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Biophilic design as an adaptive reuse of the built environment strategy and its impact on people's health and well-being perception

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Abstract

This research arises from concern about the existence of abandoned buildings and urban infrastructure, a problem that will increase after the current pandemic, with a negative effect on people's health and well-being. Adaptive reuse through Biophilic design is proposed as an answer for the built environment interventions, and this paper aims to demonstrate its impact through a case study in Taichung, Taiwan and surveys application including the World Health Organization variables and the 14 Patterns of Biophilic Design. The results revealed a significant increase in the participants' perception of health and well-being after being visually in contact with Biophilic design site.

Keywords— biophilic design, built environment, adaptive reuse, paired samples t-test.

I. INTRODUCTION

In a world with increasingly urban sprawl, this current pandemic has exposed deep inequalities and demonstrates that tackling the virus is more challenging in urban areas [1]. This situation is a largely urban problem and certainly its effects will also be reflected in our built environment. According to data from UN-Habitat (2020), as a result of confinement, digital services and teleworking have increased, generating uncertainty about future of buildings such as offices and even homes that could become obsolete. The possibilities of uses are as numerous as evolutionary needs of our cities. If there is one thing that is certain in this pandemic, it is that we must be flexible to react quickly to new urban needs. We have neither the time nor the resources (financial and environmental) to build each time from scratch. Adaptive rehabilitation that we have been practicing for centuries takes more and more strength now [2]. And the fact is that, adaptive reuse enables a building to suit new conditions. It is a process that reaps the benefit of the embodied energy and quality of original building in a sustainable manner [3]. Thus, adaptive reuse is the sustainable response for an Urban Regeneration [4] and Post-industrial cities are examples of this, as many of them have succeeded in preserving their vitality through the adaptive reuse of their built environment. According to Browning et al. (2012), the built environment is defined as places and spaces created or modified by people with particular emphasis on buildings, parks, streetscapes, and other spaces that provide the setting for human activity [5].

With all of the above-mentions in mind, it is required that all new measures prioritize and are focused on ecological and sustainability aspects. And the reason is because nature also has unusually potent power to heal broken human landscapes and to humanize and reinvigorate distressed cities and built environments [6]. In addition, incorporating nature into the built environment is not just a luxury, but a sound economic investment in health and productivity, based on well researched neurological and physiological evidence [7]. Regarding this, it is possible to

suggest one sustainable strategy designed through Biophilic principles that at the same time have an impact on health and well-being of human beings. Biophilic design promotes ecologically interrelated design solutions and in a multiple scale. The conventional design of built environment has greatly contributed to this crisis. A remedial response to this challenge has emphasized on reducing our environmental impacts through energy and resource efficiency, the use of less polluting materials, recycling, and other important strategies. Yet, this low environmental impact approach, while essential by itself, is insufficient for achieving true and lasting sustainability [8].

Authors such as Beatley (2016) in his book Biophilic City and Design states that urban planners have also rediscovered the importance of city design in advancing health [9], this one includes mental health and well-being. Then, in addition, with Biophilia, Biophilic design is essential for providing people opportunities to live and work in healthy places and spaces with less stress and greater overall health and well-being [10], and this is how its impact can be explained. According to some authors, one way to enable cities to move towards resilience is through Biophilia [11]. Thus, with Biophilic Urban Design recovery could also be possible to contribute to make healthier and more resilient environments.

This paper recognizes the importance of adaptive reuse as a response to the functional obsolescence of buildings; focuses on Biophilic design as a sustainable strategy to address this problem, demonstrating its impact on human health and well-being; and achieves this through the analysis of a case study in Taiwan that has a successful adaptive reuse of the built environment by using Biophilic design elements. Therefore, through the development of online survey that considers variables of World Health Organization and the 14 Patterns of Biophilic Design [10], the study focuses on evaluating the perception of users before, during, and after being exposed to Biophilic design and by using Photography as a tool. Through Paired Samples T-test and descriptive statistics, the study proves the positive impact of Biophilic design on health and well-being of those who come into contact with it.

II. RESEARCH PROCESS

As a way to demonstrate the impact of Biophilic design in the health and well-being from the people's perception of a site with Biophilic principles, this research combines a qualitative and quantitative method. It is mainly based on a literature review for variables identification, the data collection through surveys, and the application of Paired Samples T-test and descriptive statistics via SPSS for its final analysis and results interpretation. The research process will be explained as follows: Biophilic Design Principles Compilation, Case Study Selection, Online Survey Design, Online Survey Application and Data Collection and Data Analysis in SPSS.

Biophilic Design Principles Compilation: The research process starts with a bibliographic research to identify elements of Biophilic design that could be the basis for structuring this research and to identify its impact on effectively enhancing health and well-being in individuals and society. In the first stage, the results show 14 patterns of Biophilic design by Terrapin (2014) which were complemented by the experiences described by Interface, 2020 [12]. The importance of patterns included in this research are developed through extensive interdisciplinary research and are supported by empirical evidences and the work of Christopher Alexander, Judith Heerwagen, Rachel and Stephen Kaplan, Stephen Kellert, Roger Ulrich, and many others. Over 500 publications on biophilic responses have been mined to uncover patterns useful to designers of the built environment [10]. Regarding 14 patterns, they can be grouped into 3 categories (See Fig. 1) and each one includes both the design elements that will be taken into account for selecting the case study, as well as the experiences that are intended to be transmitted to users and that will be included in the surveys.

Case Study Selection: Once the design elements were identified, they were applied in the

selection of a case study. Taichung Cultural and Creative Industries Park (TCCIP) was chosen. This is one of five national-level cultural and creative facilities of Taiwan; the park is located near Taichung Railway Station in the city's South District. TCCIP was built as a distillery in 1916 during Japanese colonial rule (1895-1945). After World War II, the facility was administered by Taiwan Tobacco and Wine Monopoly Bureau [13]. But in 1998, due to environmental and urban redevelopment considerations, alcohol production was relocated to Taichung Industrial Park; as a consequence, 28 buildings were abandoned. In 2002, the city government took steps to preserve the unoccupied distillery by designating 16 of its 28 buildings as historic structures [13]. After a re-design proposal, the park opened to the public in 2009 and was renamed as The Cultural Heritage Park. It has been emerged as one of Taiwan's most dynamic cultural centers, offering a melange of art, educational, entertainment and historical attractions [14]. It represents a successful case of adaptive reuse of post-industrial buildings and, upon evaluation; it includes elements of each of the Biophilic design patterns in its proposal.

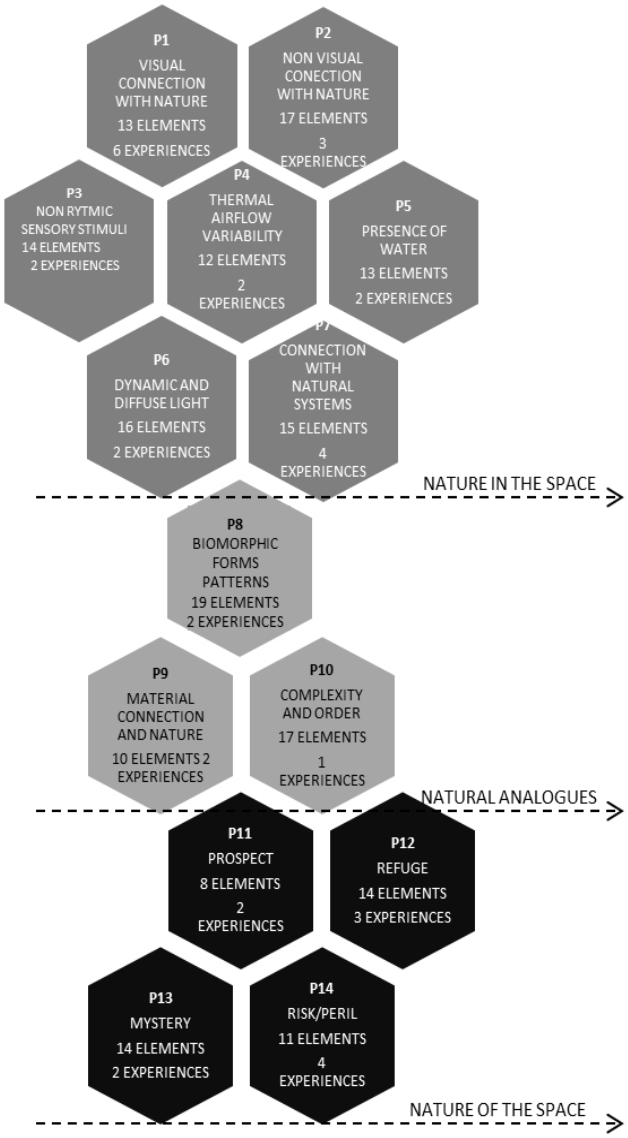

Fig.1. Biophilic Elements and Experiences

Online Survey Design: The next important stage was the design of surveys which, because of the current situation and the restrictions due to the pandemic, an online survey was chosen using Google forms with the purpose of evaluating the health and well-being perception of respondents in three important moments: before, during, and after having been exposed to a series of previously selected photographs which represented the 14 Biophilic design patterns and elements present in the case study. This survey was designed as follows and includes 5 sections:

- Section 1: Focusing on data collection such as nationality, gender, age, marital status, occupation, live and their design study background. The purpose of this section is

to profile the respondents and to establish an appropriate connections and guidelines at the moment of analyzing the collected data.

- Section 2: Using 5-item World Health Organization Well-Being Index (WHO-5) [15] which is the most widely used questionnaires to assess subjective psychological well-being. Its first publication was in 1998, and has been used in research studies all over the world, this is favorable at this stage, where it is desired to know the condition of respondents in the days prior to being in contact with design elements associated with biophilic patterns.

- Section 3: Including an evaluation during a photographic review by respondents. Fourteen representative images were selected, all of them of Biophilic design patterns taken in situ. Each image corresponds to design elements existing in the case study. The purpose of this phase is for respondents to answer about their emotions regarding 37 variables identified in 14 Patterns of Biophilic Design. Each emotion was translated into a separate question and was measured on a Likert scale, from 1 to 5, where 1 represented (not having experienced the emotion asked on the question) strongly disagree, 2 disagree, 3 neutral, 4 agree and 5 (having fully experienced it) strongly agree.

- Section 4: Asking 5 questions from section 2 on health and well-being proposed by World Health Organization. Its purpose is to find out if there is a variation with respect to the responses obtained before being in contact with Biophilic design. The differences as well as the relationships established between them will be analyzed with Paired Samples T-test in SPSS.

- Section 5: For this last stage of the survey, 5 questions were developed to inquire about satisfaction and general perception of the design and. As in previous sections, it was also evaluated using the Likert scale.

Online Survey Application: Once the survey was designed, it was applied online and kept available for two weeks, obtaining a total of 63 respondents from different countries in Asia, America and Europe. Then, in order to analyze the results, the next phase was the data analysis via SPSS, for it was imperative to identify a correct method(s) needed to test our hypothesis: Is there a significant change in individual's health and well-being perception before and after being exposed to a Biophilic design elements? Thus, to achieve this, 2 methods were identified: Means analysis which allowed to get the scores of each pattern and Paired Sample T-Test, since this one also contributed to identify if there is a difference in mean scores between the two measurement times: before test and after test. Also, it was possible to identify the most and less representative variables for this study.

Data Collection and Data Analysis in SPSS: For a better understanding, the step-by-step application of both methods: Means and Paired Samples T-test via SPSS will be explained in detail in the result section.

III. RESULTS

A total of 63 people responded this survey and their profile is shown in Table I.

TABLE I
PROFILE OF THE RESPONDANTS

Description	Frequency	Percentage
Nationality		
-Mexican	41	65.1
-Taiwanese	5	7.9
-Chinese	2	3.2
-Spanish	1	1.6
-Indonesian	3	4.8
-Vietnamese	3	4.8
-Indian	5	7.9
-Myanmar	1	1.6
-Other	2	3.2
Gender		
-Male	30	47.6
-Female	33	52.5

Age		
-Less than 20	5	7.9
-21-30	17	27.0
-31-40	26	41.3
-41-50	10	15.9
-51-60	3	4.8
-More than 61	2	3.2
Marital Status		
-Single	39	61.9
-Married	22	34.9
-Other	2	3.2
Occupation		
-Educational	20	31.7
-Government	1	1.6
-Manufacture	3	4.8
-Free Profession	10	15.9
-Housewife	1	1.6
-Student	20	31.7
-Other	8	12.7
Live		
-Alone	18	28.6
-With other	45	71.4
Years design study background	19	30.2
-0 years	8	12.7
-1-4	19	30.2
-5-10	12	19.0
-11-20	5	7.9
-21 or more		

Table II shows Mean of each experience and Means of Pattern. The study also uses means to compare or summarize the differences between variables or groups previously defined as in this case where 14 Biophilic design patterns were evaluated in Section 3.

The results showed the patterns that were best evaluated and which successfully conveyed emotions in the respondents were: Biomorphic forms patterns with a mean of 3.73; Visual connection with nature with 3.62, and non-visual connection with nature with 3.62; all 3 patterns are strongly related to visual perception. Since respondents only viewed photos of the site from online survey, it is reasonable that they were the best represented in photographs. The patterns with the lowest mean scores were: risk/peril and complexity/order, both with means of 3.05 which are related to sensory information, not easy to be represented on an online survey.

TABLE II
14 PATTERNS OF BIOPHILIC DESIGN

Pattern	Experience	Means	Means by Pattern
1.Visual connection with nature	I feel satisfied	**3.63**	**3.62**
	Grabs my attention	**3.84**	
	I feel stimulated	3.56	
	I feel calm	**3.73**	
	Conveys me the sensation of being in the present moment	3.43	
	It conveys the sensation of being in the presence of other lives	3.52	
2.Non visual connection with nature	I feel fresh well balanced	**3.63**	**3.62**
	I feel ambient conditions are perceived as complex variable	3.60	
3.Non rhythmic sensory stimuli	What I see are reminiscent of being outdoors in nature	**3.62**	
	I feel as if I am suddenly exposed to something special something fresh	**3.62**	3.58
4.Thermal airflow variability	I feel a brief but welcome distraction	3.54	
5.Presence of water	I feel refreshing active alive invigorating and comfortable	**3.65**	3.56
6.Dynamic			

and diffuse light	I feel of both flexibility and a sense of control	3.47	
7.Connection with natural systems	I feel powerful fascinating and attractive	3.44	3.44
	It gives me the sensation of movement	3.43	
	Causes feelings of drama and intrigue	3.03	3.26
8.Biomorphic forms patterns	Gives me a sense of temporality	3.48	
	My relationship to a greater whole is evoked	3.19	3.25
	I feel aware of seasonality and cycles of life	3.25	
	I feel relax nostalgic profound or enlighten	3.46	
	I feel anticipated	3.11	
	I feel interested and comfortable	**3.75**	**3.73**
	I feel fascinated attractive attentive or even absorbed	**3.70**	
9.Material connection and nature	I feel warm and authentic	3.51	3.51
	I feel like my sense of touch is stimulated	3.51	
10.Complexity and order	I feel an intriguing balance between being bored and overwhelm	3.05	**3.05**
11.Prospect	I feel released	3.40	3.43
	It gives me a sense of security and control	3.45	
12.Refuge	I feel safe and that gives me a sense of detachment from work	3.43	3.38
	I feel separate or unique in the environment	3.30	
	I feel this kind of spatial characteristics can be thoughtful	3.42	
13.Mystery	I feel that this offers the senses a kind of denial and reward	3.32	3.52
	I feel this makes me want to understand and or explore	**3.71**	
14.Risk/peril	I feel excited and with an suggested threat maybe even a little bit harmful or negative	3.03	**3.05**
	I feel a sense of danger	2.24	
	I am intrigued	3.08	
	I feel the site is worth exploring	**3.84**	

Table II also highlights the best and the worst evaluated emotions independently of the Pattern to which they belong and are those with means of 3.62 or more such as: I feel satisfied 3.63, grabs my attention 3.84, I feel fresh well balanced 3.63, I feel as if I am suddenly exposed to something special something fresh 3.62, I feel refreshing active alive invigorating and comfortable 3.65, I feel interested and comfortable 3.75, I feel fascinated attractive attentive or even absorbed 3.70, I feel this makes me want to understand and or explore 3.71, and I feel the site is worth exploring 3.84.

Paired Sample T-test is used to analyze the data since this allow to examine if the same variable is likely to have or no equal mean at two different moments (before and after viewing on

line photos). This method was explored by comparing means obtained in section 2 and section 4, both related to 5-item World Health Organization Well-Being Index. With this comparison it has been possible to answer our hypothesis and to identify if there was any significant change with regard to the perception of health and well-being of the participants after being exposed to Biophilic design elements, in this context through photos and images.

This collected data were grouped into 5 pairs, each pair containing the same variable but in two different moments, one for "before" (section 2) and one for "after" (section 4) as shown in Table III. The results show that the mean difference of both pair 3 and pair 5 are not statistically significant at $\alpha = 0.05$. However, there is an increase between means from 3.11 to 3.29 (pair 3) and from 3.40 to 3.52 (pair 5) which is not significant but it exists. On the other hand, pairs 1, 2, and 4 are statistically significant at $\alpha = 0.05$. The results indicate that a significant improvement in the perception of health and well-being in users by increasing their good feelings and emotions related to cheerful and in good spirits, calm and relaxed, fresh and rested. These results are reinforced in the means of these three pairs that increase significantly from 3.10 to 3.52 (pair 1), 3.08 to 3.76 (pair 2) and from 2.90 to 3.57 (pair 4).

As part of this results obtained, it is observed that there is a correlation between the score that participants gave to each Biophilic design elements (37 variables contained in 14 Patterns) and the variables related to their level of satisfaction demonstrated in section 5 of the survey. However, patterns 6 and 10 stand out since they are not statistically significant at $\alpha = 0.05$. This is because 'Sig. (2-tailed)' or $p>0.05$ for absolutely all satisfaction questions, which means that pattern 6 (Dynamic and diffuse light: causes feelings of drama and intrigue and give a sense of temporality) had no impact on how participants rated any aspects related to spatial design, natural environment or feelings related to the site or to make any decision about visit the case study or recommend it as a good place as well as pattern 10 (Complexity and order: I feel an intriguing balance between being bored and overwhelmed).

The correlation of the same 14 patterns and the impact they had for the participants when answering section 4 was also analyzed. It is observed that pattern 10 is the only one that is not statistically significant, in two items of the 5 analyzed. This is because for both its 'Sig. (2-tailed)' or $p>0.05$, which means that this pattern (Complexity and order: I feel an intriguing balance between being bored and overwhelmed) did not have any influence on respondents to feel cheerful and in a good spirit or to feel that their life is filled with interesting things; in other words, they felt better about these two items but not because of pattern 10.

TABLE III
HEALTH AND WELL-BEING BEFORE AND AFTER

Description	Mean	Std. Deviation	T	Sig. (2 tale)
Pair 1				
Before-I have felt cheerful and in good spirits	**3.10**	1.011	-2.865	**.006**
After- Now I feel cheerful and in good spirits	**3.52**	0.840		
Pair 2				
Before-I have felt calm and relaxed	**3.08**	1.005	-4.721	**.000**
After-Now I feel calm and relaxed	**3.76**	0.817		
Pair 3				
Before-I have felt active and vigorous	**3.11**	0.900	-1.085	.282
After-Now I feel active and vigorous	**3.29**	0.888		
Pair 4				
Before-I woke up feeling fresh and rested	**2.90**	1.160	-3.772	**.000**
After-Now I feel fresh and rested	**3.57**	0.995		

Pair 5				
Before-My daily life has been filled with things that interest me	**3.40**	1.171	-.782	.437
After-I feel that today my life has been filled with things that interest me	**3.52**	0.965		

Finally, is important to analyze the data in section 5, which concludes the survey and provides an overview of the respondents' satisfaction regarding to biophilic elements evaluated in this case study. The results are shown in Table IV.

The data at this Section was analyzed in SPSS through descriptive statistics. It was possible to confirm that participants feel mostly satisfied with natural environment that they saw in the previous images and less satisfied with things related to spatial design, which is quite interesting, first, because it matches with the patterns best rated "visual connection with nature" and "non-visual connection with nature". Secondly, it is important because the lowest characteristic rated at this stage was "I am satisfied with the spatial design shown in previous pictures", reinforced that, since this research was based on images, it is not possible to visualize the complete space. It is only done in a fragmented way, which limits its understanding and it is demonstrated by the results obtained.

TABLE IV
SITE EVALUATION FROM THE RESPONDANTS

Description	Mean	Std. Deviation
I am satisfied with the spatial design shown in the previous pictures	**3.67**	0.880
I like the natural environment that I saw in the previous images	**4.14**	0.998
Personally I think I can feel better after explore the site	3.92	0.893
If I have a chance I would like to visit there	3.98	1.094
I will recommend my friends to make a visit there	3.98	1.00

All of the above-mentions can be explained by the fact that since this is an online survey; many items in both patterns can hardly be transmitted through images, but certainly this must be clarified in a further research. Although it is important to emphasize that, even so, through this proposal online, it was possible to demonstrate a significant improvement in the perception of health and well-being of respondents.

IV. CONCLUSIONS

This research demonstrated the positive impact of incorporating elements of nature into the built environment by registering an increase in the participant's health and well-being perception.

This was possible by the design and implementation of an online survey which collected people’s perception at two important moments: before and after being exposed to a set of photos and images of a case study with an adaptive reuse that included Biophilic design elements.

As a result, those design patterns that had the greatest impact and those that were less satisfactory in the participants’ experience were also identified. Specifically, the patterns evaluated that had the higher impact are directly related to the natural environment, so it is necessary to emphasize the importance of environmental design in present and future buildings.

It also demonstrates that Biophilic design is ideal as an adaptive reuse proposal for the built environment since the well-designed built environment can be a relief of urban life, as in this case study: The Cultural Heritage Park, a former factory with a successful adaptive reuse with previously identified Biophilic elements.

In general terms, the findings imply that having contact with Biophilic design has an impact, as shown in this research, a positive one; on the health and well-being of the individuals.

This study has also important implications for Biophilic design. Since the data analysis of the different variables suggest, some identified elements could not be significant and could even be omitted in the design, based on these results, since elements from patterns 6 and 10 do not necessarily reflect an impact on the health and well-being of individuals.

And this is related to assume a more serious concern about these patterns when we do Biophilic design in the built environment. However, as this research is based on pictures, it is possible that the patterns that have greater significance and are better related to health and well-being will change when conducting the on-site surveys in a further study.

Therefore, the importance of conducting, under the same principles used in this research, on-site surveys, and consequently compare the results in this paper will certainly contribute even more to highlight the Biophilic design as a solution to increase people's health and well-being and the main patterns involved.

This paper's contributions and its importance are not only for people's health and well-being, it is also possible to go further and explore its implications at urban level, identifying its connection with socio-economic and environmental issues and then, with Healthy cities.

A subsequent research not only is relevant but necessary to continue with a comparison between case studies that will allow for an exhaustive analysis in a diversity of built environments with a variety of adaptive reuse strategies in order to have a deeper understanding of their effects when they experiment higher, lower or null presence of Biophilic design and to identify a major or less health and well-being of individual's perception in every case.

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