy (SMA) wires in smart woven composites. *International Journal of Engineering and Technology*, 2018.

[24] Qolomany, B., Al-Fuqaha, A., Guptam, A., Benhaddou, D., Alwajidi, S., Qadir, J. & Fong, A.C., *Leveraging Machine Learning and Big Data for Smart Buildings: A Comprehensive Survey*, IEEE, 2019.

[25] Kostepen, Z.N., Akkol, E., Dogan, O., Bitim., S. & Hiziroglu., A., A framework for sustainable and data-driven smart campus. *22nd International Conference on Enterprise Information Systems*, January 2020.