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Original Research

The Impact of Building Façade Colors on Sense of Place in a Residential Area

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ABSTRACT

Building façade color plays a significant role in shaping urban culture, city image, and residential experiences. However, in most urban planning practices, building façade colors have been neglected or have been considered a secondary factor in developing a sense of place. This study aimed to examine building façade color as an independent variable by considering the role of hue, saturation, and brightness as the most important factors in the context of affective responses for sense of place in relation to the conceptual dimensions of place identity, place attachment, and place dependence. A number of images were prepared by manipulating building façade colors based on the HSB color model, and the study was conducted by utilizing a semantic differential method with the aid of multiple-choice and dichotomous question methods. The study results reveal that the existing color of the building facade, which is white/neutral in color, produces the highest values of place identity and place attachment. Among the simulated colors, cool blue and warm yellow facade colors produce a high sense of place. The color characteristics influenced the emotional responses; muted saturation levels produced positive responses, and the preference for brightness varied with the façade's hue but did not have an optimum. The findings highlighted the importance of façade colors in influencing the sense of place and the need for balancing the design of colors with the context of comfort and preference.

Keywords: Building façade color, Sense of place, Place attachment, Place identity, Place dependence.

1. Introduction

Color is an essential aspect of the way we see and make sense of the world we live in. It shapes the experience of the environment, including perception, emotion, meaning, and actions [1]. Urban colors reflect culture and identity. Most importantly, they influence how people see, understand, and accept buildings and spaces [2, p.16]. In addition, urban color contributes to feelings of familiarity, a sense of unity with space, and a sense of belonging among residents [3]. Since building façades (BFs) dominate urban surfaces, building façade color (BFC) is a major component of architectural communication [4]. These perceptual and communicative functions of color directly relate to the concept of sense of place (SOP) [3]. SOP refers to the emotional and psychological bond between people and their environment, shaped by both subjective experiences, such as memories, culture, and traditions, and objective physical characteristics like design, landscape, color, and sound [5]. It consists of three interrelated components: place identity, place attachment, and place dependence [6]. It fosters a link between people and the environment, allowing them to see themselves as part of it [7]. Because color influences memory, familiarity, unity, and belonging, it contributes to how people perceive architecture and urban spaces [8]. BFC, in particular, has "a close relationship with the mood of urban residents" [4]. Although many studies have explored the relationship between urban design and SOP, evidence of the specific impact of BFC remains limited. Most studies have so far considered either the general urban area or multiple façade features together, such as shape, rhythm, or material, without isolating color as a distinct variable. For this reason, the present study aims to investigate the specific impact of BFC on SOP by isolating color as a visual variable and examining its influence on emotional responses.

2. Related Works

In this study, the literature review is divided into two main sections: studies on BFC and studies on SOP. This structure addresses a current gap in the literature, namely, the lack of empirical studies investigating the direct impact of BFC on SOP. The first section focuses on BFC. Since emotional response is closely related to the concept of SOP [7], only studies that examine the emotional or perceptual effects of BFC were reviewed. The research on BFC generally uses two main methods. The first includes studies that examine a single BF and rely on computer-simulated BFC images to identify participants' emotional responses. Studies such as those by Wang, Shen, and Huang evaluated how BFC affects visual comfort using a mix of eye-tracking tools (ET) and the semantic differential questionnaire (SDQ) approach. Their findings showed that cool BFCs of blue and green were least acceptable, whereas warm BFCs of orange and red were most preferred. Furthermore, desaturated colors were associated with greater visual comfort [4]. Çubukcu and Kahraman compared architects' and non-architects' evaluations of BFC and found that architects preferred yellow, while non-architects preferred blue [9]. Both Zhu, Liu, and Chen, and Wang, Shen, and Huang digitally created BF to explore how BFC impacts perception, instead of relying on actual BF [10], [11]. Zhu, Liu, and Chen examined how shopping mall BFC affects perception and entry decisions, using the SDQ. Warm, bright, or neutral BFCs attracted customers more than cool or dark ones [10]. Fig. 1 illustrates the typical methodological approach used in building façade color simulation (BFCS) studies.

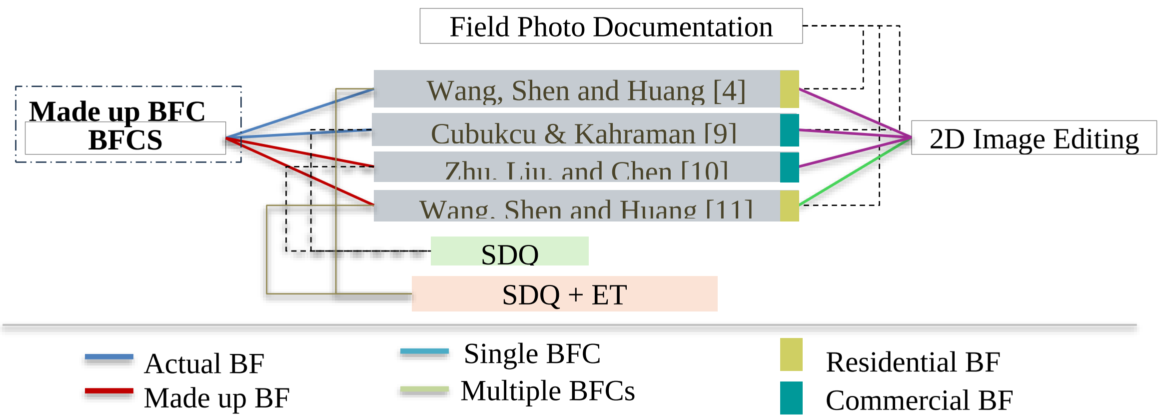

Figure 1. Overview of Methods Used in Studies Examining Simulated Building Façade Colors

The second method is research that examines several real BFs and their actual BFCs. Researchers employed three principal methods to analyze actual BFCs. The first included studies that used a color meter tool to capture BFC characteristics, such as the studies by Chen et al. [12], [13]. In one of their studies, the authors investigated the relationship between housing prices and consumers' BFC preferences. Low-income groups liked 2–3 warm BFCs, middle-income groups preferred 3 warm BFCs, and high-income groups favored 1–2 darker and richer tones [12]. The second method used pixel analysis from documented images of BFC to capture the color code of the BF, as in the research by Mehdipour, Ekhlasi, and Yazdanfar. They looked into how BFC can be classified based on an emotional scale. They found that most of the BFs can be categorized into eight types, such as warm-contrasting-heavy or cool, based on the dominant color, brightness, and color interaction [14]. Similarly, Wang, Sun, and Li selected 20 historical and 20 modern BFs through expert scoring to analyze how historical and modern BFC schemes affect human visual comfort. Participants rated historical BFCs as more visually comfortable than modern ones [15]. Zhang et al. conducted an experimental study on the emotional impact of urban school neighborhood color environments on children and found that bright, bold color contrasts boost arousal, and balanced and consistent hues enhance a sense of control [16]. The third method relied on visually analyzing BF documentation photos to determine the dominant BFC of the area. This includes the study done by Kong et al., in which they sought to understand the impact of traditional dwelling colors, especially in rammed earth homes, on the behavior of the residents. Based on the study, the preference for colors in traditional homes is understood in two ways: protective evaluation (PrEvo) and positive evaluation (PosE). From the study, it is clear that traditional colors create a sense of identity and emotion [17]. Fig. 2 Analytical methods used in building façade color analysis (BFCA) studies examining real BFCs.

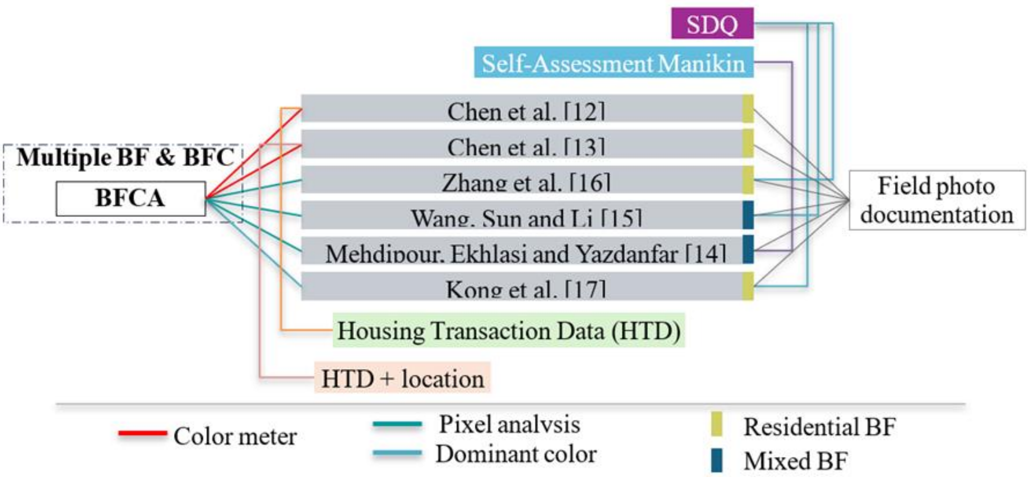

Figure 2. Analytical Methods Used in Studies Analyzing Real Building Façade Colors.

The second section attempts to explore SOP research to identify its dimensions. In their research, Hu and Chen aim to establish whether the physical aspects of the environment relate to perceptual qualities, and whether the perceptual qualities in question relate to the components of the concept of SOP, including identity, attachment, and dependence [18]. Farhad and Tanaka note that architectural identity is determined by building form and finishing materials. The aspects discussed include distinctiveness, continuity, and familiarity. In their findings, the traditional homes with the use of natural materials like stone, mud, and brown tones recorded the highest scores in terms of identity [19]. Similarly, Ariannia, Naseri, and Yeganeh examine the cognitive-emotional influence of building form on place attachment. Among the formal elements, color was one of the most effective features [20]. Furthermore, Zarrabi employed a comparative case study to investigate the relationship between BF design and place attachment in two residential complexes; residents reported greater levels of attachment and satisfaction with their environment [21]. Li et al. linked the SOP dimensions of place dependence, attachment, and identity to landscape perception, showing their combined role in restorative experiences in historic districts [22]. Maulina Fitria and Soewarno demonstrated that façade colors in urban public spaces convey place identity, influencing familiarity and reinforcing the perceptual dimensions of SOP [23]. Fu et al. showed that visual elements of arcade buildings and streetscapes, such as plaque text, windows, and plant colors, significantly influence tourists' place identity emotions[24]. Table 1 summarizes the dimensions and sub-dimensions of the SOP identified in those studies.

Table 1. Overview of Dimensions, Subdimensions, Indicators, and Operational Definitions of Sense of Place in the Built Environment and BF Context (Author).

Dimension of SOP		Subdimension	Indicator	Definition	[18]	[21]	[20]	[22]	[23]	[19]	[24]
PosE	Place	**Distinctiveness**	Distinctive built environment	Recognize visual features of the built environment as different from others.	●	●	●	●	●		●

		Continuity	Memory of the past built environment	Continuity of place through memories associated with historical or cultural places.	●	●	●	●	●	●	●
			Lifestyle (self-reflection)	Continuity of place that aligns with one's lifestyle, memory, and daily activities.	●	●	●	●		●	
		Familiarity	Physical familiarity	Feeling connected to a place through repeated physical presence.	●	●	●	●	●	●	●
	Place Attachment	**Sense of pride**	Proud of the built environment	Feeling proud and concerned about the physical condition or features of the built environment	●			●	●	●	
		Satisfaction	Feeling pleased	Seeing the place as a favorite or an emotionally uplifting space		●	●	●			
		Belonging	Feeling comfortable	Feeling relaxed and at ease in the built environment	●	●	●	●	●		●
			Feeling secure	Feeling secure and safe in the built environment	●	●	●	●			●
PrEvo	**Place Dependence**	**Comparison**	Preferring this place over others	Choosing this place over others for activities	●	●	●	●		●	
		Loyalty	Being loyal to a specific place	Not wanting to replace or exchange the place with another	●			●	●	●	

According to what has been found in the literature review, the following hypotheses can be formulated. However, the perception of color varies according to cultural and climatic contexts; thus, these hypotheses need to be tested within the local setting of Erbil in order for them to reflect perceptions from residents and achieve contextual validity.

H1: The original BFC (existing BFC) has a stronger positive effect on the place identity and place attachment dimensions of the SOP than the simulated BFC variations.
H2: Warm building façade hues (red 0° and yellow 60°) have a more positive influence on place identity and place attachment combined than cool hues (blue 225° and green 120°).
H3: Low (25%) and medium (50%) saturation levels in building façade colors demonstrate higher place dependence, as reflected by participants' preference for these façade alternatives over higher saturation options.
H4: Medium (50%) and high (75%) brightness levels in building façade colors demonstrate higher place dependence, as reflected by participants' preference for these façade alternatives over lower and very high brightness options.
H5: The original BFC (existing BFC) contributes more positively to place dependence than the simulated façade color variations.

2.1 Conceptual Framework

Based on variables identified in the literature review on BFC and SOP, a conceptual framework is developed. These variables were grouped into three variable categories: independent, dependent, and controlled, to examine their interlinking relationships. BFC is the independent variable, represented by hue, saturation, and brightness. SOP is the dependent variable, operationalized through three conceptual dimensions drawn from the literature: place identity, place attachment, and place dependence. These dimensions guided the development of measurement items, though their empirical distinctiveness in the context of color perception was treated as an open research question. These SOP dimensions, following Kong et al. [17], are categorized as positive and protective. Building shape, size, and surrounding context are control variables to isolate the effect of BFC. Fig. 3 illustrates the proposed framework used to link the visual color stimuli to users' psychological responses.

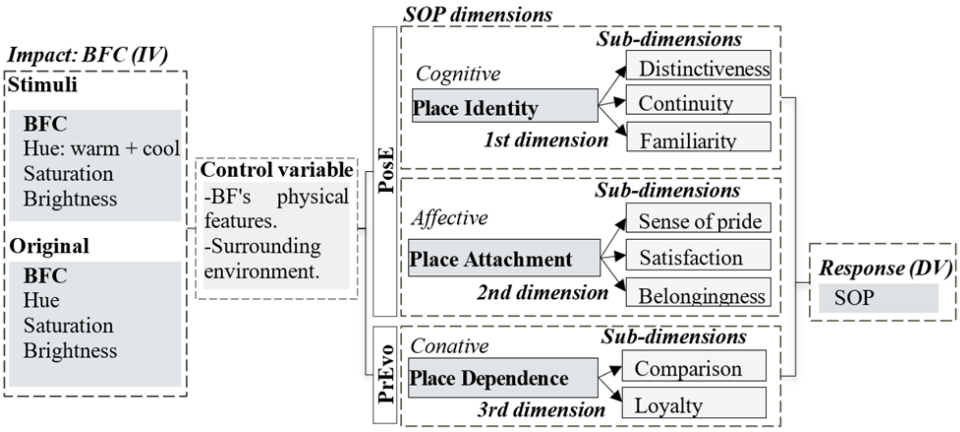

Figure 3. Proposed conceptual framework (Author).

3. Methodology

The research methodology was designed with the objective of examining the impact of BFC attributes on SOP. The research included aspects such as the selection of case studies, the preparation of digitally simulated images for BFCs, and the formulation of a questionnaire based on existing literature to assess the perceptual and emotional responses of participants.

3.1 Study Context and Setting

The present study focused on the residential area, in which the strength of the place attachment is generally higher, mainly because of the long-term association and involvement, as discussed in previous studies [25], [26]. In order to minimize the impact of external variables, the choice for residential apartment buildings was given careful consideration in relation to uniformity in their facades and minimal variations between them. Based on literature-derived criteria, the Empire Apartments (Royal Empire Phase C) in Erbil were chosen as the case study. The facades of the buildings met the requirements of the proposed methodological considerations of the earlier BFCS research. The age of the complex is close to ten years, thus making it feasible to conduct the analysis in an area in which the residents have a feeling of place and time. More importantly, when conducting the survey, the management had already begun making preparations to repaint the BFs, and residents were also aware that the upcoming changes were just around the corner. This provided a realistic research environment because the residents could imagine the possible changes that could be made to the facades of their own buildings and thus respond more thoughtfully to the color stimuli. Four identical facades were chosen for analysis based on the eight structures shown in the Royal Empire Phase C map in Figure 4, while the remaining four facades were excluded due to differences in structural features or lack of access.

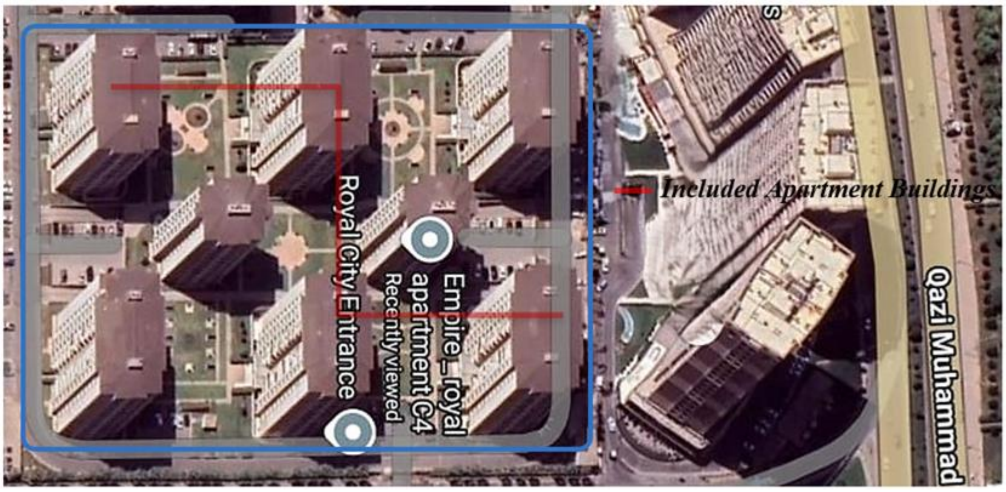

Figure 4. Royal Empire Apartments, Erbil [27]

3.2 Color Mapping and BFC Simulation Images

To study the impact of BFC attributes on SOP, we selected the HSB (Hue, Saturation, Brightness) color model, which can effectively quantify the three basic color attributes (H: 0-360°, S: 0-100%, B: 0-100%). This model is also adopted by relevant research, e.g., [4], [9], [16]. The color codes are selected according to the following three stages, as listed in Table 2.

Table 2. HSB Values Used in BFC Experimental Design.

Stage	Variable	Constants	Values
1. Hue	Hue (H)	Fix (S = 40, B = 75)	Red (0°), Yellow (60°), Green (120°), Blue (225°)
2. Saturation	Saturation (S)	Fix (B = 75, Hue = one value at a time)	S = 25, 50, 75, 90
3. Brightness	Brightness (B)	Fix (S = 40, Hue = one value at a time)	B = 25, 50, 75, 90

This process produced 36 color codes. In addition, the original white BFC (no saturation, only brightness variations) was included, yielding 40 total HSB color codes. A photograph of the selected BF case study was digitally edited using Adobe Photoshop (Version 26.3.0 Release) to generate the BFC simulation images based on the defined HSB color codes. The predetermined HSB values were applied to the façade using solid fill layers and masking techniques. To ensure the color blended naturally with the façade texture, blending and opacity adjustments were applied to integrate the color layer with façade textures while maintaining perceptual consistency across stimuli. Following this process, 40 façade color variations generated using predefined HSB values were prepared, along with one image representing the existing (original) BFC, resulting in a total of 41 stimulus images. These images were then used in the experiment to collect participants' self-reported emotion-based evaluations of SOP.

3.3 Questionnaire Design

Three types of closed-ended questionnaires were used in this research, including the Semantic Differential Questionnaire (SDQ), which was used to measure two SOP dimensions in relation to BFC, in which participants were asked to evaluate images of the original BFC (white, no hue value) and four simulated BF hues while saturation and brightness were kept constant. The SDQ employed a 5-point scale and included 10 bipolar adjective pairs. These pairs were categorized as follows: for the Place Identity dimension, the pairs were Distinctiveness–Ordinary (distinctiveness), Self-reflective–Non-reflective, Cultural fit–Cultural mismatch (continuity), and Familiar–Unfamiliar (familiarity). For the Place Attachment dimension, the pairs were Proud–Shameful (sense of pride), Inviting–Uninviting, Happy–Sad, Beautiful–Ugly (satisfaction), Comfortable–

Uncomfortable, and Secure–Fearful (belongingness). The second type of closed-ended question was multiple choice, adapting methods used in BFCS studies to measure preferred saturation and brightness levels; in this study, however, it was applied to the comparison sub-dimension of the third SOP dimension, Place Dependence. This was measured through two multiple-choice questions in which participants selected their preferred saturation level and preferred brightness level from four BFC images labeled A–D. The second sub-dimension of place dependence, loyalty, was measured using a dichotomous closed-ended question. Participants were asked whether they would prefer the color of the building façade they live in to be changed to another color, responding with either “Yes” or “No.” Place identity and place attachment were assessed using semantic differential scales to capture affective evaluations of BFC. In contrast, place dependence was measured using multiple-choice and dichotomous questions because this dimension reflects functional preference and decision-based judgments regarding the suitability of the residential environment. Due to differences in scale type between the continuous scales used for identity and attachment and the nominal/binomial scales used for dependence, the dependence items were not suitable for inclusion in the same factor analysis. Therefore, place dependence was analyzed separately using descriptive statistics and nonparametric tests.

3.4 Sampling Strategy and Sample Size Determination

The target population for this study consisted of adult residents aged 20–65 years living in the selected residential case project, comprising four apartment buildings. According to administrative estimates provided by the residential management, the complex contained approximately 667 residents in total, of whom approximately 458 were within the eligible age range at the time of data collection. The complex included 200 housing units, of which 14 were vacant, leaving 186 occupied apartments during the study period. The participants were recruited through door-to-door methods covering various apartments in different buildings. The residents were asked to participate in the survey based on voluntary consent. There were deliberate efforts made to ensure that residents from various apartments in different buildings were sampled and not from a single location. However, since the sampling was voluntary and the reliance on the willingness of residents to participate in the survey, it is a non-probability sampling method referred to as a volunteer sample or site-based sampling. In this case, each apartment contributed one respondent to the study, except in a few apartments that contributed two respondents each; therefore, there is a low degree of clustering within each household. Since we didn’t use a probabilistic sampling method, we don’t know how likely each case is to have been chosen; statistical inference is framed in terms of within-subject experimental effects and site-specific findings rather than population estimation.

3.4.1 Sample Characteristics and Planning Benchmarks

Because this study employed a non-probability volunteer sample type, the most important factor in determining sample size was its statistical power for testing hypotheses (see Section 3.4.2), not generalizability to a larger population. However, in order to have a concrete figure to guide us in our sampling process, we initially targeted a sample size of 210 respondents based on a general formula for probability sampling methods. This figure is purely arbitrary and does not have any statistical basis in relation to our final sample. We were able to retain only 144 fully completed questionnaires for analysis. Listwise deletion was used to treat missing values, which accounted for 8% of our discarded questionnaires. The final sample represents about 31% of our targeted residential population sample. Because this study employed a non-probabilistic sampling design, the margin of error cannot be computed. However, for illustration purposes only, a simple random sample of 144 respondents would have a hypothetical margin of error of about ±6.8%. While this figure should not be interpreted as a statistical confidence bound for this study, it is worth noting that a sample size yielding this level of hypothetical precision falls within the range commonly reported in field-based urban perception research conducted within bounded residential contexts [28]. This comparison serves to contextualize the achieved sample size within existing literature, further supporting its suitability for the subsequent hypothesis-driven analyses.

3.4.2 Power-Based Adequacy for Hypothesis Testing

Because the primary objective of this study was hypothesis testing using a repeated-measures design, the statistical power analysis was conducted to verify whether the achieved sample size is sufficient for detecting the effects of BFC on SOP. For this purpose, a sensitivity power analysis using G*Power 3.1 for a repeated-measures ANOVA (within subjects design) with the following input parameters was conducted (as shown in Table 3): N = 144; α = .05; desired power (1 - β) = .80; five measurements (façade color conditions); assumed correlation among repeated measures r = .50; non sphericity correction ε = 1. The results of the sensitivity analysis showed that the minimum detectable effect size is a small Cohen's f = 0.091 (partial $\eta^2 \approx 0.008$). The results of the empirical analysis (presented in Section 4) showed observed partial η^2 for the two SOP dimensions in the range of 0.272–0.363, which is significantly higher than the minimum detectable effect found in the sensitivity analysis. Moreover, observed statistical power for the results of the repeated-measures ANOVA exceeded 0.99. Thus, it can be concluded that the achieved sample size is more than sufficient for detecting façade color effects on SOP with sufficient sensitivity. Nonetheless, because the study uses a bounded case-study sample and non-probability recruitment, findings should not be generalized beyond the specific residential site.

Table 3. Statistical Criteria for Sample Size Adequacy

Parameter	**Value**
Statistical test	Repeated-measures ANOVA (within-subjects)
Number of groups	1
Number of measurements	5 façade color conditions
Total sample size (N)	144
Alpha level (α)	.05
Desired power (1–β)	.80
Correlation among repeated measures	.50
Nonsphericity correction (ε)	1
Minimum detectable effect size (Cohen's f)	0.091
Observed partial η^2 range	.272 – .363
Achieved statistical power	> .99
Margin of error (95% CI, p = .50)	±6.8%

3.5 Digital Stimulus Integrity and Presentation Control

In order to sustain the scientific integrity of the independent variables (HSB), a lossless digital process was followed. All BFC simulations were created in 4K UHD format (3840 x 2160 pixels) and 300 DPI. They were then exported as flattened TIFF files for maximum data integrity. They were then imported into the presentation software with image compression disabled and high-fidelity resolution settings enabled. These steps helped in sustaining the original 24-bit sRGB color data during digital display and preventing any deterioration in the HSB color values. The selected resolution of 300 DPI has been used as an international standard for academic publications in printed media. The simulations were presented in person using a single 4K laptop. To maintain consistency, the screen brightness was fixed at 75%, and auto-adjustment of screen brightness was also turned off. The display was shown for at least 30 seconds for each façade to maintain uniformity. The display was kept visible during the ratings of SDQ so that ratings were not affected by the memory recall of participants. To avoid possible effects of each section, a blank slide was inserted for 5 seconds between each section. After each BFC simulation, participants were given multiple-choice questions before proceeding to the next BF hue simulation. To avoid possible order effects, counterbalancing was used. Three different stimulus orders of BFC were created. The orders were A-B-C-D-E, C-A-E-B-D, and E-D-B-A-C. To avoid possible order effects of façade color stimuli, these orders were used for each participant. The questionnaire was also created based on these orders of stimuli. For the door-to-door field survey, participants were randomly assigned to one of the three groups using a systematic rotation approach. Each of these groups was shown the stimuli in a different order. Although it was not possible to field-calibrate the display, using one device with constant brightness ensured that all participants were exposed to the same visual stimuli.

3.6 Reliability Analysis

Internal consistency was assessed using Cronbach's Alpha. The Place Identity scale demonstrated good reliability ($\alpha = .823$), while the Place Attachment scale showed very good reliability ($\alpha = .893$), both exceeding the recommended threshold of .70.

4. Results and Discussion

Normality was assessed using the Shapiro-Wilk test on the overall Sense of Place composite score. The results indicated excellent normality ($W = 0.987$, $p = 0.987$), with skewness (-0.268) and kurtosis (0.256) well within acceptable limits. Therefore, parametric tests were deemed appropriate for the main analyses.

4.1 Dimensionality of the Sense of Place Scale

An Exploratory Factor Analysis was performed on the ten items using the Semantic Differential Scale. Kaiser-Meyer-Olkin measure was used to verify the sampling adequacy, and the results showed that the KMO value was .957, while Bartlett's Test was statistically significant, $p < .001$. According to the eigenvalue greater than one method, one factor was extracted, explaining 71.8% of the variance, and all items loaded very well on this factor (.649 to .891), indicating that respondents perceived identity and attachment items as an integrated affective response rather than distinct dimensions in the context of evaluating building façade colors. This finding aligns with previous research demonstrating that place-based attitude items often load on a general evaluative dimension rather than maintaining strict dimensional separation [29], [30]. Recent studies also found dimensional overlap depending upon the context of measurement and the types of stimuli used in the study [31], [32]. However, to maintain consistency with the established conceptual framework in the literature and allow comparison with future studies, place identity and place attachment are presented separately in the subsequent analyses, with the understanding that they were empirically overlapping in this study.

4.2 Effects of Façade Color on Place Identity, Place Attachment, and Sense of Place

Both Place Identity and Place Attachment were included as separate constructs to maintain consistency with the theoretical framework and to enable direct comparison with future research. In addition, an overall score for Sense of Place is included, which is the average of all ten items across all BFCs. This is justified by the unidimensional nature of the data. Three separate repeated-measures ANOVAs were conducted to investigate the impact of BFC on Place Identity, Place Attachment, and SOP. For Attachment and SOP, where sphericity was violated, Greenhouse-Geisser corrections were applied. Significant main effects were found for all constructs: Place Identity $F(3, 57) = 17.51$, $\eta^2 = .272$; Place Attachment $F(3, 57) = 21.42$, $\eta^2 = .363$; and SOP $F(3, 57) = 23.49$, $\eta^2 = .272$. Further analysis of pairwise comparisons using Bonferroni adjustments showed that there were identical results across all three dependent measures. The Original BFC was found to be significantly higher than all simulated colors. Blue and Yellow were found to be significantly higher than Green and Red, but no difference was found between Blue and Yellow. Green and Red were found to have no significant difference. The results of the SOP measure had the largest effect size (.352). The detailed statistical results are presented in Table 4.

Table 4. Repeated-Measures ANOVA Results for Place Identity, Place Attachment, and Sense of Place.

Measure	ANOVA	p	Partial η^2	Means (Orig / Blue / Green / Red / Yell)	Pairwise Summary
Place Identity	$F(4, 572) = 53.39$	$< .001$	.272	4.08 / 3.54 / 2.74 / 2.57 / 3.57	Orig > all; Blue, Yell > Green, Red; Blue ≈ Yell; Green ≈ Red

Place Attachment	F(3.76, 537.65) = 81.36	< .001	.363	4.22 / 3.59 / 2.59 / 2.29 / 3.52	Orig > all; Blue, Yell > Green, Red; Blue ≈ Yell; Green ≈ Red
Sense of Place	F(3.77, 539.30) = 79.80	< .001	.352	4.16 / 3.57 / 2.65 / 2.40 / 3.54	Orig > all; Blue, Yell > Green, Red; Blue ≈ Yell; Green ≈ Red

4.3 Paired Sample t-Test

As shown in Table 5, the paired-sample t-test conducted to test Hypothesis 2 compared warm BFC (red 0°, yellow 60°) and cool BFC (blue 225°, green 120°) hues showed no significant difference in their combined influence on Sense of Place based on Place Identity and Place Attachment ($t\ (143) = –1.936$, $p = 0.055$). Although cool hues ($M = 3.109$, $SD = 0.814$) scored slightly higher than warm hues ($M = 2.973$, $SD = 0.856$), the difference was not statistically significant. The moderate positive correlation ($r = 0.490$, $p < 0.01$) indicates that participants who rated warm BFCs favorably tended to rate cool BFCs similarly.

Table 5. Comparison of Sample Means (Warm vs Cool BFC) and Correlation Between Them.

Variable	Mean (Warm BFC)	SD (Warm BFC)	Mean (Cool BFC)	SD (Cool BFC)	Mean Difference (Warm - Cool)	t-value	df	Correlation (Warm & Cool)
Warm vs Cool BFC	2.973	0.856	3.109	0.814	-0.136	-1.936 (p=0.055)	143	0.490 (p<0.01)

Significant at level ($p<0.01$)

4.4 Saturation

Hypothesis 3 was tested by presenting participants with four BFC alternatives at four saturation levels (25%, 50%, 75%, and 90%), and they were asked to select the option they found most preferable. This forced selection method is aimed at operationalizing the concept of place dependence through a comparative evaluation method, which is in line with the theoretical definition of place dependence as the preference for an environmental condition over the available alternatives, as shown in the relationship in Table 1. The overall number of selections recorded across the different BF hues, namely blue, green, red, and yellow, was 576. According to the data in Table 6, the results show that the participants consistently preferred BFCs with lower saturation levels, as 69.1% of the overall selections were recorded at 25% saturation, followed by 17.9% at 50% saturation, while only 13.0% of the selections were recorded at the higher saturation levels of 75% and 90%. Reflecting a decrease in preference for BFCs as the saturation level increased, implying that participants generally considered BFCs with low levels of saturation as being conducive to conducting place-related activities.

Table 6. Saturation Frequency Distribution Across Façade Hues.

Saturation Level	**Blue**	**Green**	**Red**	**Yellow**	**Total (All Hues)**	**Percentage (of 576 total)**
25%	88	100	102	108	398	69.1%
50%	32	27	25	19	103	17.9%
75%	20	11	11	11	53	9.2%
90%	4	6	6	6	22	3.8%
Total	144	144	144	144	576	100%

Chi-square goodness-of-fit tests were used for each BF hue. These tests were used to assess whether or not the obtained preference distribution significantly differed from an equal and random distribution. The results of these tests are presented in Table 7 and demonstrate that all BF hues significantly differ from an equal and random distribution:

Blue saturation: $\chi^2(3, N = 144) = 111.11, p < .001$
Green saturation: $\chi^2(3, N = 144) = 158.39, p < .001$
Red saturation: $\chi^2(3, N = 144) = 166.72, p < .001$
Yellow saturation: $\chi^2(3, N = 144) = 194.39, p < .001$

Overall, across all of the BFCs, it was clear that the 25% saturation was selected far more than would be expected, and that the 75% and 90% saturation levels were consistently selected less than would be expected. This provides strong support for Hypothesis 3.

Table 7. Chi-Square Goodness-of-Fit Results for Saturation Preferences.

	Saturation (Blue)	Saturation (Green)	Saturation (Red)	Saturation (Yellow)
Chi-Square	111.111[a]	158.389[a]	166.722[a]	194.389[a]
df	3	3	3	3
Asymp. Sig.	.000	.000	.000	.000

To examine whether patterns of saturation preference varied according to different façade hues, another Chi-Square test of independence was conducted. The purpose of this analysis was to examine the relationship between hue and saturation level using all available data, totaling 576 participants (N = 576). The association was not statistically significant, $\chi^2(9) = 10.62$, $p = .303$, with a very small effect size (Cramér's V = .078), as illustrated in Table 8. This result indicates that participants' preference for saturation levels was consistent across blue, green, red, and yellow façades, and that hue did not influence or alter saturation preference patterns.

Table 8. Association Between Façade Hue and Saturation Preference (Chi-Square Test of Independence).

Statistic	**Value**
Pearson Chi-Square (χ^2)	10.62
Degrees of Freedom (df)	9
p-value	.303
Cramér's V	.078
N	576

Overall, the frequency dominance of low saturation selections combined with the Chi-Square validation of the nonrandom preference distribution and the non-significant association between hue and saturation preference, as indicated by the small Cramér's V value, cumulatively validate Hypothesis 3. The implications of these findings are that for BFCs of lower to medium saturations, there is certainly more place dependence because participants chose those alternatives over highly saturated BFCs.

4.5 Brightness

A total of 720 brightness level preferences were recorded across all simulated BFCs plus the original BFC. Based on the results shown in Table 9, the preferences did not follow the expected medium-to-high brightness levels. The highest preference was very high brightness (90%), which was selected 243 times or 33.8%; followed by medium brightness (50%), which was selected 191 times or 26.5%; high brightness (75%), which was selected 151 times or 21.0%; and low brightness (25%), which was selected 135 times or 18.8%. This distribution suggests a general preference for very high brightness levels, rather than the medium-to-high range that was predicted by H4.

Table 9. Brightness Frequency Distribution Across Façade Hues.

Brightness Level	**Original**	**Blue**	**Green**	**Red**	**Yellow**	**Total (All Hues)**	**Percentage (of 720 total)**
25%	5	25	39	40	26	135	18.8%

50%	17	47	44	39	44	191	26.5%
75%	35	35	24	29	28	151	21.0%
90%	87	37	37	36	46	243	33.8%
Total	144	144	144	144	144	720	100%

Chi-Square tests of goodness of fit were performed for each of the BF hues, checking whether the distribution of the brightness level preferences was significantly different from an equal, random distribution. The results, as shown in Table 10, indicate that the brightness level preferences were not the same across different hues, as was the case with saturation level preferences. The results indicate that the following distributions were significantly different from an equal distribution:
- Original façade: $\chi^2(3, N = 144) = 109.00$, $p < .001$
- Yellow façade: $\chi^2(3, N = 144) = 9.11$, $p = .028$

For the BF hues of blue, green, and red, the distributions were not significantly different from an equal distribution ($p > .05$).

Table 10. Chi-Square Goodness-of-Fit Results for Brightness Preferences.

Hue	**χ^2**	**df**	**p-value**
Original	109.000	3	< .001
Blue	6.778	3	.079
Green	6.056	3	.109
Red	2.056	3	.561
Yellow	9.111	3	.028

In order to find out whether there are any differences in terms of preferences for brightness across BF hues, a Chi-Square test of independence was carried out on the entire set of data (N = 720), as specified in Table 11. The omnibus test was found to be statistically significant, $\chi^2(12, N = 720) = 87.57$, $p < .001$, implying that indeed there are differences in terms of preferences for level of brightness across hue categories. Nevertheless, it is noteworthy that this is a small to medium-sized effect, as Cramér’s V is .201, implying that this is not a dominant relationship.

Table 11. Association Between Façade Hue and Brightness Preference (Chi-Square Test of Independence).

Statistic	**Value**
Pearson Chi-Square (χ^2)	87.565
Degrees of Freedom (df)	12
p-value	< .001
Cramér’s V	.201
N	720

The omnibus Chi-Square test indicated that there is a relationship between the color hue and the brightness preference. The post hoc check of the adjusted standardized residuals (Table 12) indicated that the subjects had a stronger liking for very high brightness at 90% and a weaker liking for low and medium brightness in the original façade, as well as a stronger liking for low brightness in the green and red façades, while there were no changes in the yellow façade, indicating that the preference is not just a general preference for medium or high brightness.

Table 12. Significant Adjusted Residuals for Hue × Brightness Preferences.

Hue	**Brightness Level**	**Observed**	**Expected**	**Adj. Residual (z)**	**Interpretation**
Original	25%	5	27.0	–5.3	Strong under-selection
Original	50%	17	38.2	–4.5	Under-selection
Original	90%	87	48.6	+7.6	Strong over-selection
Green	25%	39	27.0	+2.9	Over-selection

Red	25%	40	27.0	+3.1	Over-selection
Blue	90%	37	48.6	–2.3	Under-selection

However, brightness really made a difference in the way people made their choices, but the results failed to support Hypothesis 4. Medium (50%), as well as high (75%), brightness was not universally liked for all colors. Very high brightness at 90% was highly liked in the original façade, while low brightness at 25% was preferred in green and red BFs. However, the omnibus Chi-Square test found that the preference for brightness was dependent on the BF hue, and the post-hoc tests found that the preference was context-dependent. Therefore, Hypothesis 4 is rejected as the level of brightness affects the level of place dependence in conjunction with the façade hue, but does not indicate the optimum level of brightness.

4.6 The Binomial Test

The Binomial Test was used for Hypothesis 5 evaluation. The results of the test showed that 63% of participants prefer to maintain the existing façade color as it is, and 37% prefer to make changes. This has been presented in Table 13. The results of the test showed that there is a significant difference with $p = 0.002$. This shows that this preference is not due to chance. Therefore, the original façade color is perceived to strengthen residents' sense of place dependence through loyalty, as indicated by the literature of not wanting to swap or replace the place with anything else, as shown in Table 1. This finding aligns with prior studies in architectural and urban design, showing that individuals develop stronger SOP in environments that maintain a familiar and authentic visual identity.

Table 13. Binomial Test Results for Participants' Façade Color Preference.

Response Option	**N**	**%**	**Observed Proportion**	**Test Proportion**	**p-value**
No – Prefer to keep the current façade color	91	63.2	0.63	0.50	0.002
Yes – Prefer to change façade color	53	36.8	0.37		
Total	144	100	1.00		

5. Conclusions

The results showed that BFC parameters—hue, saturation, and brightness—influence the emotional and perceptual responses associated with the conceptual dimensions of SOP. The highest level of SOP was elicited by the existing BFC, implying that a greater sense of identity and attachment is typically associated with a more familiar and long-lasting environment. As suggested by [22], "the landscape perception of long-time residents could directly influence place identity." Among all the BFC stimuli, the strongest positive emotional responses and associations with place identity and place attachment were found for the yellow and blue BFCs. Across all the studies reviewed, only one study found consistent results with the current study. The study on hue–saturation–lightness preferences in BFCs found that "yellow and blue were the most liked BFCs, with architects preferring yellow and non-architects preferring blue." This indicates that the strongest positive responses were found for the yellow and blue colors in the context of building exteriors [9]. However, a recent study conducted by [4] found that red, orange, and cyan colors had higher architectural color preference, and yellow and blue had comparatively lower levels of preference. Out of simulated colors, blue and yellow performed better than red and green. This can be analyzed on both contextual and theoretical levels. In the hot climate of Erbil, where summer temperatures often reach 40°C or more, the popularity of blue can be explained by its psychological link to cold. This is further supported by research outside the architectural context. For example, a study on fashion consumption revealed that weather conditions play a significant role in shaping consumers' color preferences, which includes how "higher temperatures lead consumers to prefer cooler clothing colors" [33]. The fact that the survey was conducted during the summer months may have contributed to the preference for blue BFC. The preference for yellow BFC can be explained by its association with earth-toned hues used in traditional Kurdish architecture. This is supported by prior research on traditional architectural contexts, which revealed that earth-toned hues elicit significant positive preferences and emotional attachment among residents, as established by [17]. Red and green, despite their visual vividness, may not have been culturally associated or cognitively consistent with residential expectations. Indeed, numerous studies have shown that colors and their associated preferences can be quite culturally specific and sensitive. In particular, red and green have been shown to be culturally sensitive in their associations, as noted in a recent study by [34]. Applying [35] information processing theory, these colors likely ranked low in 'making sense'—they were not consistent with the mental model of a residential façade. Preferences for balanced saturation (25% and 50%) levels were in line with user responses, which is consistent with recent experimental research by [4], which indicated that BFC preference tends to decrease with increased saturation levels, with the highest preference occurring at 20% saturation and the lowest preference occurring at 80% saturation—again supporting that less saturated BFCs are more favorably viewed. "In contrast, brightness preferences were hue-dependent: very high brightness (90%) was preferred for the original BFC, while low brightness (25%) was favored in green and red BFCs. However, this result differs from the findings of other research, which found universal preferences across all hues, such as [10]. Their statistical analysis showed that the positive effect of brightness was independent of hue, meaning that light colors performed better than dark colors within every hue category examined. Together, these outcomes suggest that incorporating principles of color psychology and emotional perception into architectural design and urban policy can facilitate emotionally resonant and SOP-rich residential environments. The convergence of identity and attachment items into a single factor suggests that façade color evaluation may trigger an integrated affective appraisal of place rather than clearly differentiated cognitive constructs.

Declaration of Competing Interest

The author declares no conflict of interest in publishing this manuscript.

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The author carried out the research, data collection, data analysis, and writing of the manuscript under the guidance of Assist. Prof. Hamid Turki Maliki, who provided guidance, corrections, and feedback throughout the study.

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Notation list

Abbreviation	Meaning
BFC	Building Façade Color
BFCS	Building Façade Color Simulation
BFCA	Building Façade Color Analysis
BF	Building Facade
B	Brightness
ET	Eye Tracking
H	Hue
PosE	Positive Evaluation
PrEvo	Protective Evaluation
SOP	Sense of Place
SDQ	Semantic Differential Questionnaire
S	Saturation

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