Do Green Building Standards Meet the Biophilic Design Strategies?

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Abstract. Energy efficiency in buildings, comprises many things as mitigation effect of global warming and climate change, decreasing heat island effect in the built environment and also conservation of natural resources. Besides as a new phenomenon we should add biophilic design criteria to the green building tools to increase human productivity by considering human wellbeing. Biophilic design, which inspired by nature, is a new juvenile design concept that gains importance day by day because of its positive effects on human wellbeing mood and relatedly human productivity. Here some conflicts can be occurred between energy saving and human wellbeing; as natural ventilation and energy saving.

Biophilic design comprises inherent human inclination to affiliate with nature. All sensations which help to be in contact with natural components as daylight, plants or some animal species like birds; plants occupy an important place in its definition. Biophilic design seeks to create good habitat for people as a biological organism in the modern built environment that promotes people’s health, fitness and wellbeing. Scientific studies reveal that contact with nature has significant effects on people’s physical and mental health, performance and wellbeing. This phenomenon has, an increasing importance more than ever before, especially in daily life. The need for beneficial contact with nature continues in today’s built environment. This paper aims to determine whether the biophilic design strategies are match with green building tools that mostly targeting energy saving in built environment. Also paper handling whether the 14 biophilic design patterns are match with 3 main mind-body systems that are; stress reduction, cognitive performance and emotion mood preference.

Keywords: Biophilic design, natural systems, energy saving, green building tools, mind-body systems

The Term biophilia and biophilic design?
The term ‘biophilia’ was first used by social psychologist Eric Fromm (1964) at “The Heart of Man” and later popularized by biologist Edward Wilson (Fromm, 1964; Browing et al., 2014). The American biologist and entomologist, Edward O. Wilson, was the first to clarify the importance of contact with nature for the psychological development of people. Edward O. Wilson introduced and popularized the hypothesis in his book, “Biophilia”. He defines biophilia as "the urge to affiliate with other forms of life". The term biophilia means interact with other living systems and he describes the connections that human beings subconsciously seek with the other forms of life (International Well Building Institute, 2019); for millions of years our species was related to its wild environment, created a kind of dependency, an overwhelming emotional need to be in contact with other living beings. This inherent need was called Biophilia (Wilson 1984, 1993; Sanchez et. Al. 2018). The scientists Roger S. Ulrich and Stephen Kellert gave the final approach to the term Biophilia by defining it as "the innate human affinity for nature" (Sanchez, 2018).

Although the term biophilia, named by Fromm, has been proposed and defined over many times (Browning et al. 2014), it is also defined by
Kellert (2008) as an inherent human inclination to natural systems and processes and it urges us to affiliate with other forms of life (Kellert, 2008; Xue et al., 2019a). The concept of biophilia is the idea of human contact with nature. This connection has been thought beneficial for human physical and mental well-being. A study reveals the benefits of nature as healing effect (Reeve et al., 2017). As pointed out by Beatley (2016), nature is not optional, but an absolutely essential quality of modern urban life. The essential benefits of biophilia urges us not only to conserve and restore the natural elements that already exist but, insert new forms of nature for the twenty first century (Xue et al. 2019a; Beatley, 2016).

Biophilic design came in sight after the term biophilia. Alexander (2002) defines biophilic design as “integration” or sometimes “manipulation” of natural elements or systems to create sense of “life” in the built environment (Alexander, 2002). Biophilic design, defined as a response to the inherent need of human beings to be in contact with nature, improves productivity in the workplaces (Sanchez, 2018). Recently, the concept of biophilic design has received attention among practitioners and environmental psychologists (Lee, 2019). Kellert et al. (2011) explained that biophilic design inspires firms to use natural systems and processes in the design of the built environment. Biophilic design fulfills the human need for exposure to nature and several studies have shown benefits of natural features and systems into the built environment on people. Studies revealed that adding natural light and windows significantly improve participants’ mood (Kellert et al., 2011; Zadeh et al., 2014). This effect of biophilic design considered since it is related with human productivity. People’s concentration increases after they spend time in nature or even view scenes of nature; reduces stress, improves cognitive functions and creativity (Lee, 2019). As the world population continues to urbanize these qualities will be ever more important (Browning et al., 2014). The United Nations predicts that by 2030, 60% of the world’s population will live in urban environments (UN-HABITAT, 2019).

When the biophilic design considered to increase human productivity, the studies’ direction changes to follow those related subjects; Sutermeister (1976) defines performance as a quality considered output per employee hour. Accuracy and speed are the two distinct aspects to measure of human performance. Accuracy is defined as a measure of the quality of behaviour (Sanchez et al., 2018). Biophilic design modifies and apply the natural systems in the built environment for human wellbeing in many aspects and indirectly effects human performance. Biophilic spaces have been defined as spaces that strengthen life and support the sociological and psychological components (International Well Building Institute, 2019).

**Key strategies of biophilic design**

According to the biophilic design concept, 25 biophilic design strategies are identified by considering the related references. The key strategies of the Biophilic Design have been analysed and summarized as below table (Xue et al., 2019a).

| Biophilic Design Aspects | Indicators | Strategies | References |
|--------------------------|------------|------------|------------|
| Biophilic Infrastructure  | Biophilia ratio | Increase green space coverage ratio; Promotes plant canopy configuration for shading and sheltering; Enhance native species ratio; Enhance biodiversity level; | Barton and Pretty (2010); Xue et al. (2017b); Oldfield et al. (2015); Maes et al. (2016); |
Biophilic infrastructure is more related on quality than quantity. 

Sensorial design aspect, includes visual connection, non-visual connection, thermal comfort and airflow. Visual connections with nature are the most obvious methods of biophilic design and can be achieved through having window views of natural landscapes. Non-visual connections with nature engage the other senses such as through natural sound design, aromatic plant design natural elements related art works. Natural ventilation is another factor allows people to feel in-touch with nature.
Biophilic setting and performance aspect includes biomorphic forms and patterns and natural materials and colors. This creates a visual connection with nature with other benefits such as enhancing creativity (Xue et al., 2019a).

The visual connection with nature is an important strategy in the field of art, since implementation is relatively easier to create. Especially art works inspired by natural systems are in demand recently. This form of art combines natural daylight with natural inspired artwork. Stained glass designed by inspiration of natural cells structure, is used as the contemporary artwork in a public space, as shown in the example provided in Figure 1 and visual connection with water element that reflects light and weather conditions from above and invites by-passers to touch it, as in the example of the Luxembourg Gardens in Paris in Figure 2. Children or adults spend time by floating their wooden model sailboats and enjoy the pool’s climatic effect.

![Figure 1: contemporary stained glass art work inspired from cells by Ayşe G. Süter. Photo By: Pere Virgili (Süter, 2015).](image)
Biophilic design strategies and Green Building Ratio Tools (GBRTs)

Green Building Ratios are an indicator to measure green architecture. They are more focused on energy efficiency. How can we measure the biophilic designed space meets human wellbeing and improve productivity? This question’s answer is a challenge. Actually, there are many indoor stressors effective on human wellbeing and productivity, such as excessive thermal factors, lighting aspects, moisture, noise and vibration, radiation, chemical compounds, and particle fluctuations. In a place, a whole range of effects has been associated with these stressors that known as Sick Building Syndrome (SBS) (Sanchez et al., 2018). A research implemented in Keio University – which focused on the element that is most valued at the work environment - shows that in top five natural light was the most valued element, followed by indoor plants and vivid colours. Use of daylight is most effective on reducing the fatigue feeling.

Biophilic design strategies are added to the principles of Green architecture. In fact, biophilic design includes some of the green building standards but it targets not only energy saving but also human wellbeing, good mood and productivity. Biophilic strategies and their sub-relevant categories are matched with updated Green Building Rating Tools (GBRTs) as LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment) GM NRB (Green Mark Non-Residential Building), GBL (Green Building Label), WBS (Well Building Standard) and LBC (Living Building Challenge). The framework is used in a recent study to emphasize the shifting of GBRTs from the energy-oriented approach to a human-oriented approach through biophilic strategies (Xue et al., 2019b).
Table 2: Selected GBRTs

| Selected GBRTs | Classification |
|----------------|----------------|
| LEED           | Internationally most widespread, industry standard for sustainability (Shan and Hwang, 2018; Xie and Gou, 2017). |
| BREEAM         | Developed and employed in the local situations and are tailored to native climates and contexts: respectively China and Singapore (Hwang et al., 2016; Shan and Hwang, 2018; Ye et al., 2015; Zou et al., 2017). |
| GBL            | Innovative green building regulations which focus on human health and wellbeing. First protocol to address human wellness into the built environment (Morton, 2015). |

Each GBRT credit has been assessed in terms of its intent to improve human health and wellbeing. Some credits such as thermal comfort and air quality are dedicated to improving human health; these credits are easily identified as human-oriented credits. Some credits such as public transport and cycling have multi-purposes including reducing greenhouse gas emissions while improving health and wellbeing. These credits are also human-oriented credits. Other credits that are dedicated to energy efficiency and greenhouse gas emission reduction are excluded. Prominently, WBS and LBC have more credits on human health and wellbeing. The GBRT credits are generally grouped in 8 categories: Place, Transport, Energy, IEQ (Indoor Environmental Quality), Water, Material, Health and Management. The relationship between the 8 categories of GBRT credits and the 6 different GBRT’s are analysed in a cross-table by considering biophilic design strategies (Xue et al., 2019b).

As seen in Table 3.1 the biophilic infrastructure deals with essential comfortable conditions for human wellbeing as natural ventilation and day light.

Table 3.1: GBRTs matching with “biophilic infrastructure” design category and strategies (Xue et al., 2019b).

| Strategies                                      | LEED | BREEAM | GM        | GBL        | WBS | LBC |
|-------------------------------------------------|------|--------|-----------|------------|-----|-----|
| Increase green space coverage ratio;            | Place| Place  | Place     | Place      | Place|     |
| Promote plants canopy configuration for shading and sheltering; | Place| Place  | Place | Place | Place | |
| Enhance native species ratio;                   | Place| Water  | Place     | Place      | Place| |
| Enhance biodiversity level;                     | Place| Place  | Place     | Place      | Place| |
| Enlarge water area;                             | Place| Place  | Place     | Place      | Place| |
| Diverse water configuration and appearance;     | Place|        | Water     |            |      |     |
Natural landscape promotion with minimal management; | Water | Place | Place | Place | Place |
---|---|---|---|---|---|
Permeable surfaces for storm water management; | Place | Water | Place | Place | Water |
Enhance natural ventilation and airflow design; | IEQ | IEQ | IEQ | IEQ | IEQ |
Enhance daylight and shadow design; | IEQ | IEQ | IEQ | IEQ | IEQ |

“Enlarge water area” biophilic infrastructure design category does not match any of the GBRTs and “Diverse water configuration and appearance” category just match with two of the GBRTs. In this table we can summarize just three of the credits as water, place and IEQ related with biophilic infrastructure design category.

Table 3.2 presents the sensorial design category of biophilic design strategies that match with GBRT credits like Place, IEQ (Indoor Environmental Quality) and Health.

Table 3.2: GBRTs matching with “sensorial design” design category and strategies (Xue et al., 2019b).

| Strategies | LEED | BREEAM | GM | GBL | WBS | LBC |
|---|---|---|---|---|---|---|
Optimize window view of the natural landscape. i.e. forest, seascape, water motif, etc.; | IEQ | IEQ | | | IEQ | IEQ |
Optimize window view of weather changes (i.e. the sunshine, rain, snow); | IEQ | IEQ | IEQ | | | |
Provide indoor potting plants; | | | Health | Health | | |
Provide indoor green walls; | | Health | IEQ | Health | | |
Provide observable artworks (i.e. painting, sculpture); | | | Health | Health | Health |
Natural sound design (i.e. the wind, song of birds and insects);

Aromatic plant design (i.e. certain trees and flowers);

Urban farming (i.e. plants-tasting and tasting activities);

Openable window for natural ventilation;

Individual/group thermal comfort controls (i.e. air temperature, air speed, and)

| Strategies                                      | LEED | BREEAM | GM  | GBL  | WBS  | LBC  |
|------------------------------------------------|------|--------|-----|------|------|------|
| Biomorphic building form and façade for energy cost reduction; |       |        |     |      |      |      |
| Biomorphic ornament design (i.e. Golden mean and Fibonacci series); |       |        |     |      |      |      |
| Surface pattern design from natural environment (i.e. pattern of animal skin); |       |        |     |      |      |      |
| Natural material selection, i.e. wood, bamboo, rock, etc.; | Material | Material | Material | Material | Material | Material |

Table 3.3. presents the relation to the built environment, through materials, textures, forms and structures. It is at this level where energy efficiency provided by the thermal insulation and ventilation is tackled.

Table 3.3: GBRTs matching with “Biophilic setting and performance” design category and strategies (Xue et al., 2019b).
Table 3.4 emphasized the fact that Place, Health and IEQ (Indoor Environmental Quality) credits are dominant in the transportation connectivity category of biophilic design strategies.

Table 3.4: GBRTs matching with “transportation connectivity” design category and strategies (Xue et al., 2019b).

| Strategies                                                                 | LEED | BREEAM | GM | GBL | WBS | LBC |
|---------------------------------------------------------------------------|------|--------|----|-----|-----|-----|
| Locate public bus/MRT station within 300m walking distance;              | Transport | Transport | Transport | Transport | Transport | LBC |
| Provide a fully connected pedestrian network;                             | Transport | Transport | Transport | Transport | Transport | LBC |
| Provide shaded corridors/bridges between buildings and districts;         | Transport | Transport | Transport | Transport | Transport | Place |
| Provide fully accessible and dedicated cycling lanes;                    | Transport | Transport | Transport | Transport | Transport | Place |
| Configure with bike parking facilities;                                  | Transport | Transport | Transport | Transport | Transport | Place |
| Configure with change room and shower facilities;                       | Transport | Transport | Transport | Place | Place |
| Provide landmark in public open space for attraction and gathering;      | Place | Transport | Transport | Transport | Transport | Place |
| Effective visual information system design for wayfinding and collaboration; | Place | Transport | Transport | Transport | Transport | Place |
| Locate public bus/MRT station within 300m walking distance;              | Transport | Transport | Transport | Transport | Transport | Transport |
“Transportation connectivity” category includes just transport and place credits in biophilic design strategies match. GM and LBC seen weaker in this category match. Table 3.5 indicates “place” and “management” credits that meet with the work-live-play integration category of the biophilic design strategy.

Table 3.5: GBRTs matching with “work-live-play integration” design category and strategies (Xue et al., 2019b).

| Strategies                                                                 | LEED   | BREEAM | GM       | GBL  | WBS       | LBC       |
|---------------------------------------------------------------------------|--------|--------|----------|------|-----------|-----------|
| Share public green spaces, open plaza and community spaces;               | Place  | Management | Management | Place | Management | Place      |
| Share food & beverage, food court facilities;                             | Place  | Management | Management |      | Management |           |
| Share learning and collaboration facilities;                              | Place  | Management | Place     |      |           |           |
| Security management (i.e. patrol, CCTV);                                 |        | Management |           |      |           |           |
| Enhance facility and site maintenance;                                    | Management | Management | Management | Management | Management | Management |

“Work-live-play” integration category includes just management and place credits in biophilic design strategies match again GM and LBC seen weak in this category match. “Green space place making” category mostly matches with WBS and includes just place and management credits.

Most of the biophilic strategies (%85) are matching with GBRTs. 5 biophilic strategies that are presented below does not match any of the GBRTs;
- enlarge water area,
- aromatic plant design,
- shaded corridors/bridges between buildings and districts,
- landmark in public open space for attraction and gathering
- shaded outdoor seats for café and restaurants.
Table 3.6: GBRTs matching with “green space place making” design category and strategies (Xue et al., 2019b).

| Strategies | LEE D | BREEAM | GM | GBL | WBS | LBC |
|------------|-------|--------|----|-----|-----|-----|
| Provide shaded outdoor seats for café and restaurants; |       |        |    |     |     |     |
| Volunteer-engagement for urban farming; |       |        |    |     |     |     |
| Provide Friday/holiday market (vegetable, food, and other commercial sales); | Place |        |    |     |     |     |
| Provide outdoor performance/exhibition of art events during lunch breaks (i.e. live) | Place | Managemen t | Managemen t | Managemen t | Managemen t |     |

Biophilic patterns and mind-body systems

Mind-body systems that relate directly with people’s health and well-being are impacted by the environment. Table 4 clarifies the relationships between 14 biophilic design patterns and mind-body systems with related references. Biophilic design addresses to people as a biological organism, respecting the mind-body systems as indicators of health and well-being. There are three factors identified in mind-body systems. Those considered main mind-body systems are; stress reduction, cognitive performance and emotion mood preference.

Table 4: 14 Biophilic Design Patterns matching with Mind-Body Systems (Browning et al., 2014).

| No  | Mind-body systems                                                                 | Cognitive performance                                                                 | Emotion, mood preference                                                                 |
|-----|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| 14 patterns | 3 Stress reduction                                                                | Improved mental engagement/ attentiveness (Biederman & Vessel, 2006)                    | Positively impacted attitude and overall happiness (Barton & Pretty, 2010)               |
| Visual connection with nature | Lowered blood pressure and heart rate (Brown, Barton & Gladwell, 2013; van den Berg, Hartig, & Staats, 2007; Tsunetsugu & Miyazaki, 2005) |                                                                                          |                                                                                          |
| Non-visual connection with nature | Reduced systolic blood pressure and stress hormones (Park, Tsunetsugu, Kasetani et al., 2009; Hartig, Evans, Jammer et al., 2003) | Positively impacted on cognitive performance | Perceived improvements in mental health and tranquility (Li, Kobayashi, Inagaki et al., 2012; Jahncke, et al., 2011; Kim, Ren, & Fielding, 2007; Stigsdotter & Grahn, 2003) |
| Non-rhythmic sensory with stimuli | Positively impacted on heart rate, systolic blood pressure and sympathetic nervous system activity | Observed and quantified behavioral measures of attention and exploration (Windhager et al., 2011) |                                                                                          |
| Natural Analogues | Positively impacted comfort, well-being and productivity (Heerwagen, 2006; Tham & Willem, 2005; Wigö, 2005) | Positively impacted concentration (Hartig et al., 2003; Hartig et al., 1991; R. Kaplan & Kaplan, 1989) | Improved perception of temporal and spatial pleasure (allosthesia) (Parkinson, de Dear & Candido, 2012; Zhang, Arens, Huizenga & Han, 2010; Arens, Zhang & Huizenga, 2006; Zhang, 2003; de Dear & Brager, 2002; Heschong, 1979) |
|------------------|-------------------------------------------------|-------------------------------------------------|--------------------------------------------------------------------------------|
| Thermal & Airflow with variability of Water | Improved concentration and memory restoration (Alvarsson et al., 2010; Biederman & Vessel, 2006) | Enhanced perception and psychological responsiveness (Alvarsson et al., 2010; Hunter et al., 2010) | Observed preferences and positive emotional responses (Windhager, 2011; Barton & Pretty, 2010; White, Smith, Humphryes et al., 2010; Karmanov & Hamel, 2008; Biederman & Vessel, 2006; Heerwagen & Orians, 1993; Ruso & Atzwanger, 2003; Ulrich, 1983) |
| Dynamic & Diffuse light | Positively impacted circadian system functioning (Figueiro, Brons, Plitnick et al., 2011; Beckett & Roden, 2009) | Increased visual comfort (Elyezadi, 2012; Kim & Kim, 2007) | Enhanced positive health responses; Shifted perception of environment (Kellert et al., 2008) |
| Connection with natural systems | Decreased diastolic blood pressure (Tsunetsugu, Miyazaki & Sato, 2007) | Improved comfort (Tsunetsugu, Miyazaki & Sato 2007) | |
| Biophoric Forms & Patterns | Observed view preference (Vessel, 2012; Joye, 2007) | |
| Material Connecti on with Nature | Positively impacted perceptual and physiological stress responses | Observed view preference (Saltingaros, 2012; Hägerhäll, Laike, 2008) | |
Table: Nature of the Space and Biophilic Patterns

| Nature of the Space | GBRT | Description | Supporting Research |
|---------------------|------|-------------|---------------------|
| Prospect            | 3    | Reduced stress | (Grahn & Stigsdotter, 2010) |
|                     |      | Reduced boredom, irritation, fatigue | (Clearwater & Coss, 1991) |
|                     |      | Improved comfort and perceived safety | (Hægerhäll, Purcella, & Taylor, 2004; Taylor, 2006) |
| Refuge              | 3    | Improved concentration, attention and perception of safety | (Grahn & Stigsdotter, 2010; Wang & Taylor, 2006; Wang & Taylor, 2006; Petherick, 2000) |
| Mystery             | 2    | Induced strong pleasure response | (Biederman, 2011; Salimpoor, Benovoy, Larcher et al., 2011; Ikemi, 2005; Blood & Zatorre, 2001) |
| Risk/Peril          | 1    | Resulted in strong dopamine or pleasure responses | (Kohno et al., 2013; Wang & Tsien, 2011; Zald et al., 2008) |

* numbers are giving the patterns which are supported more empirical data

Discussion and Conclusion

When we examine the GBRT’s with biophilic design strategies; it is obvious that the GBRT’s are insufficient to meet the needs of biophilic design. New approaches and additions should be provided to meet those strategies in the concept of human wellbeing, good mood and productivity. In the other hand it is obvious that biophilic patterns are effective on mind-body systems positively. However, it needs more empirical data on that. Some nature interactions can even induce stress or fear responses. Fortunately, an emerging number of studies teach us which specific interactions with nature are restorative and which are stressful. Understanding how people viscerally respond to nature and how such beneficial experiences can be supported in urban settings is essential to shaping a healthy and vibrant society. Biophilic design must be implemented correctly to optimize health benefits (Ryan, 2014).

The therapeutic influence of the natural environment on human is being lost, touch of nature into our daily lives can raise this again. The scientific results that supporting biophilic design is still emerging. Deep down, we know that the connection to nature is important. While empirical evidence is accumulating, we ought to go about restoring the human-nature connection in the built environment. In coming decades, it is projected that 70 percent of the world’s population will live in cities. It makes human more be in search of nature to feel fresh. This is estimated that biophilic design will get more important day by day. Biophilic Design helps shed light on the importance of the human connections with nature in our built environment and encourages people to challenge convention by bringing biophilic design patterns into a vision for healthy homes, workplaces and cities.
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