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Original Research Article

Classifying Façade Colors in Residential Buildings Based on Color-Emotional Scales*

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Abstract | The lack of facade color control programs in urban planning policies in Iran and the choice of facade color based on the designer's taste make it necessary to design façade colors based on scientific principles and users' evaluations. In color studies, emotional scales have been used to describe color. Due to the relative nature of emotional terms and the lack of consensus on definitions of these scales under the influence of contextual factors and individual characteristics of users, there is a need to redefine these scales in the context of Iran.This study aims to identify and determine the scales and components to classify the color combination of the façade. For this purpose, a combination of qualitative and quantitative methods was used. Twenty experts in the field of design and color participated in the Delphi survey, and the data were analyzed using the Q method. The finding presented three bipolar scales: temperature, harmony, and weight, to classify the facade color combination. In the next step, through semi-structured interviews with five architects and urban planners, components were determined to describe these three scales. Then, the authors of the study prepared a questionnaire to confirm the components completed by 20 former experts. Components affecting three scales and selected photos of each scale were extracted by analyzing data using the Q method in two steps. The quantitative values were collected through the color strip and HSL system codes of the final photos based on the percentage of color area in the façade, the number of hues, and their temperature, lightness, and saturation. Based on the results, the façade color combinations can be classified into eight treatments: cool-harmonious-light, cool-harmonious-heavy, cool-contrasting-light, cool-contrasting-heavy, warm-harmonious-light, warm-harmonious-heavy, warm-contrasting-light, and warm-contrasting-heavy, each of which can be defined using quantitative values.

Keywords | *Façade, Color Combination, Emotional Scales, Residential Building, Q method.*

Introduction| Considering the psychological and emotional effects of color in understanding the quality of urban environments, it is necessary to pay attention to the color design of the environment, including the facade color as part of the urban body. The issue of the facade color of buildings in the beauty controls of urban planning policies of many advanced countries shows its importance. The lack of a specific urban policy to control façade colors in Iran has resulted in public dissatisfaction and chaos in urban views. Color evaluation studies show that facade color design according to the user's needs and based on scientific studies and knowledge of color evaluation can make the suitable conditions of the buildings' exteriors by eliminating visual disturbances (Khakzand, Mohammadi, Jam & Aghabozrgi, 2013).

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In color studies, color assessment is a vague concept with no universally accepted theory. Some studies have considered color assessment universal and definitive (Munsell, 1912). In the color control programs of buildings' facades in some countries, usually, a general plan is introduced by the planners, which causes its prescriptive and inflexible nature. In these studies, color systems have been used to define colors, distinguish between colors, and evaluate and determine color classifications. The types of color systems include the CIELAB system, CMYK system, Munsell system, NCS system, Pantone system, sRGB system, and HSL system. In each of these systems, colors are defined based on some of the features. Based on most color preference studies, colors are defined and described by physical dimensions of color, i.e., hue, lightness, and saturation (Han, 2013; Santosa & Fauziah, 2017; Shinomori, Komatsu & Negishi, 2020).

However, the studies based on environmental psychology indicated that the nature of color assessment is more regional and diverse. Based on the results, color assessment depends on several factors, including contextual factors (environmental conditions, distance, the viewing angle of colors, Etc.) and individual characteristics such as culture and attitudes, Etc. (Anter, 2000). These studies have shown that color evaluation may be based on emotions that are associated with colors. In these studies, several color emotion scales have been investigated, including harmonious-contrasting, hot-cold, light-heavy, active-passive, etc. (Lee & Pai, 2012; Palmer & Schloss, 2015; Xin, Cheng, Taylor, Sato & Hansuebsai, 2004). These researches have occasionally reached contradictory results, which can be attributed to the relative nature of emotional terms related to color. In fact, in these studies, the ambiguity of terms such as harmony, contrasting, active, passive, etc., as well as the lack of consensus in the definitions of these scales due to contextual factors and individual characteristics of users, have led to the results of these studies cannot be generalized to the urban environments of Iran. Therefore, this research aims to fill the research gap. In this regard, the present study aims to provide a classification and quantitative and measurable definitions of the color combination of residential facades in Tehran based on that classification.

Research Background

Studies in the color evaluation, façade color have been investigated using different emotional scales.

Including, Garcia et al. in addition to luminance and saturation, different hues were used to classify the harmony-contrast scale, regardless of their temperature (Garcia, Hernandez & Ayuga, 2003). In the O'Connor study the hues on one side in the color cycle of the HSL system were used as harmonious/warm or harmonious/cool. Contrasting color combinations were defined using the combination of cool and warm hues on the opposite side of the color cycle based on urban planning policies in Sydney (O'Connor, 2008). Kuang and Zhang defined color contrast based on hues on the opposite side of the color cycle and the difference between the luminance of hues (Kuang & Zhang, 2017). In the Sarica and Cubukcu study the temperature scale was defined based on the warm and cool hues in the color space of the HSL system. Similar hues were used on one side of the HSL system as harmonious/warm or harmonious/cool. Contrasting color combinations were defined by using a combination of cool and warm hues on the opposite side of the color cycle of the HSL system (Sarica & Cubukcu, 2018). Huang and Lalig et al. have also used opposite hues in the color cycle to define harmony/contrast (Huang, 2018; Lalji, Gupta & Sharma, 2021). Jiang et al. defined harmony/contrast based on the hues' temperature and saturation rate (Jiang, Foing, Liaschlacht, Yao, Cheung & Rhodes, 2022). In Cubukcu & Kahraman's study the lightness/heaviness scale was used to classify the façade colors based on the luminance rate of the hues (Cubukcu & Kahraman, 2008). Kurbanova defined the scales of temperature and activity based on the two halves of the color cycle (Kurbanova, 2021).

In these studies, the physical dimensions of color in the HSL system have been used to define the emotional scales, without explaining a measurable scientific criterion for defining the scales. Therefore, there is no theoretical consensus in these studies and the different results of these studies can be related to the differences in their definitions and criteria. So the scientific and quantitative definition of the emotional scales of color is necessary for the classification of the façade color.

Research Questions

According to the purpose of the research, two main questions are raised:

1- How many classes residential facades can be classified into based on their color combinations?

2- What is the quantitative and measurable definition of each color combination class of residential facades?

Theoretical Framework

There are a variety of approaches and models that try to describe and define color as well as the relationship between color and its evaluation, which can be summarized in two general approaches. Some ontological approaches suggest that color assessment is essentially deterministic. This approach means that color assessment is a universal, particular, and unchangeable phenomenon that can achieve using specific color combination formulas (Chevreul, 1839; Munsell, 1912; Ostwald, 1916). It assumes a high degree of causality between the aesthetic response and beauty without considering individual, cultural, environmental, and temporal factors. Other ontological approaches suggest that the concept of color assessment is more subjective, less predictable, and definitive, which makes a clear distinction between the objective properties of color and subjective responses to color (Albers, 1963; Hard & Sivik, 2001). In this ontological approach, the color assessment does not accept the state of the global phenomenon. Some recent studies have confirmed that individual differences such as familiarity, preference, and cognition, as well as cultural, environmental, and temporal factors, affect color assessment (Chuang & Ou, 2001; Janssens, 2001). These studies were performed based on many emotional scales such as harmony-contrast, cool-warm, compatibility with the environment, Etc. These studies concluded that emotions related to colors correlated with a color assessment, so these emotional scales are often used instead of the physical dimensions of color to describe color (Palmer, & Schloss, 2015). Therefore, emotional scales of color can be considered as a criterion for defining and classifying the façade color of buildings.

Research Method

In this exploratory research, both quantitative and qualitative methods were applied. The studies on emotional scales describing color combinations during 1960-2023 were studied using content analysis. The purpose of content analysis was to answer the question of what the emotional scales of color evaluation are. According to previous studies, among the 97 emotional scales of color evaluation, only ten scales of cool/warm, harmonious/contrasting, active/passive, soft/hard, and light/heavy were defined based on the physical dimensions of color, and the researchers agreed on their definitions. In addition, these ten items were the scales considered in most color evaluation studies. This consensus was made based on a universal and defined approach regarding the definition of these scales in the studies; in fact, these scales consider the attributes of the color itself. Although these definitions were not exact, there was a general commonality in these definitions. In all these studies, in the classification of color based on temperature, half of the color wheel (colors related to red and yellow) were defined as warm, and the other half (colors related to blue) were defined as cool colors (Manav, 2017; Gunes & Olgunturk, 2019; Liu, Hutchings & Luo, 2020, Zhang, Zhou & Yang, 2021). In the classification of color based on harmony, a color that has hues with the same temperature was considered harmonious, and a color that has hues with different temperatures was considered contrasting (O'Connor, 2011; Fang, Muramatsu & Matsut, 2015; Saeedi & Dabbagh, 2021; Serra, Gouaich & Manav, 2021; Zimnicka, Baanicka, & Kroll, 2022). Color saturation has been used to classify color activity. In this way, colors with high saturation were defined as active colors, and colors with low saturation were defined as passive colors (Koo, & Kwak, 2015; Hanafy, & Sanad, 2016; Boeri, 2019; Boeri, 2020; Wan, et al., 2020). For the classification based on weight and hard/softness, the luminance of the color has an effect. Colors with high luminance were light and soft, and colors with low luminance were considered heavy and hard (Koo & Kwak, 2015; Hanafy & Sanad, 2016; Boeri, 2019; Boeri, 2020). The rest of the scales were defined differently according to individual, culture, Etc. and did not have fixed and definite dimensions. In the studies, these scales were only adjectives to express a person's feelings towards color without defining them. Therefore, the studies' results were inconsistent and non-generalizable due to the lack of a scale with the exact definition (Lee & Pai, 2012).

Next, a questionnaire was prepared from these five bipolar scales and 100 photos of building façades as the first Delphi survey tool (For details on recording and selecting photos, refer to the previous article by the authors, Mehdipour, Yazdanfar, Ekhlasi & Saleh Sedghpour, 2021 & 2023). To gain group knowledge for forecasting, helping to make decisions, gathering information, and also group consensus, the Delphi survey was used, which was conducted during two survey rounds. O'Connor and Jiang et al., (2022) used the Delphi method to gather expert opinions for reporting findings on features of color and building façade based on their knowledge and experience (O'Connor, 2008; Jiang, et al, 2022). The population included 20 experts in color and design (architecture, painting, graphic, and industrial design Profs). Hundred façade photos showed on a laptop for ten seconds and then asked to be graded from 0 to 9 based on five bipolar scales (0 and 9 being the two ends of the bipolar scale spectrum). Based on the previous research, the appropriate time for viewing each photo is 10 seconds[1]. Since the Delphi survey, the sample size of the experts' questionnaire cannot be large in the experts' survey; the Q factor analysis method was used to analyze the data. Three emotional scales were selected to classify the façade color combination, and some photos were selected for each scale.

According to the aim of the second step, the authors proposed components to identify the emotional scale of color combination evaluation based on the selected photos of the previous step. Then, a semi-structured interview with experts was used. In the interview, the selected façade photos of each scale were shown to the experts. Then, they gave their opinion about the components proposed by the authors and added their proposed components. Nine components were effective in the assessment of the emotional scales describing the color combination of the building façade was extracted, which include the 'Luminance rate of color combination', 'Saturation rate of color combination', 'Number of hues in combination', 'The area of dominant hue in combination', 'The area of openings', 'Luminance rate of the color of openings (windows) in the photo', 'The formal composition of façade', 'The formal composition of openings (windows)', and 'Details of The façade'. A Delphi survey was conducted to confirm the validity of these qualitative data. Nine effecting components suggested by the experts and the selected photos of the first questionnaire provided data for the Delphi survey in the second stage. The group of former experts (20 experts in design and color) completed three questionnaires. The photos of each scale were shown on a laptop. They graded each photo from 0 (completely disagree) to 9 (completely agree) based on the effect of each component in detecting each scale. Finally, the effecting components to detect each color combination scale of the building façade were extracted using the Q factor analysis method.

The color strip and codes of the HSL system were applied to measure and analyze the colors used in the color combination of the selected photos quantitatively. Many studies, such as O'Connor and Tadayon used color strips (O'Connor, 2008; Tadayon, Ghalenoee & Aboee, 2018). Thus, it was possible to provide quantitative values to define the color combination of the building facade based on three scales. The selected façade photos were first simplified[2] to prepare the color strip. Then the area of each color relative to the total area was put together in the color strips (whose length consists of one hundred units), which shows the percentage of each color in the color combination of the façade (Fig. 1). shows the color strips of the selected photos of the façade in the detection of the weight scale of the color combination.

The HSL system was used according to the objectives, and theoretical framework of the research since this system determines the numerical values of the physical properties of color, hue (H), saturation (S), and luminance (L). Based on the color strips and the HSL system codes, tables were prepared to perform technical studies on the colors used in the facade in terms of saturation, luminance, and hue (Fig. 2). shows the HSL system codes of the selected photos of the façade in the detection of the weight scale of the color combination.

• Statistical population and sample size

To collect data for the fulfillment of the objectives, we included samples from articles, books, resources, and research available in Persian and Latin in the field of environmental color assessment during 1960[3]-2023. In the Delphi survey analysis, 10±15 populations are sufficient

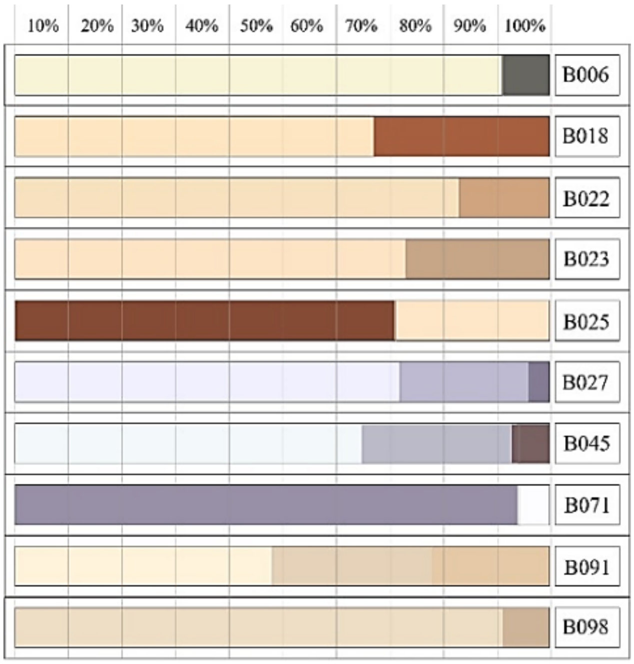

Fig.1. The color strips of the selected photos of the façade in the detection of the weight scale (B006,... are the number of facade photos). Source: Authors.

for describing participants' beliefs (McKeown & Thomas, 1988) and attitudes based on the snowball sampling method[4], and the sample size was formed after theoretical saturation. Therefore, the population consisted of 20 design and art experts, including architecture, painting, graphics, and industrial design teachers. They were selected as the participants in both questionnaires based on their familiarity with the research topic, nonprobability, and targeted sampling with the small sample size. The selection of experts in each discipline was based on their color and design expertise. Then, each expert introduced other members for participation. In a semi-structured interview, five architectural teachers were selected based on the snowball sampling method, and the sample size was formed after theoretical saturation. The second questionnaire had more detailed questions related to the first questionnaire, and the same statistical population was used for its completion.

• Validity and reliability of the instrument

Content validity has been used in the quantitative form, and the content validity ratio (CVR) has been calculated to check the validity of the questionnaires. Experts checked each item based on the options "necessary," "useful but not necessary and "not necessary" to determine CVR. Then the answers were calculated according to the following formula:

$$CVR=\frac{n_E-\frac{N}{2}}{\frac{N}{2}}$$

"n_E" is the number of experts who answered the "necessary" option.

"N" is the total number of experts.

Considering that the number of participants was 20, according to the CVR table, its coefficient should be more than 0.42 (Jam, Azemati, Ghanbaran & Saleh Sedghpour, 2019). Calculating this coefficient for each question in the questionnaires can mean that the data collection tool in this research is valid.

Colour	H	S	L	Area
B006				
	53	13	97	91%
	50	6	40	9%
B018				
	45	14	99	77%
	22	62	75	23%
B022				
	36	23	97	83%
	27	39	82	17%
B023				
	33	22	99	73%
	29	32	78	27%
B025				
	17	60	52	71%
	34	21	99	29%
B027				
	244	6	100	72%
	250	11	82	24%
	260	16	58	4%
B045				
	203	3	98	74%
	240	7	78	19%
	0	20	47	7%
B071				
	261	14	65	94%
	240	1	100	6%
B091				
	40	14	100	48%
	33	20	90	30%
	32	27	90	22%
B098				
	37	17	93	91%
	31	26	81	9%

Fig. 2. The HSL codes of the selected photos of the façade in the detection of the weight scale (B006,... are the number of facade photos). Source: Authors.

Internal consistency was used to measure the first survey questionnaires' reliability, and Cronbach's alpha coefficient was calculated (Sarmad, Bazargan & Hejazi, 2015). Cronbach's alpha coefficients were higher than 0.7 in all questionnaires of the first survey, as shown in Table 1.

The reliability of the proofreaders[5] was used to determine the reliability of the semi-structured interviews. The obtained values of the agreed coefficient among the proofreaders of three interview tests (more than 70%) indicate the appropriate reliability. The reliability of the three questionnaires in the second survey was also assessed using internal consistency and calculating Cronbach's alpha coefficient. Cronbach's alpha coefficients in all questionnaires were higher than 0.7.

In this stage, the objective-content table was used to measure the content validity of the questionnaires, which five architecture and urban planning experts confirmed.

Results and Discussion

If the cumulative percentage of all factors is more than 60%, it indicates the existence of an external fact about that scale, which caused the least possible view of the respondents to be drawn to it. Based on the cumulative percentage of all components in the first five questionnaires using SPSS software, only cool/warm, harmonious/contrasting, and light/heavy scales effectively assess the color combination of building facades from the experts' point of view. Data analysis of each of the three effective scales after rotation in SPSS software indicates that seven components for the cool/warm scale, eight for the harmonious/contrast scale, and six for the light/heavy scale were obtained. By using the statistics of the rotated component matrix, the constituent variables of each factor can be identified. Any variable that has a factor loading greater than ±0.3 is significant and is included in that category. According to the mentioned cases and the statistics of the rotated component matrix of the item "temperature scale" (one of the 3 emotional scales of color description), the first factor consists of 5 experts, the second factor consists of 4 experts and the third factor consists of 3 and the fourth, fifth, sixth and seventh factors Each consists of 2 experts. Photos had to be selected that were representatives of the three emotional scales assessing the color combination of the façade. Photos at least half of the experts (in the case of agents with two experts, both) gave them points of 8, 9,

Table 1. Cronbach's alpha coefficients of the first questionnaire. Source: Authors.

	Active/Passive Scale	Soft/Hard Scale	Light/Heavy Scale	Harmonious/Contrasting Scale	Cool/Warm Scale
Cronbach's alpha coefficient	0.727	0.749	0.750	0.884	0.866

or 0, 1 were selected to find the common thought of the experts. Then, through a semi-structured interview, the practical components in identifying the three emotional scales of façade color combinations based on experts' opinions were obtained. A questionnaire was used again to determine the validity of the qualitative data obtained from the interview. To analyze the quantitative data obtained from the questionnaire, the Q-factor method was used in two stages. The obtained factors were re-analyzed using the Q factor method to review and confirm the results of the first order of the Q factor.

In the second survey, the cumulative percentage of the three scales is shown in Table 2. The cumulative percentage above 60% of the total factors indicates that a good percentage of the experts' thoughts about the topic under discussion were shared, which means that there is an external reality about that topic. Data analysis after rotation in SPSS software shows that six factors for the temperature scale, seven for the harmony scale, and seven for the weight scale were obtained.

According to the statistics of the rotated component matrix of the item "Luminance rate of color combination" (one of the effective components on the assessment of emotional scales), the first factor consists of 7 experts, the second factor consists of 4 experts and the third factor consists of 3 and the fourth, fifth, and sixth factors Each consists of 2 experts. To find the common thought of experts on the component, 'Luminance rate of color combination', affecting the recognition of emotional scales of façade color combination, the components in each factor that at least half of the experts (in the case of agents with two experts, both) scored 8, 9, or 0, were selected. The Q-factor method was performed on the obtained factors for the second time to confirm the results, and all the cases mentioned above were repeated. Therefore, by confirming the preliminary results, the practical components of recognizing each of the three emotional scales describing the color combination of the façade were obtained. Thus, based on the three scales and using color strips and codes of the HSL system, the components and quantities for defining and describing the color combination of the façade were identified as follows:

-**Temperature scale**: Components related to the form of façade properties (formal composition of façade and openings, façade details) had no significant effect on color combination temperature detection. However, those related to color properties (saturation rate and hues number) and that related to the dimensional properties (hue area) are essential to detect the temperature of the façade color combination. Based on color strips of the selected photos of the façade, the prominent hues of the façade surface include at least 60% of the façade surface. Therefore, the temperature of the façade color combination is the same as the hue temperature, which covers at least 60% of the façade surface. The HSL codes of selected photos show that more than 90% of the façade surface has more than 50% luminance. Furthermore, at least 60% of the façade surface has a saturation above 25% of the façade with warm color.

In Sarıca & Cubukcu's study the temperature scale is only defined based on the warm and cool hues of the HSL system. The present study confirms this result. In addition, this study has identified other components to define the temperature of façades' color combination.

The effect of the hue area of the façade in detecting the temperature of color combination can be explained as follows. According to the figure-ground organization of Gestalt psychology, small surfaces are perceived as figures and large surfaces as ground. Based on this theory, the ground color of the photo is seen at first glance (Wagemans et al, 2012). Thus, the ground color of the façade photo attracts attention, and the façade is seen in the color of a larger area. As the hues number increases, it becomes challenging to identify the figure-ground, so it becomes difficult to detect the dominant color and, consequently, the temperature of the color combination. The effect of saturation of warm hues in detecting the color combination's temperature is related to the warm hues which arouse the nervous system while cool hues calm down this system. High saturation of colors arouses and attracts people. Therefore, increasing the saturation of warm hues helps to detect the temperature of the color combination due to increasing attention.

-**Harmony scale**: Components related to color properties (difference in luminance and difference in saturation of the combination colors, number of hues in the combination, and the color of the opening in the photo) are influential in determining the harmony of the color combination, while the components related to form (formal composition of façade and openings, façade

Table 2. Cumulative percentage of all components of temperature, harmony, and weight scales. Source: Authors.

	Light/Heavy Scale	Harmonious/Contrasting Scale	Cool/Warm Scale
Cumulative percentage	66.801	70.559	68.097

details) and the dimensional properties (hue area and openings area) have no significant effect on determining the color harmony of the façade. Based on the HSL codes, a contrasting combination is considered that the difference in luminance between the brightest color and the other colors of the combination is very high (at least 45%). In the color combinations considered harmonious, the luminance difference between the combination's hues was meager (up to 20%). The issue related to the hues is that the hues' luminance with an area of about 6% and less did not significantly affect the harmony-contrast detection of the color combination. The HSL codes showed that the distance between the saturation of the harmonious combination hues was a maximum of 15%. The difference between the saturation of the hues of a contrasting combination was at least 20%. In these photos, the hues area of 5% or less did not significantly affect the harmony-contrast detection of the color combination of the façade. In both groups, the hues used in the combination intended as harmonious had the same temperature (cool: 91 to 270 degrees or warm: 0 to 90, 271 to 360 degrees), which is not necessarily the case for contrasting color combinations. So, although the non-uniform temperature of the color combination necessarily causes a contrast, there are photos that look contrasting despite the same temperature of the colors.

The results of the present study confirm the classification of contrasting color combination in terms of temperature differences of hues in Sarıca & Cubukcu's study (2018); in this way, the non-isothermal hues in combinations makes them look contrasting. However, this is not the case with harmony, which means that the same temperature of the combination's hues does not necessarily make it look harmonious. The results of the present study also confirm the findings of a study by García et al. (2003). In addition to luminance and saturation, this study used different hues to classify the harmony/contrast scale, regardless of their temperature. However, the present study found that the hues' temperature was also influential in classifying the harmony/contrast of the color combination of the façade.

The effect of the difference between the luminance and the difference between saturation on harmony/contrast detection can be explained based on the types of color contrast proposed by Itten. Itten expressed seven types of color contrast, which contrast based on different levels of luminance and saturation, justifying the effect of these two components in detecting the harmony/contrast of color combination (Hagtvedt, 2016). The opening color in the photo is part of the color combination of the façade. This component can also be explained based on the types of color contrast proposed by Itten (1961) regarding the contrast in terms of hue temperature (Itten, 1961). As the number of hues increases, it becomes difficult to detect the difference between luminance and the difference between saturation, so it becomes difficult to classify the harmony/contrast of color combination.

-**Weight scale:** Components related to color properties (luminance rate of combination colors and the openings color in the photos) and dimensional properties (opening area and hue area) are influential in determining the weight of the façade color combination. Based on the color strips of selected photos related to the hue area, the prominent colors of the façade surface included at least 70% of the color area of the façade. Therefore, the color combination weight of the facade will be the same as the hue weight that covers at least 70% of the area of the façade. Based on the HSL codes, a light combination was considered in which the luminance of the combination colors of the façade surface and openings was high (at least 90%). In addition, at least 70% of the façade surface had a saturation rate of less than 30% in the façade with warm hues, and at least 70% of the façade surface had a saturation rate of less than 5% in the façade with cool hues. Further, in the color combinations considered heavy, the luminance of the combination colors of façade surface and openings was less than 65%.

The present study's findings confirm the Light/heavy classification of color combination of façade in the Cubukcu & Kahraman study.

The high effect of the luminance on the weight of the color combination of the façade can be explained that the bright hues look lighter and dark hues look heavier (Alexander, 1976; Hagtvedt, 2016). The effect of colors' area of the façade in detecting the weight of color combination can be explained as follows: According to the figure-ground organization of Gestalt psychology, small surfaces are perceived as figures and large surfaces as ground (Wagemans et al, 2012). Based on this theory, the ground color of the photo is seen at first glance, and the façade is seen in a dominant color. This theory makes it easy to detect the weight of the color combination. The colors of the openings in the photos are part of the color combination of the facade, so their luminance has an effect in determining the weight of the color combination of the facade. The effect of the size of the openings in determining the luminance of the combination comes from the fact that the presence of the opening as an empty space makes the facade look light.

Based on these three scales, the color combination of the facades can be classified into eight color combination treatments; façade with the cool-harmonious-light color combination, façade with the cool-harmonious-heavy color combination, façade with the cool-contrasting-light color combination, façade with the cool-contrasting-heavy color combination, façade with the warm-harmonious-light color combination, façade with the warm-harmonious-heavy color combination, façade with the warm-contrasting-light color combination, façade with the warm-contrasting-heavy color combination. The components and quantities are as follows to define these eight treatments of color combination of the façade, which are summarized in Table 3.

Conclusion

The lack of façade control programs in urban planning policies in Iran and façade design based on the designer's taste and lack of attention to users' evaluation make it necessary to design facades based on the scientific principles of environmental design and user evaluation. To obtain the strategic principles of façade color design, a single scale and criteria must be considered for defining the façade color of buildings so that façade colors can be defined and classified based on that. This research found three emotional scales describing color combination, including temperature, harmony, and weight, to classify the color combination of residential-apartment building facades. Thus, the color combination of residential building façade can be classified, based on the unified and specific scales, into eight color combination treatments, including cool-harmonious-light, cool-harmonious-heavy, cool-contrasting-light, cool-contrasting-heavy, warm-harmonious-light, warm-harmonious heavy, warm-contrasting-light, and warm-contrasting-heavy. These scales were defined based on the components such as the hues number, hues area, opening area, luminance, and saturation rate, the difference between luminance, the difference between saturation, and the quantitative values. The exact definition can be provided for each of the treatments of façade color combinations using the quantities obtained. This definition makes it possible to repeat the study and evaluate the different treatments of the façade color combination, thus generalizing the studies' results. Also, this principle allows future research to improve the design of the color combination of residential building façades. So that by using these definitions, the colors of the facades can be evaluated. It will be determined which of the eight color combination treatments of building facades is preferred by users using the results of users' evaluation. In this way, using the selected color treatment and based on the quantitative definition of that color, it is possible to obtain principles for designing façade colors of other buildings. In this way, based on the preference of one of the 8 facade color treatments by the users of each region or neighborhood of the city, it is possible to provide instructions by the facade committee of each region based on the quantitative definitions of that color combination treatment to be implemented. These instructions will include the area

Table 3. Quantitative values relate to eight treatments of façade color combination based on temperature, harmony, and weight scales (H: Hue; S: Saturation; L: Luminance). Source: Authors.

Treatments of Façade Color Combination	Number of Hues	Dominant hue Area %	Façade Color based on HSL Codes			Openings Area %	Opening Color based on HSL Codes			Difference in Luminance	Difference in Saturation
			H	S	L		H	S	L		
Warm-Harmonious-Light	2 or 3 Warm Hues	≥70%	Warm	≥25%	>90%	≥30%	W	-	>90%	<20%	<15%
Warm-Harmonious-Heavy	2 or 3 Warm Hues	≥70%	Warm	≥25%	<65%	-	W	-	<65%	<20%	<15%
Warm-Contrasting-Light	2 or 3 Warm & Cold Hues	≥70%	Warm	≥25%	>90%	≥30%	-	-	>90%	>45%	>20%
Warm-Contrasting-Heavy	2 or 3 Warm & Cold Hues	≥70%	Warm	≥25%	<65%	-	-	-	<65%	>45%	>20%
Cold-Harmonious-Light	2 or 3 Cold Hues	≥70%	Cold	≤15%	>90%	≥30%	Cold	-	>90%	<20%	<15%
Cold-Harmonious-Heavy	2 or 3 Cold Hues	≥70%	Cold	-	<65%	-	Cold	-	<65%	<20%	<15%
Cold-Contrasting-Light	2 or 3 Warm & Cold Hues	≥70%	Cold	≤15%	>90%	≥30%	-	-	>90%	>45%	>20%
Cold-Contrasting-Heavy	2 or 3 Warm & Cold Hues	≥70%	Cold	-	<65%	-	-	-	<65%	>45%	>20%

percentage of each color in the facade, the luminance and saturation rate, and whether the color is warm or cold quantitatively. The possibility of defining and describing the composition of facade colors based on a unique principle removes its design from taste-oriented and individual design. This definition brings it closer to design based on scientific principles. In addition, by using this strategy, a unified color combination will be obtained for the streetscape of each neighborhood or region.

Limitations and Future Research

The present study has the following limitations: This study was limited to 2D digital photos and 1 façade of buildings in one neighborhood in Tehran which was a representative of real building façades. The study examined residential facades not as a streetscape. Another limitation was non-standard measuring instruments. Therefore, future studies can use photos of other directions of the building façade of different neighborhoods as a streetscape is recommended.

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Declaration of Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Endnote

* This article is an excerpt from Maryam Mehdipour's PhD thesis entitled "Strategic principles of designing the color combination of building exterior in residential-apartment buildings based on emotional and cognitive evaluations" which was guided by Dr.Seyed Abbas Yazdanfar, Dr.Ahmad Ekhlasi and advised by Dr.Bahram Saleh Sedghpour in the year 2019 at the school of architecture and environment design of Iran university of science and technology.

1. The duration of viewing a photo should be such that while the viewer perceives the entire photo, he/she does not have time to pay attention to its details. Because paying attention to other details may affect the test results (O'Connor, 2008; Tadayon et al, 2018).

2. Each building façade has different elements, including the main surface, frames, windows, details, extensions, Etc. The multiplicity of colors used in them: only the colors of the main elements have been considered in the color strips.

3. The agenda for environmental design was set in 1960. The development of environmental design as a distinctive paradigm significantly impacted the conceptualization and practical use of color in architectural and urban design. According to the environmental color design approach of the present study, the sources studied were reviewed in the period 1960 to 2023.

4. This type of sampling is a non-probability method that also has a random selection mode and is suitable when the members of group or society cannot be identified easily (McKeown & Thomas, 1988).

5. In order to determine the reliability of descriptive tests whose scores are affected by the judgment of the correctors, two or more correctors who independently correct the answers of the examinees should be used. Correlation between scores of different correctors is considered as the reliability index of correctors (Seif, 2003, 449).

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