

# Public Preference of Biowall Area Configuration by Virtual Reality Assessment

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**Abstract** A biowall has the potential to provide human health and well-being benefits. However, some users consider a biowall as a hobby for their happiness. For this study, the general public's preference for a biowall was explored. The assessment was based on five criteria, perceptual, thermal, visual, respiratory, and audial comfort. The method assessed public preferences regarding the biowall in virtual reality for living and family rooms in urban dwellings. Six biowall configurations were virtualized in both rooms. These configurations included control conditions without biowall, single potting biowall, hidden single potting biowall, multiple potting biowall, linear potting biowall, and fully potting biowall. One-way ANOVA with Tukey HSD analyzed the data with the main result that the variants of the public's preferences for the biowall configuration were significantly different. The final result showed that the fully potting biowall was the highest rating configuration, with a preference value of 4.64 (N = 25) for the family room and 4.81 (N = 25) for the living room. The variables with the highest preferences for perceptual, thermal, visual, respiratory, and audial comfort were interest, chillness, color, freshness, and spaciousness-magnificence, respectively. The most dominant variable influencing preference was the ability of biowall to provide freshness and magnificence in the room. Generally, the public preferred the addition of biowall in the room.

**Keywords** Biowall, Virtual Reality, Living Wall,

Perception

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## 1. Introduction

Humans have an innate tendency to be affiliated with the natural environment, including vegetation. This is observed from the new phenomenon where several people are integrating biowall, which is in the form of vegetated wall surfaces [1], such as the vertical vegetation grown on building facades and adjacent wall surfaces in urban public spaces [2]. This phenomenon does more than beautify an area due to its ability to keep people alert and productive, reduce stress, and improve the sense of well-being [3]. Biowall is associated with the physical comfort of the occupants, including the thermal, visual, audial, and respiratory aspects [4].

Humans spent most of their time indoors. So, it was essential to discuss the relationship between biowall and human physical comfort in the house, mainly tropical landed dwellings. This research aimed was determine whether the size and configuration of the biowall affected people's preferences. The question was: 1). What biowall area configuration was the most popular among the public? 2). What were the highest preference variables of the public's preference for biowall area configuration perceptually, thermally, visually, respiratory, and audial? 3). What were the dominant variables influencing the

public's preference for the overall configuration of the biowall area? 4). In general, was biowall of greater interest to the public? But it was discovered that biowall has not yet been incorporated into the interior of landed housing; therefore, this research uses virtual reality (VR) as a substitute for the required space. Family and living rooms were selected for the assessment based on their perception as a public space in a house accessible to all occupants.

## 2. Literature Review

There are several nomenclatures to explain biowall terminology and these include vertical gardens [5], active living walls [6], and green walls [7,8,9,10,11,12,13,14,15,16,17,18]. Therefore, this research defines a biowall as a living wall consisting of certain plants with specific substrates in a container assembled on a vertical wall [19] in the interior of a landed housing.

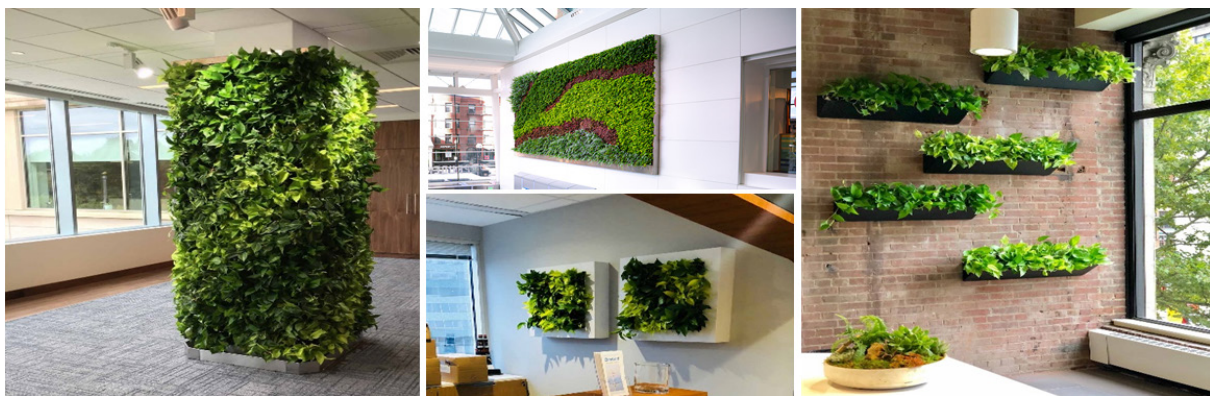
Biowall is usually used for the interior [20] and consists of four available systems: the trellis, planting container, felt, and planting pot systems [21], as shown in Figure 1. Trellis systems use support structures to propagate plants directly on the soil surface and container box below the building. Planting container systems do not have direct soil contact and select non-vines vegetation. The felt system uses geotextile material. Hence it is flexible and can adjust to the surface of the wall that needs to be textured. The planting pot system has an iron frame hanging by plant pots.

It was discovered that most of the previous studies on biowall were conducted in universities and schools [20,21,18,22], while some others used high-rise apartments or condominiums [23,9,24,25] and office buildings [26,27,28,29]. In Indonesia, biowall is usually found in public buildings such as restaurants, offices, and schools.

Therefore, it is essential to discuss the lack of its placement and research on interior landed housing to understand the linearity with studies at other loci.

The ability of biowalls to induce physical comfort has been proven partially in the thermal, visual, audial, and respiratory aspects. Meanwhile, previous research was observed to have only focused on one of the user sensations, with none discovered to have discussed all the sensors simultaneously. For example, based on the thermal comfort sensation, the application of biowall was reported to have reduced the surface temperature of the outer wall by 15.5°C and the interior wall by 1.7°C compared to the bare wall [22]. Another study showed that the usage of an active living wall in a university hall in Spain reduced the interior temperature by 0.8°C and 4.8°C at different distances [23].

The focus on visual comfort showed that the greenery facade in the tropical area with a west orientation reduced sunlight by 31.18 to 51.71 % while the southern orientation had a 28.4 to 54.87 % reduction [32]. Moreover, the Vertical Greening System for the *Shibataea* plant species was observed to have the ability of reducing average interior air temperature by 0.5 to 2°C with a maximum temperature difference of 5°C and a light reduction of 26.95% [29]. In terms of audial condition, biowall was found to be a good sound absorber using soil composition in the echo chamber laboratory [33]. This was indicated by the average acoustic absorption coefficient obtained through the simulation of a system thickness of 16 cm, green facade, and living system modular walls which were found to be 0.2 (300-1000 Hz), 0.2 (200-1000 Hz), and 0.9 (300-1000 Hz) respectively [34]. It was also discovered that a plant layer on the green wall with polyethylene material and a façade with 20-30 cm wire mesh was able to increase sound insulation by 1 dB for traffic noise as well as an increment ranging between 2 to 3 dB [35].



Source: <https://bostoncityscapes.com>, 2022

Figure 1. Type of Biowall

For respiratory comfort, the application of *Nephrolepis exaltata Bostoniensis* on the green wall was observed to have removed 0.3 to 0.5 PM levels, thereby leading to 45.78% and 92.46% improvement in IAQ [16]. Moreover, the addition of a potted plant in the building interior was reported to have reduced Volatile Organic Compound (VOC) and formaldehyde levels by 48% and 145%, respectively [36].

In-situ research has also been conducted on the ratio of the biowall area to the room using different sizes. Bianco compared a 2 m x 1.8 m x 1.8 m room and nine modules of biowall @ 0.4 x 0.5 m<sup>2</sup> [37], while some other studies have 3 m x 3 m x 3 m space with the entire wall surface covered [38]. It was also discovered that some researchers only mentioned the size of the room, such as 5.1 m x 3.1 m x 3.1 m [39], 0.8 m x 2.45 m x 2.45 m [40], 2.5 m x 4 m x 2.9 m [41], 3.8 m x 7.8 m x 3 m [31], and 3 m x 3 m x 3 m [35] without indicating the proportion of the wall covered.

This background information showed that there is no previous study on tropical landed housing focused on exploring the configuration of the biowall area based on the perception of the observers. It is pertinent to note that the biowall size is simultaneously associated with four aspects of physical comfort which include the thermal, visual, audial, and respiratory aspects. This is the reason it is interesting to conduct this research because its findings can be used as a reference in applying home-scale biowall to provide physical comfort, and this is essential because humans spend 80% of their time indoors.

### 3. Methods

#### 3.1. Research Location

The study location was set by simulating the middle-class urban dwellings designed using 200 m<sup>2</sup> to 600 m<sup>2</sup> dimensions in Semarang, Indonesia. The topography of the study area was observed to be between 321 and 573 masl with an average temperature of 25°C. Moreover, the family and living rooms selected were based on the applicable provisions of the Ministry of Public Works and the Ministry of Public Housing. The dimensional room was approximately 6.5 m x 8.2 m x 3.4 m or 53 m<sup>2</sup>. It is important to note that neither the location of the research

object nor the study's time has an effect on the settings used for the simulation. Furthermore, the simulation process was not considered the dry and rainy seasons. The research was conducted from May to June 2022.

#### 3.2. Research Object

Light gray Carrara stone was used as the setting floor material to render the family and living rooms, while the walls were designed using a combination of walnut wall paneling, light gray wall painting, and clear glass. Moreover, white paint on the gypsum board was used for the ceiling, while the lighting was based on sunlight through clear glass and spotlight #12, while solid wood and fabric were applied for each door/door jamb and curtain.

The furnishing of the family room includes a rug, a three seaters sofa, with a gray texture fabric, and six dining chairs with hard beige color fabric. There is also a dining table, a credenza, a side table, and a built-in rack with a Carrara stone top table and mahogany wood base. Meanwhile, the living room furnishing includes a three seaters sofa, a lounge chair with a pillow, and a seater sofa, all designed using gray texture color fabric as well as six dining chairs with hard beige color fabric, a credenza, a side table, a built-in rack, and a coffee table. All the materials were produced using a Carrara stone top table and mahogany wood base.

The selection of medium-sized houses was based on the consideration that it is the major residence and also reflects the average economic level. The minimum standard of space required for family and living rooms by the government is 9 m<sup>2</sup> and the setting of each room including the space-filling elements, colors, and materials are based on those commonly used in both spaces in Indonesia, thereby, representing the actual condition.

#### 3.3. Biowall Specification

The replicas were completed in a 360 panoramic image and the process was initiated by drawing the layout of the room followed by rendering the 360 panoramic images after which the output was converted into a Virtual Reality. The next stage was the reading process using the Virtual Reality Headset Series for Android in a room conditioned at approximately 22-26°C.



Source: Author Documentations, 2022

**Figure 2.** Family and Living Room Simulation Configuration

It is important to note that there are several types of biowall and these include felt, trellis, planting container, and planting pot. This research used the planting pot for the simulation and this type involves using a metal frame to hang and arrange plants in pot media according to design [21]. The simulation was conducted based on six conditions as shown in Figure 2. The first (BF0 and BL0) is the control where the rooms are without biowall, the second (BF1 and BL1) is the room with single potting biowall, the third (BF2 and BL2) is the room with a hidden single potting biowall, the fourth (BF3 and BL3) and fifth

(BF4 and BL4) used multiple and linear potting biowalls respectively while the sixth (BF5 and BL5) is a room with a fully potting biowall.

The single potting biowall has an estimated area of 2.9 m<sup>2</sup> with the walls visually covered by plants and visible pots. A mixture of different foliage arranged with a specific composition was used, and several pots were combined into one large module, which did not fill the wall area. Meanwhile, the hidden single potting type is almost the same as the single potting, but the pot is fully covered by vegetation.



The multiple potting type has three parts and each section has an estimated area of 1.25 m<sup>2</sup>. It is configured with three units of biowall arranged in succession and diagonally. In this condition, the surface is fully covered by vegetation which is a mixture of various foliage combined with a specific composition. The biowall is organized into several small modules which are not tightly arranged with each other.

Linear potting type is almost similar to multiple potting but has five pots arranged linearly in a zig-zag configuration. The area of each part is 0.5 m<sup>2</sup> and this means it is approximately 2.25 m<sup>2</sup> in total. In this condition, the pot's surface is not entirely covered by vegetation which is also a mixture of different foliage arranged with a specific composition. This type uses elongated pots standing independently and which are set horizontally as needed.

The fully potting biowall uses a complete biowall configuration from the ceiling to the floor covering and an area of 9 m<sup>2</sup>. The pot used is entirely covered by vegetation which is a mixture of various foliage arranged based on a specific composition. The types of plants used in each classification are generally the same and the difference is only in the configuration and arrangement for each kind.

### 3.4. Research Instruments and Data Collection

A questionnaire and a Virtual Reality Headset for Android were used as the research instrument. Moreover, the visual assessment was based on the physical quality of the biowall and the psychological quality of the respondent, which was determined based on memorable experiences, background, age, and level of socioeconomic life. The locus of this research is Semarang, which is a medium-sized city in Indonesia considered to represent the average condition of Indonesian society. The respondents were selected using a purposive sampling technique based on certain predetermined criteria, which include being between 18 years and 60 years of age, being physically and mentally healthy, and having a permanent job. Meanwhile, the respondents were not limited to people with special skills or certain economic levels in order to have diverse data on gender, social and economic conditions, interests, and backgrounds, as well as to ensure the general condition of the public is represented.

The questionnaire was designed using a semantic differential system, which involves applying psychological measurement to the aesthetic aspect in order to form visual characters. The method usually uses adjectives as stimulus characters and the questionnaire focused on the five items related to the effect of the biowall, which include the perceptual, thermal, visual, respiratory, and audial comfort. It is important to note that the thermal comfort was based on the touch sensor. Another thermal point is about the emissivity, which shows the heat radiation of a surface compared to the heat radiation of an ideal 'black body.' It depends on surface texture and color. So, the adjectives

used included hot-cold, moist-dry, and rugged-smooth surfaces. The visual comfort was based on sight sensors and the adjectives used were plain-colored, dark-light, and gloomy-bright. Audial comfort relates to the sense of hearing. The sound intensity absorption was influenced by the size, density, and thickness of the vegetation used in the biowall. So, the adjectives used like narrow-broad, tight-fitting, and thick-thin. The respiratory comfort was based on the human lungs' needs with adjectives such as arid-shade, dry-fresh, and warmth-coolness while perceptual were explored based on adjectives that describe the existence of biowall such as bad-magnificence, uninterest-interest, dynamic-static, complex-simple, ordinary-unique, classical-modern, formal-informal, and not varied-varied.

360 panoramic images were presented with a #1 to #7 scale on differential semantic variables provided for the respondents. The highest ratings of #7 and #1 indicate high interest from the respondents, #6 and #2 for ordinary interests, #5 and #3 mean not interested, and #4 represents neutrality or lack of interest in the two characters being compared.

The room where the respondent saw VR and filled out the questionnaire was set comfortably. Although the VR assessment focused more on visuals, the other sensors were constant for all biowall configurations. For thermal and respiratory sensors, the room was conditioned to be around 22 – 26°C, with 60% humidity. The 360 panoramic images were set with the same sound background for all conditions. And for respiratory, the amount and shape of the furniture did not change, and the doors were closed so there would be no contaminants from outside affecting the smell and dust.



Source: Author Documentations, 2022

**Figure 3.** Respondents with Virtual Reality Headsets

The data collection mechanism required the respondents to view the 360 panoramic images of the simulation results for the 12 biowall configurations through a Virtual Reality Headset (as shown in Figure 3) and assess them based on the psychological variables. Data collection was set randomly for people who are experienced in VR or have

never been. That was to describe the actual reality. The time to observe the 360 panoramic images was about 30 minutes. Respondents were free to see the 360 panoramic images first and then answer the questionnaire. Respondents could look back at the 360 panoramic images while answering the questionnaire. The responses provided were later analyzed using one-way ANOVA descriptive statistics to show the similarity in the preferred variant, the highest trend of each variable and configuration, and the dominant factors generally influencing the public's preference.

## 4. Results

### 4.1. Respondents Demography

Data were collected from 25 respondents with different attributes placed in a room with a special condition and asked to assess their visual experience concerning the video presented using a virtual reality headset. The demographic profile showed that there were 17 male and 8 female respondents, aged between 20 and 51 years, and an average respondent has a diploma educational background, works as an employee, and was married.

### 4.2. Hypothesis and Significance Analyze of Biowall Configuration

The normality test conducted on public preferences of six family room configurations showed a significance value between 0.102 to 0.676, while the values for the six living room configurations were between 0.098 to 0.930. This means the data provided by the respondents were normally distributed as indicated by the values being more than 0.05 and can be used for parametric analysis through one-way ANOVA.

The Homogeneity of Variances test for public preferences for six family room configurations showed a p-value of 0.411, while six living room configurations had 0.763, which is higher than 0.05. This means the data for the 12 biowall configurations are the same or homogeneous and this means they meet the assumption required for homogeneity.

This led to the formulation of two hypotheses which include  $H_0$  and  $H_a$ . The  $H_0$  states that the six configurations of the biowall area have the same preference variant, while  $H_a$  states that the six configurations of the biowall area have different preference variants. Moreover, one-way ANOVA test results showed that the F-value for the family room was around 5.795 to 14.409, while the living room had 7.102 to 12.702. The F-table showed 2.60, thereby leading to the denial of  $H_0$ . This means the six configurations of the biowall area in each room have significantly different preference variants.

### 4.3. Preference Based on Perception and Comfort Variable

The results of the preference assessment conducted for each variable in the family room using the Post Hoc Test one-way ANOVA (Tukey HSD) are presented in the following Figure 4. It was discovered that the highest tendency of public evaluation of biowall in the family room was found in the magnificence and interest variable for the multiple potting type (BF3) with 5.76 (N = 25). The highest trend for the living room was also reported in the magnificence variable for the multiple potting (BL3) with 5.88, (N = 25) as shown in Figure 5. Multiple potting biowall (BF3 and BL3) was a configuration with several biowalls covering a total area of 3 by 1.25 m<sup>2</sup> and arranged diagonally. This configuration has a more attractive arrangement, dynamic design, not monotonous, medium area category, and a more aesthetically pleasing combination of vegetation and frames. The perceptual judgments were considered this type more beautiful, interesting, varied, and unique. Meanwhile, room conditions without biowalls were considered more modern and formal.

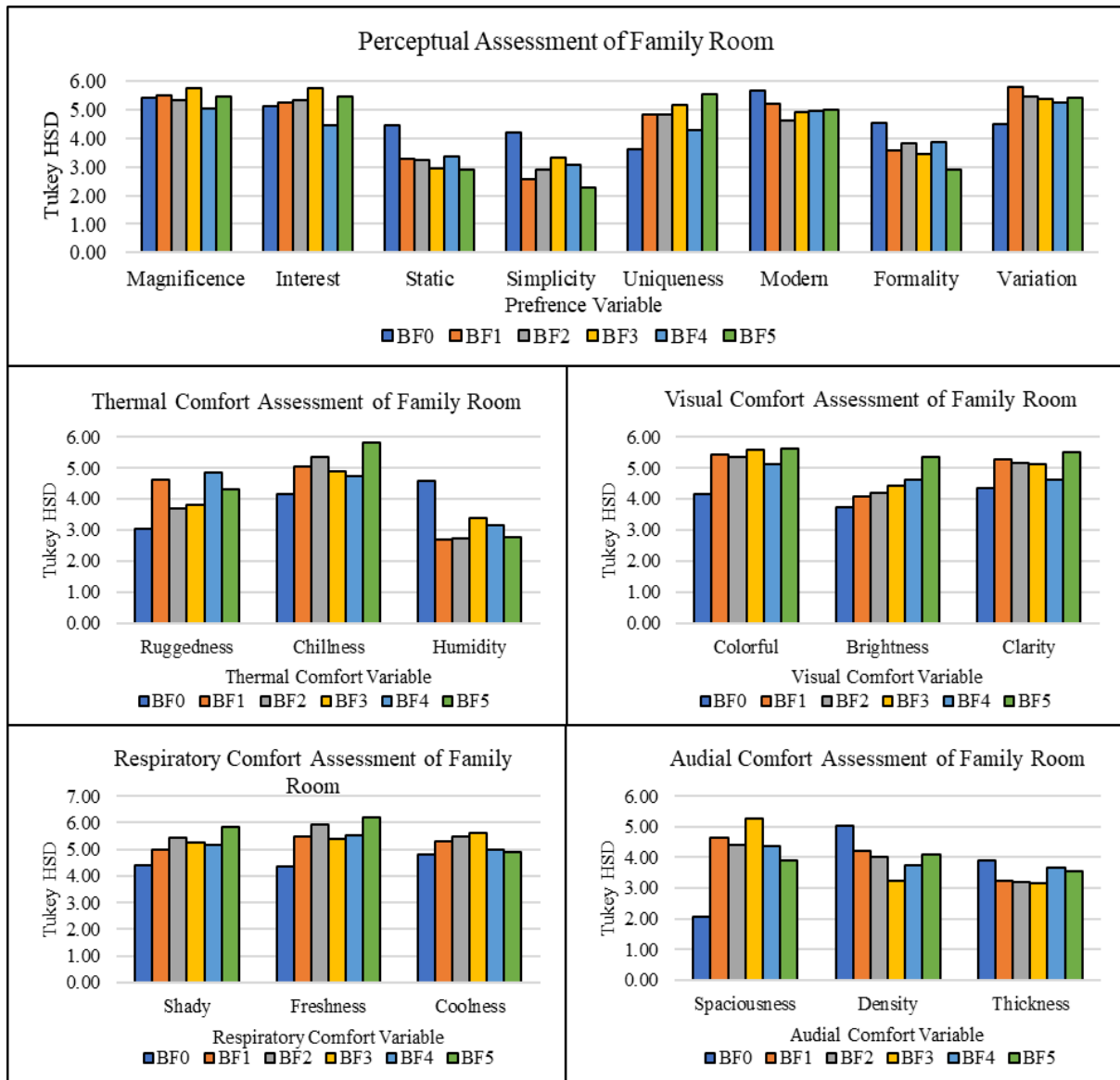
Regarding thermal comfort, chillness in the fully potting configuration (BF5) had the highest preference value of 5.80 (N = 25) for the family room because its coverage of the total area of 9 m<sup>2</sup> is considered to give the room a cold atmosphere. Meanwhile, chillness in the hidden single potting type (BL2) had the highest preference in the living room with 5.32 (N = 25) because the pot is covered by full foliage with an area of 2.5 m<sup>2</sup>. This means a denser coverage of the wall by leaves tends to create more attraction to the public due to the perception that it provides a cooler inner space and atmosphere. Public thermal assessments of rooms without biowalls showed that they were more humid.

The colorful variable achieved the highest preference value for visual comfort in the family room in the fully potting biowall (BF5), with 5.62 (N = 25). Meanwhile, the hidden single potting biowall (BL2) was considered more colorful in the living room, with an assessed value of 5.76 (N = 25). This means complete plants in a room could provide a brighter atmosphere than a plain one. And the dominant green color made the public more fill colorful. Meanwhile, the public considered clarity for the room without biowall.

The highest preference value for respiratory comfort was found with freshness, especially in the fully potting configuration (BF5) in the family room with 6.20 (N = 25) and the multiple potting designs (BL3) in the living room with 5.60 (N = 25). It was discovered that a larger or more concentrated area of biowall provides higher freshness compared to the others.

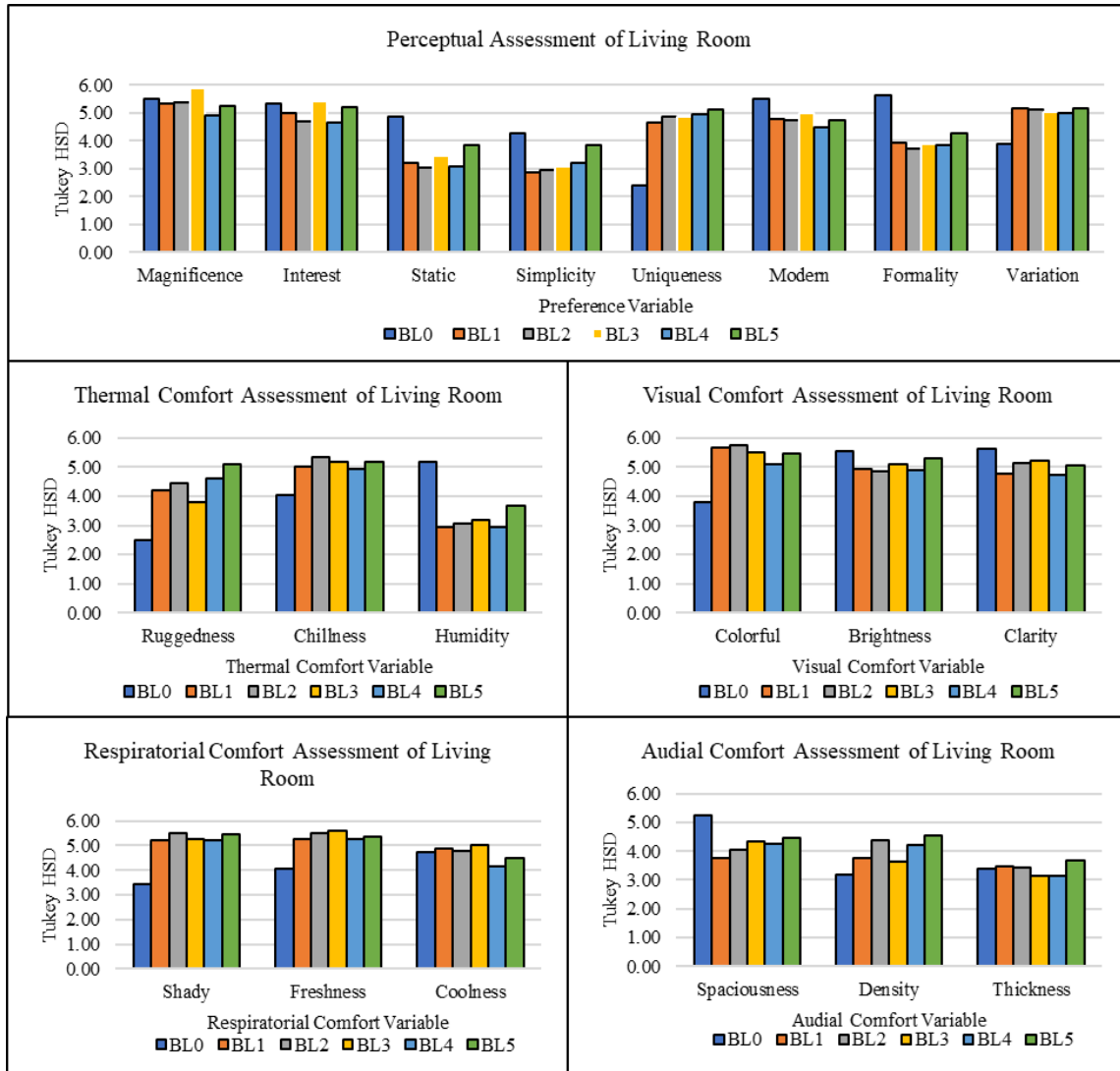
The findings also showed that spaciousness in multiple potting biowall (BF3) had the highest preference rating for audial comfort, with 5.28 (N = 25). This means the configuration with three by 1.25 m2 with a diagonal arrangement improved the room's audial condition. The impression of biowalls spaciousness significantly affects the attenuation of sound and reverberation. It means that

the sound was clearer because of noise reduction and absorption by biowall. However, the living room without biowall (BL0) was found spaciousness as indicated by the 5.24 (N = 25). The public considers a room without a biowall wider. This assessment may occur due to a misunderstanding in translating the breadth of space with the range of the biowall.



Source: Author Analysis, 2022

Figure 4. Variable Value of Family Room Biowall Configuration uration



Source: Author Analysis, 2022

Figure 5. Variable Value of Living Room Biowall Configuration

#### 4.4. Preferences Based on the Variables of Each Biowall Configuration

The preference assessment for each biowall configuration in the family room is presented in the following Figure 6. It was discovered that the family room without biowall (BF0) which was used as the control had an average preference value of 4.30 (N = 25) and the highest variable was modern with 5.68 (N = 25), while the living room (BL0) had 4.23 (N = 25) and the highest variable was formality and clarity with 5.64 (N = 25). This means a room without a biowall is considered more modern, clear and formal.

The mean value of the single potting biowall configuration (BF1) for the family room was 4.55 (N = 25) and the public preference variable was observed to have the dominant influence. Moreover, the public prefers using a single potting configuration because it is considered more varied as indicated by the 5.80 (N = 25) value and this can

be associated with the high degree of variation linked to the large module with a 2.9 m<sup>2</sup> area enclosing different kinds of leaves. It was also discovered in Figure 7 that the mean variable rating for the single potting configuration (BL1) in the living room was 4.39 (N = 25) and the dominant factor was colorful with a preference value of 5.68 (N = 25).

The mean variable rating of family rooms with a hidden single potting biowall (BF2) was recorded to be 4.52 (N = 25) and the dominant factor influencing public preference was freshness with 5.92 (N = 25). This is possible because the entire area of the biowall is covered with green leaves without the slightest pot visible in the middle. Meanwhile, the average rating for the living room with the same configuration (BL2) was 4.49 (N = 25) and the most influencing factor was colorful with a preference value of 5.76 (N = 25).

The mean preference value for the multiple potting configuration type in the family room (BF3) was recorded to be 4.59 (N = 25) and the most influential variable was

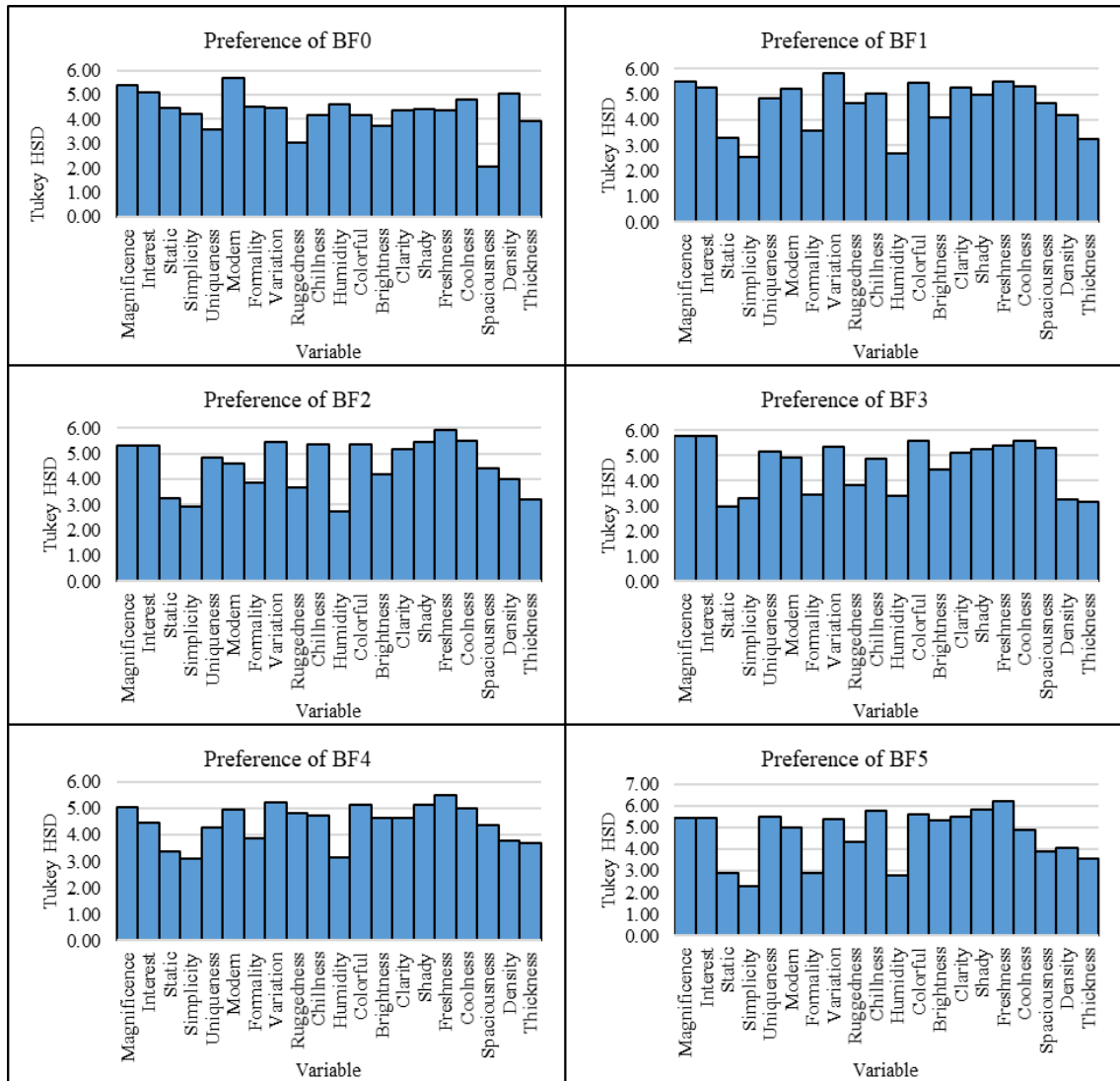


magnificence and interest with a preference value of 5.76 (N = 25). Meanwhile, the average value in the living room (BL3) was found to be 4.51 (N = 25) and the dominant factor was magnificence with a preference rating of 5.88 (N = 25).

The most dominant variable influencing the preference for linear potting configuration in the family room (BF4) was found to be “most refreshing” with 5.52 (N = 25) and the average assessment value for this configuration was recorded to be 4.44 (N = 25). A similar trend was observed in the living room but freshness was found to be the most

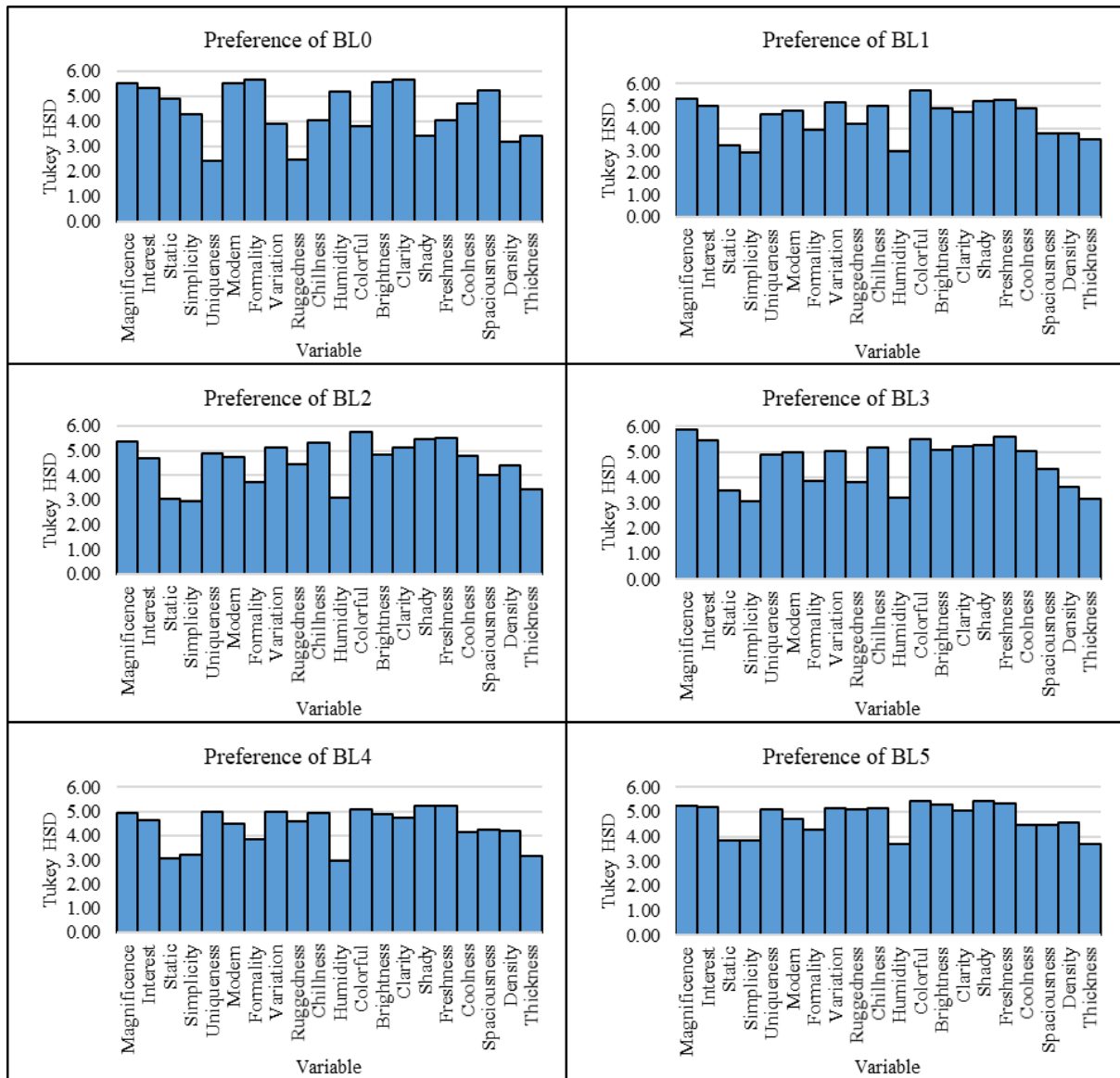
dominating factor for BL4 with a preference value of 5.24 (N = 25), while the mean assessment value was 4.35 (N = 25).

The mean variable rating for family rooms with fully potting configuration (BF5) was 4.64 (N = 25) and freshness was the most dominating factor with a preference value of 6.20 (N = 25). Meanwhile, the mean rating for the living room (BL5) was 4.73 (N = 25) and the most dominant factor was shade and color with a preference value of 5.44 (N = 25).



Source: Author Analysis, 2022

Figure 6. The Value of Biowall Configuration Preference for Family Room



Source: Author Analysis, 2022

Figure 7. The Value of Biowall Configuration Preference for Living Room

It was generally observed that the most dominant variable influencing the public preference for biowall in the family room was freshness, with a mean score of 5.48 (N = 12), as indicated in Figure 8. This is based on the belief of the people that adding a biowall in the family room can give freshness. Meanwhile, the variable with little impact is simplicity, as indicated by the average value of 3.06 (N = 12) and this shows that people ignore the impression of a simple design in selecting the choice of biowall configuration for the family room.

The dominant variable influencing the preference of the public to have a biowall in the living room was found to be magnificence, with an average value of 5.37 (N = 12) as indicated in Figure 8. This is based on their belief that a biowall can add to the magnificence of the room. Meanwhile, the variable with a minor effect was simplicity,

with a mean value of 3.37 (N = 12).

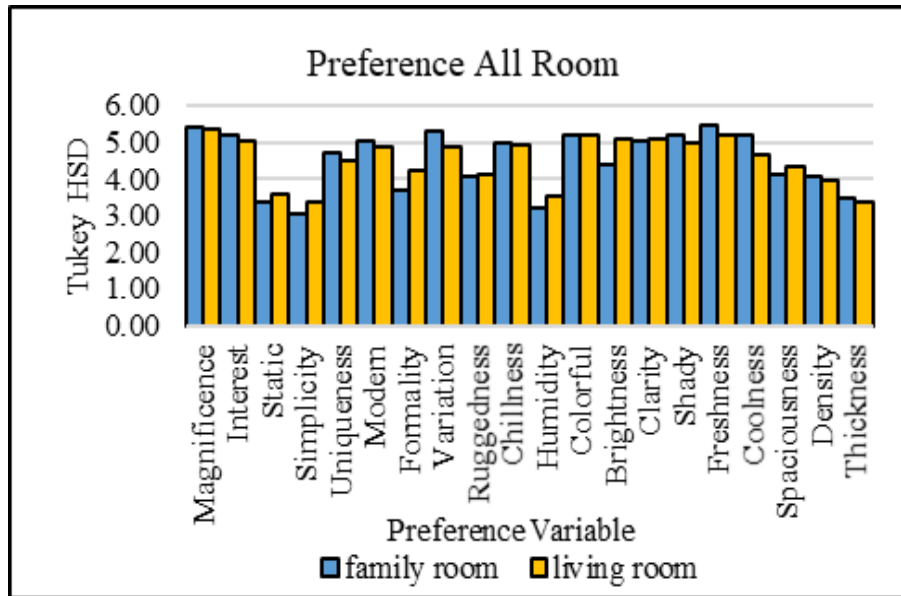
The findings showed that BF0 and BL0 were assessed more from the perceptual and visual perspectives. Room with biowalls configurations in both family rooms (BF1, BF2, BF3, BF4, and BF5) and living rooms (BL1, BL2, BL3, BL4, and BL5) were more associated with perceptual views, visual comfort, and respiratory comfort. Significantly few public assessments have linked the presence of a biowall with audial and thermal comfort. So, this needs to be formulated further for similar research virtually in the future.

#### 4.5. Preferences Based on Biowall Configuration

The biowall configurations most preferred in family and living rooms are presented in Figure 9 and the average

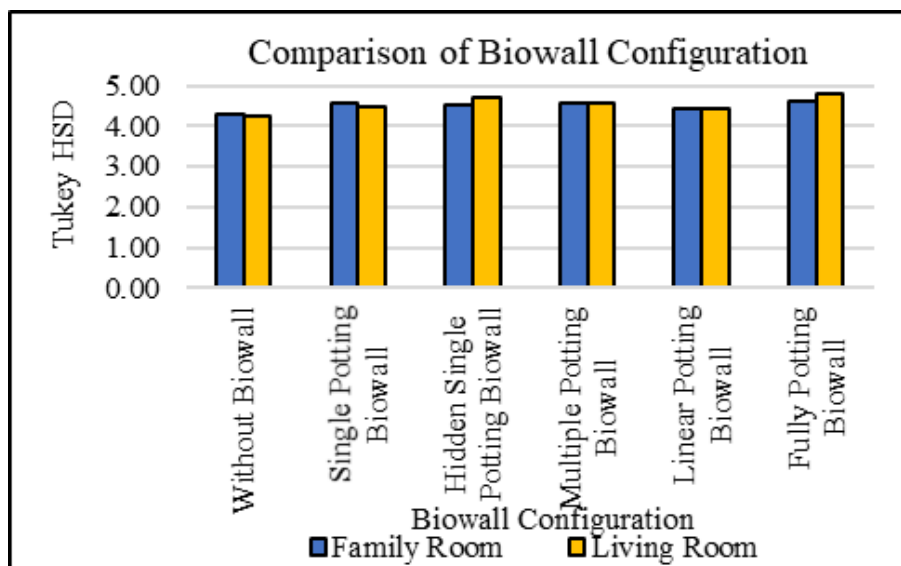
Tukey HSD value of the overall preference was recorded to be 4.51 and 4.54 (N = 25) respectively. Moreover, the least preferred configuration in the family room was linear potting, with a preference value of 4.44 (N = 25), while the one for the living room was 4.45 (N = 25). The comparison with the rooms without biowall showed a general tendency such that the preference value for the family room was 4.30 (N = 25) while the living room had 4.23.

The most preferred configuration in the family room was the fully potting, with a rating of 4.64 (N = 25) and the same was found in the living room with 4.81. This type covers the complete area from ceiling to floor and this means the size of the biowall affects people's preferences because people were observed to be more interested in the wider configurations.



Source: Author Analysis, 2022

Figure 8. The Overall Variable Value



Source: Author Analysis, 2022

Figure 9. The Overall Configuration Value

## 5. Discussion

The preference based on comfort shows that the public believes that the main reason for the application of biowalls in the family and living rooms is to provide magnificence and interest, thereby leading to their interest in the multiple potting type. This is in line with the review conducted by Sutton that stunning, pleasing, and ecological beauty are the aesthetic reasons for the usage of biowalls in a space [42]. It was also discovered that the presence of plants in space increases attractiveness [43] because the design is usually beautiful, natural, memorable, relaxed, compatible, colorful, aesthetic, unique, reliable, and functional [44]. Meanwhile, it can provide magnificence and create interest in the room only when the plants grow evenly and under good care. This means there is a need to maintain the plants to ensure they grow healthy, evenly, and not wilted by removing dry leaves, preserving the leaf color, cleaning, and trimming parts that are too dense.

It was discovered from the thermal comfort aspect that the presence of biowall affects chillness. A room is perceived to be cooler, especially in the fully potting and hidden potting configurations, because these types ensure a higher density of the leaves attached to the wall and do not spread separately. This cooling effect was also observed in several studies conducted using different significant user sensations. It was reported that the existence of the Vertical Greenery Modular System reduced heat by 23 °C in Turin and decreased the energy performance by 40% [37]. Another study also showed that the simulation conducted using Energy Plus in the Hong Kong area proved the ability of the Vertical Greenery System to reduce the temperature of the building facade in summer by 26 °C or by 3% of cooling energy consumption [45]. The cooling impression is associated with the dominant cluster of green color, which is classified as a cold color range on the wall. However, further analysis is needed to determine whether the selection of plant species with a red-yellow color range for application in biowall can provide the same effect.

Figures 3 and 4 show that the highest preferences for visual comfort are color. It is psychologically believed that a bright atmosphere allows a positive evaluation of the activities of space users. The colorful impression becomes a differentiating factor because biowall is a living ornament compared to other interior ornaments such as paintings, sculptures, and others. Moreover, Thatcher's review shows that the usage of plants in interiors, besides being attractive, also provides fewer stress symptoms, improves mood, and enhances physical health [46]. The light intensity due to the biowall in the tropics with a western orientation can reduce sunlight by 31.18 – 51.71% and in a southern orientation by 28.4 – 54.87 % compared to a facade without plants [32]. Veisten also reported that colorful biowall plants could add aesthetic value to the built environment [47].

Freshness is the highest factor associated with the effect of biowall on respiratory comfort. This condition was

found to be the same for family and living rooms designed with fully potting and multiple potting configurations. The integration of plant-based systems into interior spaces of urban buildings is particularly important to produce viable fresh air [48]. Moreover, edible plants can also be used as biowalls in restaurants to offer an impression of a fresh supply of vegetables and an exciting background for diners [3]. Psychologically, people feel refreshed when in the wild or in contact with something natural such as the presence of biowall in the interior. There is a need to further explore the preferences of people for the application of artificial biowalls in the interior of buildings.

The spaciousness of the multiple potting configuration type and the space without the biowall were discovered to be highly preferred to enjoy audial comfort by the people. This shows a relationship between the area of the biowall and the audial quality of the room in terms of reverberation, sound absorption, and sound reflection. This is possible because the ability of plants to reduce reverberation time, sound absorption, and sound reflection depends on leaf thickness, leaf density, and plant surface area, which serve as the medium to absorb or reflect sound sources. Meanwhile, a building with a relatively extensive and dominant biowall is considered spectacularly beautiful and helpful in revitalizing the atmosphere [1].

The preference based on the variables of each configuration showed that the single potting (BF1 and BL1) was preferred for two reasons by the public. It is more varied in the family room and more colorful in the living room. The high variation is in line with the findings of Zhuang that visual attractiveness and color configuration are positively associated with aesthetic preference and emotional valence [49]. Meanwhile, the colorful aspect was confirmed by Radić that the biowall size affects the perception of its design, including the color, as complete [50].

The hidden single potting biowall configuration (BF2 and BL2) was also preferred for two reasons by the public. It provides freshness in the family room and is considered colorful in the living room. This configuration is a combination of whole leaves attached to the wall without the pot being the slightest visible and this means it allows the combination of several more colorful plants, which are denser because the pot is hidden. The new aesthetic concept combines plant species, texture, pattern, shape, and density of foliage, as well as color variations as the main factors [51].

The dominant factors influencing the preference for multiple potting biowall configurations (BF3 and BL3) are magnificence and interest factors. It is important to note that it is only the magnificence in the living room, and this is in line with the findings that biowall provides a healthier indoor atmosphere and a more aesthetic space [52], as indicated by the growing interest in this phenomenon [53]. It was also observed that a high proportion of excellent color and green vegetation significantly increases aesthetic preference and emotional valence [49].

The most dominant variable influencing people to select biowall linear potting configuration (BF4 and BL4) in both rooms is its freshness. This was confirmed by a study conducted using double-layer facades as well as the combination of Azolla by Parhizkar as a natural air purifier to provide fresh air and absorb occupant bio-waste in indoor spaces [54]. Meanwhile, the fully potting biowall configuration (BF5 and BL5) was observed to be preferred in the family room due to its ability to provide freshness and in the living room because it can provide shade and color. This is very rational considering the vast area of the biowall and was discovered to align with the findings of Jain that biowall provides shade by reducing building temperature depending on plant density [5].

The highest factors observed to have a general influence are freshness in the family room and magnificence in the living room. The difference in these results is possibly due to several conditions such as the number, position, dimensions, color, the material of furnishing, respondents' background, and rendering quality. Therefore, more specific research is needed in the future to develop a biowall area from a strictly controlled room to avoid uncertainties.

The preference values for each configuration are shown in Figure 9 and the room without biowall was the least in both the family and living rooms. This means people prefer to add plants to their rooms and this is in line with the finding of Meral that participants wanted to see the biowall around them [44]. Meanwhile, the highest preference in both rooms was found with the fully potting configuration. The data showed that people prefer to apply vegetation with large areas to the interior of their buildings. The application of indoor plants such as potted plants reduces hostile feelings and relieves physical discomfort. Han also recommended simple exposure to a potted plant placed at approximately three meters to occupants in a room for about 20 minutes to increase positive psychological perceptions [55].

Fully potting biowall was the highest public preference. Some of the advantages of using this system are that it is easy to disassemble for maintenance [51], the possibility for a variety of plants' aesthetic potential [56], and an attractive design [57]. Moreover, the perception of a biowall depends on its color, several plants, and size [43,49]. The dimensions need to consider that the unit value of the biowall has an impact on the estimated cost efficiency [47]. It was also mentioned in another study that diversity and size strengthen the aesthetic perception of biowall [44]. Meanwhile, Vries noted that the size and quantity of the wall are not as important to general health as the quality [58]. The size affects the perception of beauty, aesthetics, diversity, extraordinariness, color, naturalness, memorability, compatibility, relaxation, reliability, distinctiveness, worth, and functionality [44].

## 6. Conclusions

The one-way ANOVA test conducted showed that the six configurations of the biowall area in each room had significantly different preference variants with the F-value (5.795 to 14.409 for the family room and 7.102 to 12.702 for the living room) greater than the F-table (2.6). Moreover, the Post hoc test showed that the factor mostly considered by the public in using biowall in a family room was magnificence and interest with 5.76 (N = 25) and the factor considered in the living room was magnificence with 5.88 (N = 25). It was also discovered the variable mostly considered in terms of thermal comfort for the family and living rooms was chillness by cooling with 5.80 (N = 25) and 5.32 (N = 25) respectively. In terms of visual comfort, the factor considered in both rooms was colorful with a rating of 5.62 (N = 25) in the family room and 5.76 (N = 25) in the living room. For respiratory comfort, the influencing factor for family and living room was freshness with 6.20 and 5.60 (N = 25) respectively. Furthermore, the most considerable factor regarding audial comfort was spaciousness with 5.28 and 5.24 (N = 25) respectively.

The comparison of all the configurations showed that freshness is the most important factor in the family room with 5.48 (N = 25), while magnificence is for the living room with 5.37 (N = 25). The most important conclusion is that the public prefers having biowall in their rooms rather than having a bare wall and the most preferred configuration is the fully potting which has the most significant area among other configurations. This is indicated by the average magnitude of preference recorded to be 92.76 in the family room and 95.08 in the living room on a 140 scale (N = 25).

These positive results showed that there is a need to effectively formulate the appropriate configuration area and size. The positive contribution of biowall configuration to the physical and psychological comfort of the occupants is also highlighted and not only the aesthetic aspects. The differences between the two spaces were found to be possible due to several conditions such as the number, position, dimensions, color, and furnishing materials. Moreover, different space design concepts can also contribute to the variations in the preference values as well as the background and rendering quality of the respondents. These uncertainties need to be minimized in future research.

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