

The Innovative Application of Eco-Technology in Architectural Design

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Abstract: Technology brings a significant power in building development. While it is true that we often place more emphasis on technology in design but ignore the negative environmental problems it produces, innovative design can reduce this adverse impact. Therefore, this study studies the innovative application of eco-technology in architectural design. This study utilized qualitative methods and different cases were represented as models classifying ecological technology. Referring to Brand pointed out the 6S's of architectural elements as a criterion, we attempted to identify elements affected by technological innovation and their relationship with geographical region through comparative analysis. Results indicated that the elements of service equipment, structure and skin are more likely to affect technological innovation and that technological innovation is limited by regional development. Essentially, developed countries actively employ ecological high technology and passive technology while developing countries prefer the latter. Finally, we administered questionnaires to verify the results obtained in the theoretical analysis. In future studies, we aim to concentrate on contextual innovation.

Key words: Innovative application, high eco-tech, passive eco-tech, architectural design, sustainability

INTRODUCTION

Technology plays an important role throughout the history of architecture development (Edwards, 2001). Building design and technology have a very special relationship since without the technologies to achieve the constructed form architecture would exist only in our minds (Emmitt, 2013). However, technology is a double-edged sword, not only possessing building power but also destructive ability. "In particular, the focus in best technical practices tends to result in an interpretive squeeze in which problems amenable to technical fixes are foregrounded at the expense of a range of other environmental concerns" (Guy and Farmer, 2001). Therefore, a consensual view of environmental and technological change wherein a progressive process of innovation decreases the adverse impacts of development is required (Blowers, 1997).

The term architectural innovation denotes the recombination of existing components to obtain a new product design or technical and organizational structure without leaving the well-established technological development path (Hirsch-Kreinsen, 2015). The essence of architectural innovation is the reconfiguration of an established system to link existing components in a new way (Henderson and Clark, 1990).

Recently in this area, there are several specific technology innovation applications in architectural design for individual cases. As Foster and Partners indicate (Crysler *et al.*, 2012): "the focus is on technological ingenuity, utilizing the latest materials, computer aided design and controls, intelligent climatic control and energy-generating technologies to create smart buildings that act autonomously to generate power, modify climates, deal with waste and actively mediate technonatural relations". Most research and writing on creativity have focused on such individual creativity (Smith, 2003).

The aim of this study is to discover which architectural elements affect higher innovation and the relationship between technological innovations and geographical regions by analyzing different technology innovation cases, further evaluating technology innovation.

MATERIALS AND METHODS

Research objects: Sustainable environment design technology comprises two aspects: high eco-technology and passive eco-technology. In exploring these cases, we illustrate how each technological choice functions within a specific design strategy.

High Eco-technology: “High-Eco is high-tech” was submitted at the 2000 Hannover World Exposition. That is ecological architecture is inseparable from high technology making it a powerful driving force for the development of ecological architecture. Eco high technology refers to architectural designs that employ modern high-tech means, new materials and construction technology to optimize the physical properties of buildings, ensuring coordination between buildings and nature. While the material and energy consumption tends to be recycled and reused, the high-tech position forms a branch of this reformist ecology, promoting science and technology as solutions for repairing ecological damage without inhibiting consumerist lifestyles or world views (Crysler *et al.*, 2012). Here three typical high-tech cases were represented, namely high-tech, high-tech and high emotional, high-tech and cultural integration, respectively.

Centre Georges Pompidou, France (CGP): Seminal buildings such as Paris’s Centre Pompidou embody the high-tech architectural movement (Slessor and Linden, 1997). It is made of steel pipes and glass tubes with an exposed skeleton of brightly colored tubes for mechanical systems. Characterizing architectural vocabulary, it focuses on the importance of modern mechanical equipment, structures and pipes including abstract technical language and color-coded functional structural elements to create a prominent effect in the traditional environment. Therefore, since it concentrates primarily on technical performance skills and lack of emotion, it has become the focus of debate.

Tjibaou Cultural Center, France (TCC): This architecture was constructed with modern technology through the study of local dwelling customs and the structure and function of high-footed scaffolding by employing the “weaving” building concept and selecting original material. Specifically by reducing the height, the vertical elements were more exposed in the upper portion, increasing the ventilation effect thereby reducing heat. A clear “dot and line” model was employed in the space layout, making the building well arranged from a distance it looks like sails while a closer perspective presents an indigenous headdress, harmonious with the sky, sea and trees. It has been noted as “showing a combination of high technology and high emotion” (Edwards, 2001).

Arab World Institute, France (AWI): A typical high-tech building focuses on the application of two modern materials, steel and glass and the corresponding building technology during construction. To achieve this, the south facade of the building consists of high-tech, photosensitive mechanical devices that control the light

levels and transparency. It uses a geometric hole like a camera aperture; aluminum is utilized through the internal mechanical drive aperture to open and close it, adjusting the amount of light in the room based on the weather. This aperture device is not only a technical lighting measure but also a metaphor for Arabic culture whose symbols are cleverly integrated into the architectural context.

Passive eco-technology: Innovation is often associated with high eco-technology. However, passive eco-technology is also a field of intense innovation where architectural designs meet the user’s needs by employing orientation, wind direction, sunshine, materials, building layout, etc., to improve energy efficiency. Passive eco-technology covers a considerable part of traditional technology, low-tech, intermediate technology, suitable technology and other concepts and is a direct expression of the modernization of traditional technology. Here are three typical examples of passive eco-technology: traditional technology, low-tech and low-tech-based combination of energy-saving technology.

Wind tower of New Gournia Village, Egypt (NGV): Low technology can be used to solve problems in developing countries. Traditional builders in the Middle East often employed wind towers to capture high-level airflow that was clean and powerful (Frederic *et al.*, 2012). This method leads the airflow to interior spaces through a series of designs. The wind tower can provide fresh air to various rooms. This traditional and effective natural ventilation method ensures local dwellings are cool and comfortable under hot conditions. In the representative works of Hassan Fathy, the new Gournia village, architects updated the ventilation of traditional buildings with this ingenious design.

Earthship Home, America (EH): Mike Reynolds of Taos, New Mexico builds passive solar houses made of natural and recycled materials called Earthships. Since, electrical energy is not employed for heating and cooling, the interior temperature is regulated by thermal mass and passive solar heating and cooling properties. They use recycled material or commonplace scrap items such as earth-rammed tires, aluminum cans and plastic bottles. The load-bearing, earth-rammed tires are wrapped with soil to provide rigid insulation around the building. Non-load-bearing walls comprise a honeycomb of recycled cans made from concrete or “bottle-can masonry” (Nathaniel, 2016). Given the fundamental concept, it is entirely pan-regional, applicable worldwide.

Barclaycard Headquarters, UK (BH): This is a successful ecological building utilizing passive building design combined with advanced energy-saving technology (Edwards, 2006). Making the maximum usage of sunlight, the South of this building uses adjustable louvers to reduce direct sunlight and utilizes natural ventilation to minimize the usage of fans. Meanwhile, using an innovative cavity floor to make the layout of the building space flexible, the building does not obstruct natural ventilation. The roof panels are exposed to avoid air conditioning, absorbing the heat during the day and emitting the cold at night. The installation of a comprehensive and effective intelligent lighting system automatically compensates for the daylight level and the lights are controlled separately.

RESULTS AND DISCUSSION

Promoting the innovation of architectural design is not primarily for the development of science and technology but rather aims at breaking through building structure, technology and construction craft to affect design innovation (Tao, 2007). As Brand (1995) points out: a building properly conceived is several layers of longevity of built components. There are “six S’s” as Fig. 1 demonstrates.

Site: The geographical setting or urban location, legally defined as a lot whose boundaries and context surpass generations of ephemeral buildings.

Structure: “The foundation and load-bearing elements are perilous and expensive to change; their structural life ranges from 30-300 years”.

Skin: The exterior surfaces that now change every 20 years or so to sustain technology, style or large-scale repair.

Services: The working cores of buildings such as electrical wiring, plumbing, HVAC (Heating, Ventilation and Air Conditioning) and elevators that might wear out after 7-15 years of construction.

Space plan: The interior layout such as walls, ceilings, floor, doors, etc. which meet basic functional need.

Stuff: “Chairs, desks, pictures, kitchen appliances, lamps, all the things that twitch around daily to monthly”. The technology innovation in the design application of the earlier-mentioned six buildings and space objects were observed based on these six aspects. The results are

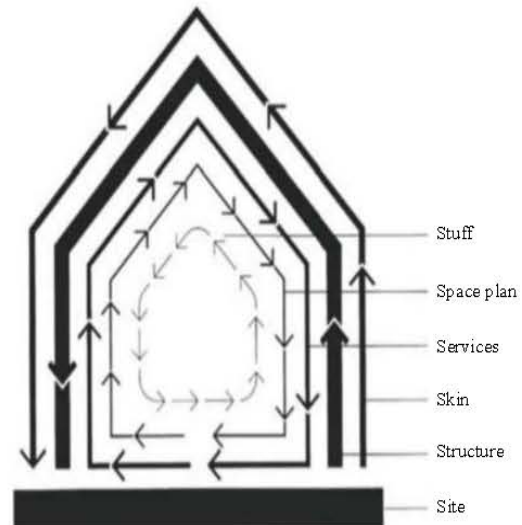


Fig. 1: Six parts to any building structure

presented in Table 1. Our survey indicated that the innovative application of eco-technology in architectural design was obtained in two directions: affected elements and geographical region.

Service, structure and skin are most affected by technology innovation: The results of observing the objects of study indicated six points related to technology application on the aspects of site, structure, skin, service, space plan and stuff. The maximal application of technological innovation was on the service aspect with 4 of 6; the second was structure with half; the skin aspect accounted for 2 of 6; the space plan and stuff aspects were both 1 of 6 while there was no innovation on the site aspect. The top three aspects were service, structure, skin.

Technological innovation is important for service equipment. Without excellent service equipment, it is difficult to make a major breakthrough in innovation. The rapid development of technology is easily reflected in service. Relevant service equipment innovation include lighting system, heating, water supply and drainage and fire technology system innovation (Tao, 2007). Continuous improvement and innovation alone can contribute to high-speed development for large spaces and other building types, ensuring comfort and saving energy.

As the main portion of building support, the structure of building construction innovation plays a role in restricting and promoting which has become the subject of intense study as they promise to play an

Table 1: The innovative application of technology on case studies objects

Name	CGP	TCC	AWI	NGV	EH	BH
Region categor	France high-tech	France high-tech and high-emotion	France high-tech integrate culture	Egypt traditional-tech	American low-tec	UK low-tec and energy-saving tech
Site	-	-	-	-	-	-
Structure	✓	✓	✓	-	-	-
Skin	-	-	✓	-	✓	-
Service	✓	-	-	✓	✓	✓
Space plan	-	✓	-	-	-	-
Stuff	-	-	-	-	-	✓

important role in technology (Leydecker, 2008). In the technological innovation of architectural design, the structural factors of creative research may enhance the attractiveness of a building through the innovation of shape and image. For example, we use structural bionic technology as well as the structure of the system to design corresponding architectural structures. The application of this bionic technology can enhance the stability and robustness of the structure and increase creativity as well.

Innovation in skin technology is primarily reflected in the creative breakthrough of new materials whose radical properties were successfully studied to be applied in architectural material. New species have properties that should be able to fulfill some of the exciting new developments promised by 21st century technology (Leydecker, 2008). Therefore, new technological innovations bring new material innovations that in turn produce new technological innovations. We can study new materials from the perspective of design and through their touch and vision, develop creative designs for new buildings to enhance a sense of architectural art.

Technology innovation is related to geographical region:

As Table 1 shows high technology is connected to developed countries (e.g., France, America, UK) while passive eco-technology is related to developing and developed countries (e.g., Egypt).

Technological innovation in design is compatible with the standard of regional development. In general, the geographical region is constrained by the degree of economic development. Following the accumulation of long-term industrial development, the standards of developed countries in social material and technical level has been quite high. In this case, they still make an effort to develop science and technology as well as focus on various technical means including low-tech design.

Meanwhile, in developing countries like Egypt where the economy is trailing behind and actual material conditions are poor, they employ the “low-tech”

Table 2: Creativity evaluation

Cases	CG	TCC	AWI	NGV	EH	BH
Practicality	4.00	3.93	4.20	4.00	4.33	3.87
Originality	3.80	4.20	4.13	3.73	4.00	3.80

approach to solve building problems based on local characteristics to ensure localization. As Edwards (2001, 2006) mentioned: “Asia and Africa act out good green practices by instinct and their point of reference is not Newton of Einstein but the local wisdom keeper. As a general statement, the spiritual approach to green design is found in the underdeveloped world and the low-energy, high-material approach in the developed”.

To summarize, the research findings on technology innovations prove convincingly that it is connected with specific local conditions including economic levels, technical strength, ethnic customs and climatic conditions.

Reflection: We utilized questionnaires to obtain views from 30 respondents regarding which are the higher elements in innovative technology in architectural design and to verify the results indicated in Table 1. Questionnaires were conducted face-to-face and through online surveys in PowerPoint using colorful pictures and text. Designers and teachers with backgrounds in architecture and interior design were invited to participate to evaluate higher creativity.

In the field of creativity studies, it is generally acknowledged that there are two major components of creativity. The first is novelty and the second is value or usefulness (Runco and Pritzker, 1999). Design results were evaluated based on the method proposed by Finke *et al.* (1992) that is from the two viewpoints of practicality and originality on a five-point scale. The aim was to discover which cases scored higher in terms of creativity. Table 2 shows the average rate for each case.

According to the creativity criterion, originality is high among EH, AWI and CGP while TCC, AWI and EH are higher in practicality. To judge the scores accurately, we used a stacked bar (Fig. 2). Therefore, EH and AWI

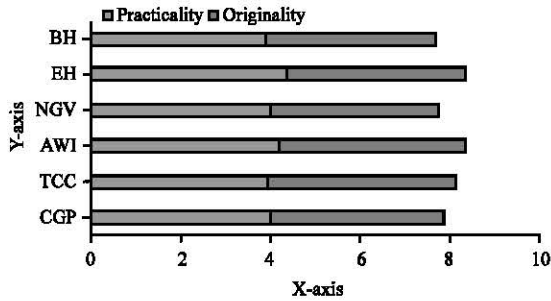


Fig. 2: Creativity evaluation for six cases

which represent service, structure and skin, more easily affect technology innovation, making it consistent with the previous analysis.

CONCLUSION

In the six case studies presented above according to the eco-technology categories, this study focuses on the innovative application of technology in architectural design. Analysis of which elements predominantly affect technological innovation indicated that service, skin and structure most effortlessly display higher innovation. In addition, technology innovation is affected by geographical region. Passive eco-technology is related to developing and developed countries while high technology is connected to developed countries. Finally, we administered questionnaires to justify the results obtained in the theoretical analysis. Acknowledging how a technical, performance-based method to understanding architectural design has been beneficial, we should consider how technological change affects social and cultural processes and practices as well (Guy, 2010). This implies not only focusing on technological innovations but also on the “human” element of eco-innovation such as those involving cultural and contextual transformation. In future studies, we will focus on contextual innovation.

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