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Research Paper

Determining the Components Describing the Harmony-Contrast of the Color Combination in Residential Buildings Exterior

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Abstract

In addition to its roles in urban settings, color also affects people's feelings and their assessments about the environment's quality. There are no control programs of building exterior's color in urban planning policies in Iran. Color design of building exterior is done based on the designer's taste, regardless of user's preferences. These issues have caused public dissatisfaction with their visual quality. These factors remind us of the need to pay attention to building exterior color, based on the user's evaluation. To evaluate the color of the buildings' exterior, we must describe and classify its color combination. In color evaluation studies, there is no theoretical consensus on the emotional scales of the color description and the components affecting their assessment and definition, unlike physical dimensions of color. Therefore, the questions which arise are: what are the emotional scales of the color description of building exterior? And What are the components affecting the assessment to define and classify the color combinations of building exterior? In this regard, research aimed to identify and determine components describing and defining the color combination of building exterior as harmonious and contrasting. To achieve this purpose, we have used a combination of qualitative and quantitative methods. First, content analysis and then Delphi survey was done by 20 experts in design and color. Having analyzed the results through Q-method, three scales, harmony, temperature, and weight, were extracted to classify the color combination of building exterior and several selected building exterior images of each scale. Due to the wide range of topics, we examined only the harmony-contrast in this research. In the next step, we determined components to assess the harmony of the building exterior's color combination through semi-structured interviews with five architects and urban planners. According to the qualitative results, we used the Delphi survey to confirm these components. A questionnaire was prepared based on these components and selected images of the harmony scale in the first survey. Twenty former experts completed this questionnaire. We extracted the components affecting the building exterior's color combination's assessment harmony by analyzing the data through Q-method. Quantitative values were obtained using the color strip method and HSL codes and based on the components. These values defined the harmony-contrast scale of the color combination of the building exterior. Significant components were the difference between the hues' luminance, the difference between the hues' saturation, the number of the hues in combination, and the color of openings. The form of openings, the formal composition and details of building exterior, and the area of openings and hues in combination did not have any significant effect on the harmony assessment. Therefore, to describe and classify the color combination of building exterior as harmonious, the color combination of building exterior should have a maximum of two or three hues and the same temperature. The difference in luminance between the hues of the combination should be less than 20%. The difference in saturation between them should be less than 15%. The color temperature of its openings should be the same as the temperature of other building exterior colors. The color combination of the building exterior as contrasting should have a maximum of two or three hues and different temperatures. The difference in luminance between one hue and other hues should be more than 45%. The difference in saturation between this hue and other hues should be more than 20%.

Keywords: *Building exterior, Visual preference, Color scales, the harmony of color combination, Q-method analysis.*

1. INTRODUCTION

Color has a significant effect on our understanding of a city's visual qualities thanks to its essential role in urban settings such as expressing structure and creating visual integrity, a sense of place, and a hierarchy to guide people. City or district, streetscape, individual buildings, and details (e.g., windows, shutters, street furnishings) are four scales of the color scheme in cities (Moughtin, Oc, & Tiesdell, 1999). In terms of environmental aesthetics, one of the essential scales is the color of building exterior, which affects environmental experience and aesthetic assessments, considerably. In architecture and urban design, the color issue of building exterior in the aesthetic controls European countries and Australia planning policy. Some other countries show the importance of study in this field. The lack of such control planning of the building exteriors' color in the Iranian context has caused visual disturbance and confusion of building exterior (Figure 1).

The artificial environment's patterns and color combinations affect people's experiences, feelings, behaviors, and judgments about the environment quality. People usually perceive changes in the artificial environment's color and texture and consider colorless architecture as cold, impersonal, lifeless, dull, and indifferent (Meerwein, Rodeck, & Mahnke, 2007). The psychological and emotional effects of color on urban settings' quality justify the need to review traditional approaches to environmental color design. These approaches often consider color as a secondary element in the construction of form and structure, address color selection in contemporary cities' design based on fashion trends and designer color preferences, and ignore the preferences of the public's preferences and aesthetic expectations (McLachlan, 2013). The selection of color by architects and urban designers based on personal preferences and underestimating the value of theoretical knowledge in color design often leads to the public's dissatisfaction with urban settings' visual quality. Color design can retrieve environmental conditions by balancing visual stimuli, eliminating visual disturbances. It can also facilitate positive emotional responses based on scientific studies and users' needs. Therefore, it is necessary to study the color of building exterior based on the users' evaluation and knowledge about color.

Most studies and theoretical knowledge on the color of building exterior have considered the response to environmental color preference as a universal and deterministic phenomenon. In the aesthetic control planning of building exterior color, planners usually introduce a general design, narrowing, and prescriptive nature. They consider the response to the color of the building exterior as universal and deterministic. The studies on color in environmental psychology have considered environmental color response as more regional and less deterministic. Several factors affect the perceptions about the building exterior's color and the response to the building exterior's color preference. These factors include contextual factors (environmental observation conditions, distance, angle of the view of environmental colors, etc.) and individual differences (culture, attitudes, etc.) (Fridell Anter, 2000). They have often been neglected in these studies. Focusing on a single color is another challenge in urban color evaluation research; however, colors have often been combined in urban environments. In addition, the previous studies' review showed that most data, techniques, and questionnaires are related to countries other than Iran. The cultural, individual differences, tendencies, etc affects the relationship between the color of building exterior and the users' preference; the results of these studies cannot be generalized to building exterior in Iran. Therefore, it is necessary to examine the color of the building's exterior and the users' evaluation in the Iranian context.

Evaluating the building exterior's color combination, we first need a method to describe and classify the building exterior's color combination. The color combination of the building exterior can be defined based on that. In most studies on environmental color evaluation, color has been described based on its physical dimensions: hue, saturation, and luminance. Several studies have indicated that color evaluation may be based on emotions associated with colors. These studies have focused on many scales of color-emotion, including harmonious/contrasting, warm/cold, light/heavy, etc. The studies on color evaluation in urban settings have employed several emotional scales such as harmonious-contrasting, warm-cold, and congruity relative to the building's surroundings. These studies reported that emotions related to colors have a high correlation with color preferences. These emotional scales are often used instead of the physical dimensions of color to describe them. According to the purpose of these studies, they have used different scales. Therefore, identifying and determining the emotional scales of the building exterior's color combination was the first purpose of this research.

Evaluation studies of environmental color based on color emotional scales have sometimes provided conflicting results. These could be attributed to the relative nature of the emotional terms used for color. The ambiguity of terms such as harmony and contrast and the lack of consensus on their definitions have led to inconclusive results. Therefore, we conducted this study to bridge the research gap in this field. In this regard, the present study aimed to determine the components describing the harmony-contrast scale (one of the three color-emotion scales for evaluating the color combination of building exterior obtained from the first step) to define the building exteriors' color combination. This study was motivated by the following research questions:

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What are the color-emotion scales to describe and classify the color combination in residential buildings' exterior?

Which components describe the harmony-contrast of the color combination in residential buildings exterior?

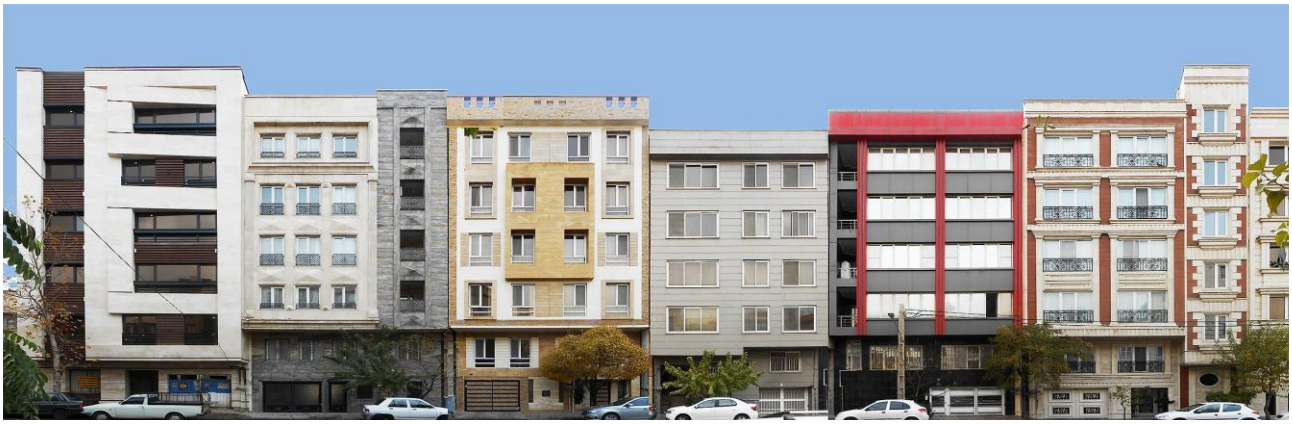

Fig 1. The part of the building's exterior of Alian street in Koye-Nasr

2. THEORETICAL FRAMEWORK

The research topic is in two areas: 'color evaluation' and 'building exterior.' Few studies have evaluated the color of interiors (Kueller & Mikellides, 1993; Savavibool, Gatersleben, & Moorapun, 2018) and building exterior (Cubukcu & Kahraman, 2008; García, Hernández, & Ayuga, 2003; Janssens, 2013; O'Connor, 2008; Santosa & Fauziah, 2017; Sarıca & Cubukcu, 2018). Most of these studies have focused on monochromatic evaluation. For example, O'Connor (2008) examined monochrome use on buildings in color harmony with its natural surroundings. Only a limited number of studies have examined the color-emotion of the color combination in building exterior Sarica & Cubukcu (2018) compared people's responses to abstract color combinations and color combinations of the building exterior in urban settings in terms of some color-emotion scales. European countries and Australia's urban planning policies also consider the building exterior's color in their aesthetic control plan (ABC, 2005; WAPC, 2007). However, Iran's urban planning policy has neglected the building exterior's color.

It is essential to examine color systems for studying the color of the building's exterior. Color systems provide a method to specify, order, manipulate, and effectively display the intended object colors. Besides, they could be used to define colors, distinguish between them, judge similarities between them, and identify their categories for some applications (Plataniotis & Venetsanopoulos, 2013). We can refer to CIELAB, CMYK, Munsell, NCS, Pantone, sRGB, and HSL systems among different color systems. Color is defined based on some features in each of these terms. The physical dimensions of the color, namely, hue, saturation, and luminance, are among them. Color is informed based on these physical dimensions in most studies on color preference (Cho, 2015; Guo, Li, Nagamachi, Hu, & Li, 2020; Han, Kim, Choi, & Park, 2016; Li, Yang, & Zheng, 2020; O'Connor, 2008; Shinomori, Komatsu, & Negishi, 2020). Hue is defined as the differentiation of the colors from each other. Luminance (tone or tonal value) is the luminance or darkness of a hue, which has different degrees from absolute black to absolute white. Finally, saturation (chroma or chromaticity) is the level of hue intensity or purity, ranging from neutral gray to the highest degree of saturation at any hue level (Mahmoudi & Shakibamanesh, 2005) (Figure2).

In addition to the physical dimensions of color, some studies on environmental color preference have evaluated color in terms of emotional scales such as harmonious/contrasting, warm/cool, light/heavy, active/passive, etc. (AL-Ayash, Kane, Smith, & Green-Armytage, 2016; Boeri, 2019, 2020; Chamaret, 2016; FANG, MURAMATSU, & MATSUI, 2015; Güneş & Olguntürk, 2020; Hanafy, 2016; Huang, 2018; Koo & Kwak, 2015; Kuang & Zhang, 2017; Liu, Hutchings, & Luo, 2020; Manav, 2017; Naz, Kopper, McMahan, & Nadin, 2017; Odabaşıoğlu, 2015; Ou et al., 2018; Palmer & Schloss, 2015; Prado-León, Zambrano-Prado, Herrada-Rodriguez, & Felizardo-Gomez, 2018; Rostami, Izadan, & Mahyar, 2015; Shinomori & Komatsu, 2018; Slobodenyuk, Jraissati, Kanso, Ghanem, & Elhajj, 2015; Sokolova & Fernández-Caballero, 2015; Wardono, Hibino, & Koyama, 2017; Weingerl & Javoršek, 2018). O'Connor's study (2008) used the harmony-contrast scale based on urban planning policies in Sydney. Sarica & Cubukcu (2018) evaluated the color combinations of urban settings based on temperature and harmony-contrast scales. Due to the various scales in different studies, there is no standard tool to select the scale evaluating and describing the building exterior's color combination. Therefore, it is necessary to determine scales evaluating and describing the color combination of the building exterior.

In most of these studies, there was no clear definition for the scales. Among other things, harmony is a vague concept for which there is no unique theory in studies on color. In an approach, color harmony arises from combinations of color samples that exhibit completely different or complementary colors. Another approach to color harmony suggests that it arises from combinations of color samples that exhibit similarity of hue or saturation level or luminance level. The third approach does not attempt to equate the notion of color harmony with formulaic groupings of color samples. It considers color harmony as an unpredictable phenomenon (O'Connor, 2008).

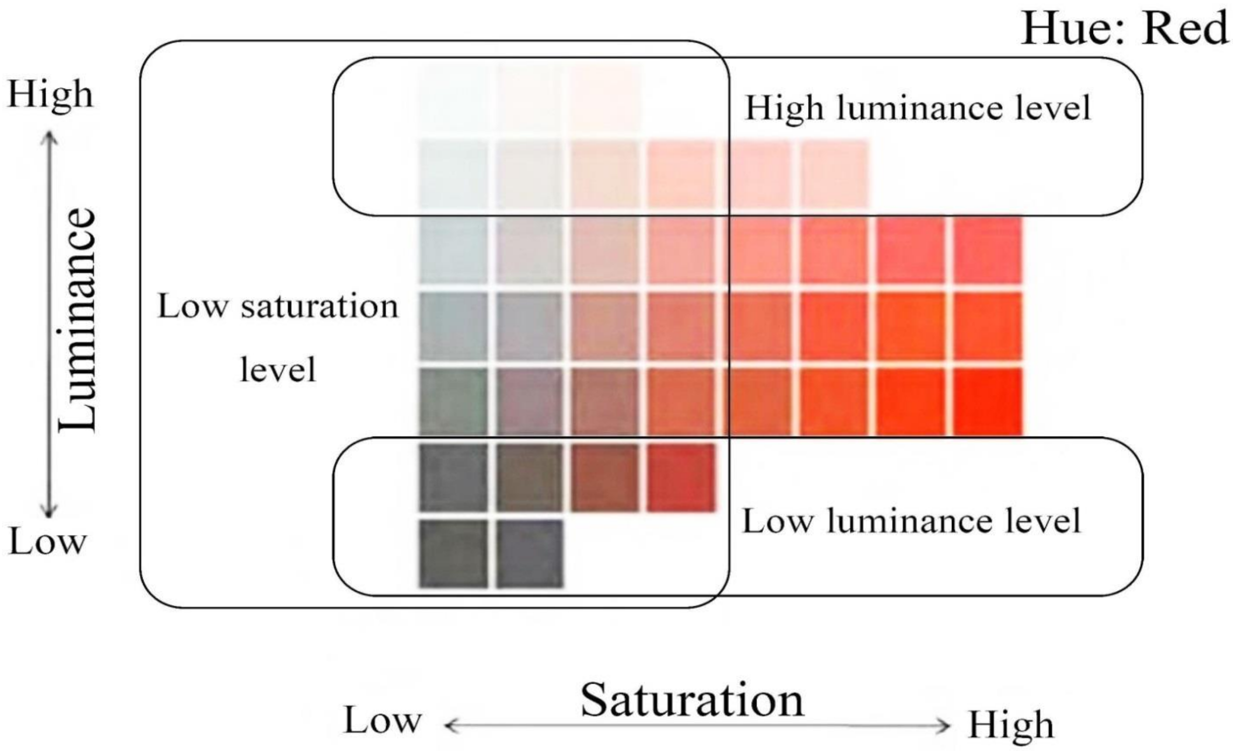

Fig 2. Physical dimensions of color: hue, luminance, saturation (O'Connor, 2008)

A lack of consensus with the notion of color harmony can be partly attributable to the two opposing ontological approaches evident in the literature. The first ontological approach suggests that color harmony is a predictable and universal phenomenon. The second ontological approach suggests that color harmony is not accorded a universal phenomenon's status. It is not considered deterministic (same). This approach is also evident in some recent studies. These studies found individual differences, cultural, contextual, and temporal factors to influence color harmony definition (Janssens, 2013). Based on this ontological approach, different color evaluation studies have used various color harmony definitions. For example, in O'Connor's study (2008), a range of hues was used which harmony or contrast with the colors of the surroundings. Sarica & Cubukcu (2018) considered harmonious color to be adjacent to a color wheel model. Contrasting colors are those located on opposite sides of a color wheel model. Garcia et al. (2003) used a range of hues, luminance levels, and saturation levels, which have harmony or contrast with the surroundings' color. These studies have shown that some components, such as surrounding color or other elements' color in building exterior, may influence the color scales' definition.

Other challenges in environmental color evaluation studies are using the term 'preference' instead of 'harmony' (Palmer, Schloss, & Sammartino, 2013) or using terms such as 'harmonious' and 'sympathetic' without any definition. These have led to inconsistencies in the literature. These contradictions may be because emotional terms related to color are arbitrary and subject to many factors. Hence, it is crucial to evaluate the components describing the harmony-contrast of color combinations in the residential building exterior.

3. MATERIALS AND METHODS

3.1. Methodology

Due to the exploratory nature of the research subject, we used qualitative and quantitative methods. Since the participants' selection was based on nonprobability and targeted sampling with the small sample size, the method is considered a qualitative method. Data analysis through factor analysis was considered the quantitative part of the study (Sepasgar & Manouchehri, 2014).

Figure 3 shows the related literature on color preference evaluation scales was retrieved by searching library documents and online scientific databases such as Google Scholar and Scopus using descriptive-analytical and logical reasoning methods. We selected Forty sources, emphasizing color-emotion scales from many sources with relevant titles and abstracts published between 1960 and 2020. After examining the selected sources' full-text versions, we collected 97 color-emotion scales of color preference evaluation. Based on the results of earlier studies, there were only ten scales among 97 scales, which could be described based on the physical dimensions of color. There was consensus among experts about the definitions in these scales. Table 1 shows all these scales: harmonious-contrasting, warm-cool, active-passive, soft-hard, and light-heavy. Other scales had different definitions due to cultural and individual differences, leading to no theoretical agreement about their attributes.

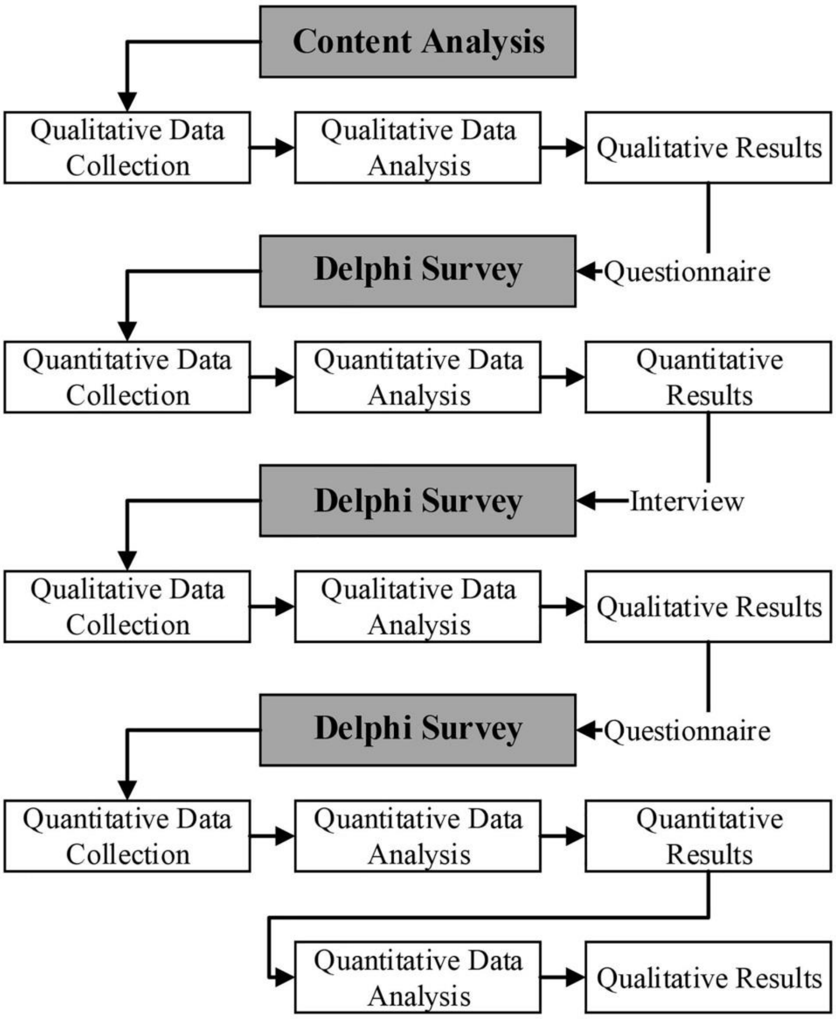

Fig 3. The research process

Table 1. Color-emotion scales could be described by the physical dimensions of color that

No	Dim	Ref No
1	Warm	6,11,16,17,18,19,22,24,26,27,28,29,30,32,33,34,36,39,40,42,44
2	Cold	6,11,16,17,18,19,22,24,26,27,28,29,30,32,33,34,36,39,40,42,44
3	Soft	16,19,23,24,28,29,30,32,39,40,41
4	Hard	16,19,23,24,28,29,30,32,39,40,41
5	Active	17,19,23,24,26,28,30,36,39,42
6	Passive	17,19,23,24,26,28,30,36,39,42
7	Heavy	16,17,18,19,22,23,24,26,28,30,33,36,39,41,42
8	Light	16,17,18,19,22,23,24,26,28,30,33,36,39,41,42
9	Harmonious	6,11,18,20,25,26,27,29,31,32,35,36,37,44
10	Contrasting	6,11,18,20,25,26,27,29,31,32,35,36,37,44

Next, as the first Delphi[1] survey, twenty experts in design and color (e.g., professors of architecture, painting, graphics, & industrial design) evaluated 100 photographic images of building exterior based on five color-emotion bipolar scales. Since the sample size cannot be large in the Delphi survey, Q-method[2] was used to analyze the

[1] Delphi survey is used to examine the consensus of an expert group on a specific topic (Sarmad, Bazargan & Hejazi, 2015).
[2] The Q-method is a method for identifying the mentalities about a topic which uses the systematicity of quantitative methods with a qualitative approach (Sepasgar & Manouchehri, 2014).

questionnaire data. In the Q-method, a small number of respondents answers a large number of questions. In fact, in this method, instead of variables, individuals are evaluated (same). The Q-method analysis results showed that the color combination of building exterior could be defined and described in three color-emotion bipolar scales. These scales are harmonious-contrasting, warm-cool, and light-heavy. Based on this analysis, the most suitable and representative photographic images for each of these three scales were selected among 100 images.

The analysis of all the scales was beyond this study's scope, mainly due to budget and time constraints. Therefore, we examined only the harmony-contrast scale in the present study. Next, we used semi-structured interviews to explore the five architecture and urban design experts' views about the color combination' harmony assessment components. We obtained nine components from the analysis of these interview data. We used these components and 16 selected images of the harmony scale to construct the last step's survey tool. The first group of experts (i.e., twenty experts in design and color) completed this questionnaire. The data of the questionnaire were analyzed using Q-method in 2 steps. Then, we extracted the components that affected the harmony assessment of color combinations of building exteriors using the color strips and the HSL codes of selected images' color.

We used the HSL system based on the aims and theoretical framework of the study. Because of the numerical values of physical properties of a color, i.e., hue (H), saturation (S), and Luminance (L) can be specified in this system. Figure 4 shows the model of this system. The hue is measured by the angle between 0 and 360 degrees around the vertical axis. It indicates a distinct color in each degree. In this model, the luminance ranges between 0 and 1. Its value is relative and measured in percentages from 0% (black) to 100% (perfectly bright color). Saturation is a ratio ranging from 0 on the 'I' axis to 1 on the surface of the cone, which extends radially and is measured from 0% (white) to 100% (utterly saturated color) (Sarıca & Cubukcu, 2018).

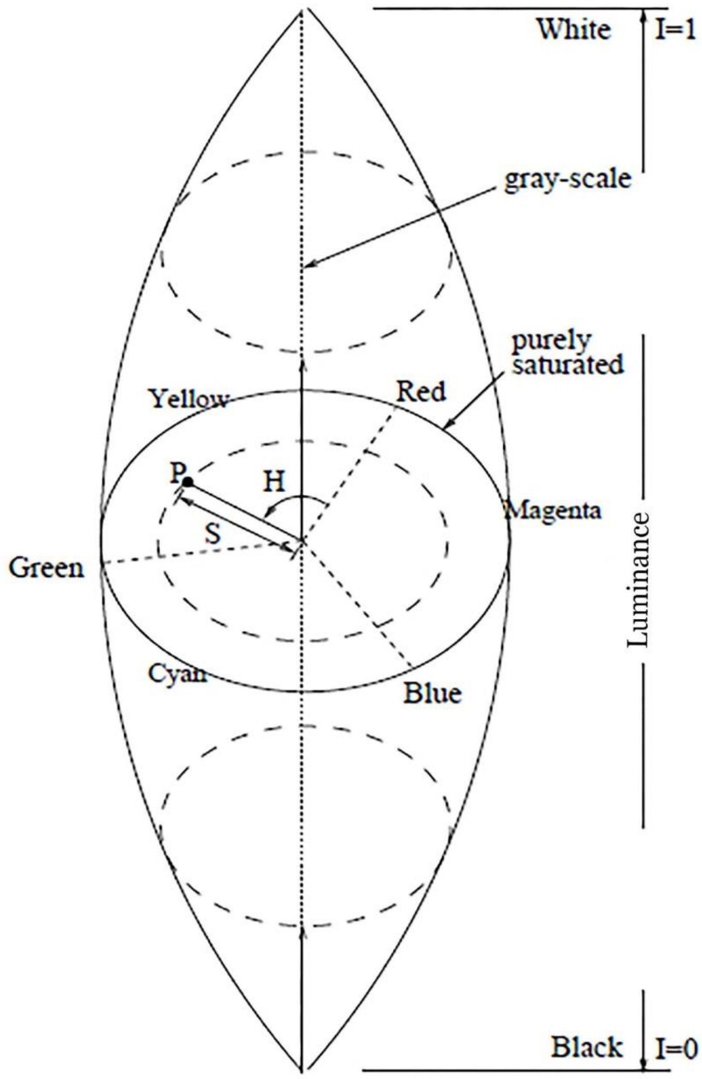

Fig 4. The HSL color system (Sarıca & Cubukcu, 2018)

3.2. Survey of the photos of the building exterior

Contextual colors should be used to evaluate color preference in architecture and urban design. However, the use of full-scale models and real settings is not always possible, affordable, and efficient. Several researchers have used photographic images as representations of real objects and settings. For example, Janssens (2013) used photographic images of architectural exteriors. These studies showed that responses to color photographs accurately reflect on-site responses (Cubukcu & Kahraman, 2008). So we used the photographic images in this study. Photographic images should be a suitable representative of the residential building exterior in Tehran. Since no previous research had been conducted in Iran, there was no standard tool to record the images. Therefore, Tehran neighborhoods were first studied. In the study conducted under the title of 'Cultural, Social and identity typology of Tehran neighborhoods' by the Tehran urban research & planning center (2015) (the institute of social studies and research, 2015), Tehran neighborhoods have been classified based on 12 criteria. Due to the lack of a standard tool to select the appropriate neighborhood, we consulted experts. According to five teachers of architecture and urban planning, 11 neighborhoods in Tehran were selected. After visiting the 11 neighborhoods and taking pictures of existing building exteriors, former experts selected the Koy-E-Nasr neighborhood. They selected this neighborhood for the following reasons:

- The chess streets that were almost equal in width (Ability to record images from the same distances)
- Buildings of almost the same age
- Buildings with almost the same width and number of floors
- Buildings with the same function (almost all residential)

Therefore, the present study used color photographs of residential buildings exterior of the Koy-E-Nasr neighborhood taken by a digital camera. The selection and survey of images of the building exterior were performed as follows:

Selection of the buildings: Due to the effect of age, scale, and application of a building on color evaluation and preference (Janssens, 2013), photographic images were taken of 6-7-story residential apartments with a maximum age of 10 years located in the northern plot of land with a width of approximately 9-12 meters. All photographic images of the building exterior were taken by one camera[1] at a straight and constant angle, 10 meters from the building exterior. Six hundred ninety-two images were taken of all residential buildings in the Koy-E-Nasr neighborhood with the features mentioned above. A total of 100 photographic images were chosen for analysis by five former experts. These images showed the entire exterior with no visual appendage, or these appendages could be corrected by photoshop software.

Time and conditions of recording the images: Due to the change of color based on light conditions at different times of the day and different seasons and climates (Zareh & Lotfi, 2017), we recorded the images between 12:00 and 2:00 PM for one month. This time had maximum sunny conditions with a minimum amount of shadows.

Setting the white balance of the photographic images: Different light sources in various conditions convert white to different colors, which the human brain corrects them. However, suppose we do not set the white balance in digital cameras; in that case, we obtained utterly different colors in different light conditions. Therefore, we recorded a photograph sample using a white reference card[2] in the 'preset manual' mode to check stable light conditions. Then, we used the 'Levels' setting in the photoshop software to re-align (Tadoyon, Ghaleh Noei & Abui, 2018).

The correction of photographic images: We used the Skew setting of the Transform tool in the Edit menu of photoshop CC 2017 to have images in the same viewing angle, independent of perspective. Due to the effect of environment colors on color-emotion (Cubukcu & Kahraman, 2008), the adjacent building exteriors were deleted and painted in neutral gray[3]. Unique blue was chosen as the color of the sky[4] in each recorded image. We changed the ground floor color in all images darker and deleted visual appendages such as utility pole, power cable, and trees from the images as much as possible (Figure5).

3.3. Participants and data collection

The content analysis's statistical population included all available sources and studies in evaluating color preference and building exterior. Based on the studies, if the purpose is to explore and describe the participants' opinions and attitudes, 15±10 samples are sufficient to conduct the survey given the time and resources available (Sepasgar & Manouchehri, 2014). Therefore, twenty experts in design and color (i.e., professors of architecture, painting, graphics, & industrial design) responded to the first and second questionnaires. We selected these individuals based on their familiarity with the research topic, nonprobability, and targeted sampling with the small sample size. In the semi-structured Delphi interviews, we selected five architecture teachers via snowball sampling. We continued the interviews until theoretical saturation was achieved.

3.4. Reliability and Validity

[1] Nikon Coolpix S2700.

[2] White reference card is a standard reference in photography to determine light quality. In this research, a white A4 paper was used as a white reference card.

[3] $H0^0$, S0%, L76%.

[4] $H218^0$, S37%, L76%.

The internal consistency of the questionnaires was estimated through the calculation of Cronbach's alpha coefficient of reliability. The coefficients' overall value in the first and second questionnaires was 0.7 and 0.78, indicating the scales' acceptable reliability. The K-M-O test was used as a sample adequacy index in Q-method analysis to check the variables' appropriateness in the correlation matrix. The value of more than 0.7 indicates that the data's correlations are appropriate for factor analysis (Takaneh & Ferguson, 2011). Table 2 shows that this value is 0.7 in the first questionnaire and 0.715 in the second questionnaire indicating the sample size's adequacy. In Q-method analysis, the significance of Bartlett and Chi-square should be tested. Bartlett's zero assumption test shows that the correlation matrix is unique, and the variables are only correlated with themselves. The rejection of this assumption means that the correlation matrix has significant information. The value of the Chi-square test in Table 2 met this expectation. Besides, factor analysis is suitable to identify the factor model. If Bartlett's test of sphericity is less than 0.05, it means that it is significant. As shown in Table 2, the test is significant (Sig=0.00).

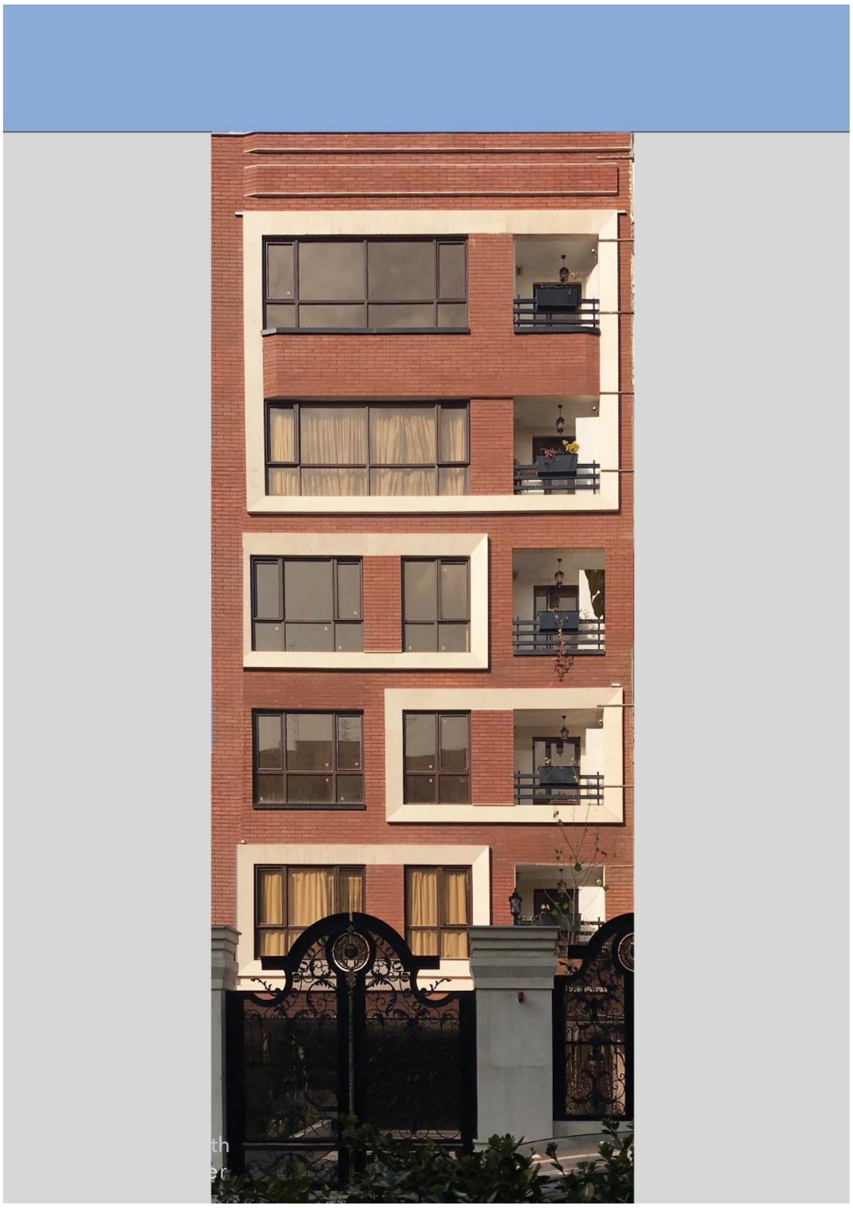

Fig 5. Sample image of residential building exterior that recorded and corrected

Table 2. K-M-O and Bartlett's test

K-M-O Measure of Sampling Adequacy		0.715
Bartlett’s Test of Sphericity	Approx. Chi-Square	1275.430
	Df	190
	Sig.	.000

4. RESULTS AND DISCUSSION

The data analysis after rotation in SPSS software showed seven factors whose total rotation sums of squared loadings are more than 1 (Table 3). About 70.559% of all factors' cumulative frequency indicate that about 70% of participants' thoughts were common. About 30% was individual thought, which may be related to individual tendencies and awareness. This percentage shows an external fact that has attracted 70.559% of the respondents' attention.

Based on the rotated component matrix and factor loadings statistics, the variables making up each factor could be identified. The variable with factor loadings of more than ±0.3 is significant. It places in the category of that factor. Table 4 shows the number of experts included in each factor. The first factor included six experts. The second factor included four experts, each of the third and fourth factors included three experts. Each of the fifth and sixth factors included one expert, and the seventh factor included two experts. The fifth and sixth factors were not considered in the analysis since they included just one expert. This case shows that others did not share the views of two experts.

The change of the scree plot shape in factor analysis indicates the principal factors (O'Connor, 2008). As shown in the screen plot (Figure 6), the graph's hypothetical line is broken and flattened from factor 5. The first factor is large and significant, and the second, third, fourth, and fifth factors are significant and definable.

Table 3. Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.156	25.781	25.781	5.156	25.781	25.781	4.296	21.478	21.478
2	2.256	11.282	37.063	2.256	11.282	37.063	2.305	11.523	33.001
3	1.749	8.746	45.809	1.749	8.745	45.809	1.827	9.134	42.135
4	1.572	7.861	53.670	1.572	7.861	53.670	1.705	8.524	50.659
5	1.251	6.254	59.924	1.251	6.254	59.924	1.462	7.310	57.969
6	1.124	5.621	65.545	1.124	5.621	65.545	1.333	6.666	64.636
7	1.003	5.014	70.559	1.003	5.014	70.559	1.185	5.923	70.559

Table 4. Rotated component matrix

	Component						
	1	2	3	4	5	6	7
18	.890	.063	-.003	-.184	-.134	.049	-.040
12	.787	.241	.122	-.063	.238	.163	.005
13	.783	.159	-.018	-.241	-.174	-.210	.055
16	.749	.107	-.034	.273	-.318	-.112	-.059
19	.698	.107	.066	-.126	.426	.102	.196
15	.690	.257	.105	.034	.394	.194	.140
4	.088	.855	-.020	-.175	-.082	-.018	.133
9	.181	.852	-.126	.131	.049	.046	-.073
14	.302	.590	.261	-.072	096	-.132	-.189
6	.386	.425	-.233	-.337	.413	.245	.059
2	-.125	.073	.848	.140	.022	-.062	.020
10	.211	-.174	.764	-.072	-.185	.0139	-.030
11	.118	.196	.417	.324	-.217	-.386	-.217
8	-.067	-.023	-.291	.666	.154	.471	-.143
17	.397	-.014	-.204	-.657	075	-.018	-.013
1	.070	-.254	.163	.571	-.011	-.169	.397
7	-.034	-.006	-.126	.036	.720	-.057	-.057
3	.081	.007	.064	.041	-.068	.794	-.106

20	.182	-.019	-.068	-.019	.051	-.153	.731
5	.429	-.063	-.032	.127	.307	-.200	-.530

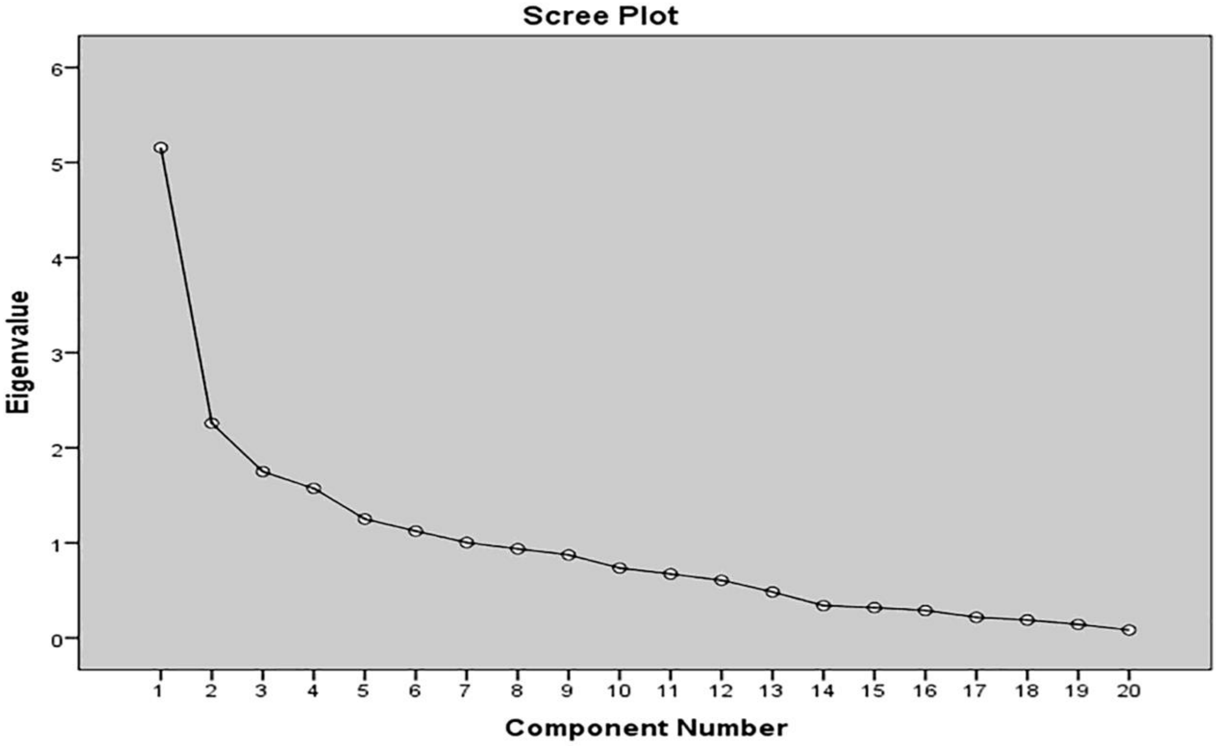

Fig 6. Scree plot- Factor analysis of 20 variables

We considered the questions that at least half of the experts of that factor gave them a score of 8, 9 and 0, 1 in each factor, to find the experts' shared ideas about components. Then, due to the wide range of the obtained results, factor analysis was performed on the obtained factors for the second time. We used this step's results to determine the components affecting the harmony assessment of color combinations in building exteriors and selecting several photographic images of building exterior as the best representative of harmonious/contrasting color combinations. The factor analysis provided three components: the difference between the hues' luminance, the difference between the hues' saturation, and the number of hues in combination. It is noteworthy that five components did not significantly affect the harmony-contrast assessment, such as the form of openings (windows), the formal composition and details of the building exterior, the area of hues in combination, and the area of the openings. Furthermore, the component of 'color of opening (windows)' affected the harmony assessment of color combination in some photographic images. In contrast, it did not have much effect on some others. The contents of these components are briefly described as follows.

Difference between the luminance of hues in combination: The small difference in luminance between the lightest and the darkest hue in color combination of building exterior led to its assessment as a harmonious combination. The massive difference in luminance between the lightest and the darkest hue in color combination of building exterior led to its assessment as a contrasting combination.

Difference between the saturation of hues in combination: The small difference between the saturation of hues in combination facilitated the assessment of the color combination of building exterior as a harmonious combination. All hues of these combinations were either high saturated or low saturated. The relatively large distance between hues' saturation in combination facilitated assessing contrasting combinations.

The number of hues in combination: In color combination considered harmonious, the small number of hues in color combination of building exterior made it easy to assess the harmony. It did not necessarily apply to contrast color combinations.

The form of openings (windows): The shape, form, and location of openings on building exterior had no significant effect on the harmony-contrast assessment of the color combination in building exterior.

The formal composition of building exterior[1]*:* The formal composition of the building exterior, as either a plate, with no protrusions and indentations of more than 15

[1] The formal composition of building exterior, as a plate, with no protrusions and indentations of more than 15cm in the building exterior, as a relief with protrusions and indentations of more than 15cm in the building exterior, and as a volumetric composition with volumetric protrusions and indentations was considered. Due to the predominant formal composition of building exteriors in Tehran (plate and relief), building exterior as a volumetric composition was not studied in this research. Thus, the results of the present study cannot be generalized to building exteriors as a

cm in the building exterior, or as a relief, with protrusions and indentations of more than 15 cm in the building exterior, did not facilitate the harmony-contrast assessment of the color combination in building exteriors.

The building's exterior details[1]*:* The presence or absence of details on the building exterior has not helped the harmony assessment of the building exterior's color combinations.

The area of openings (windows): The ratio of the area of the openings to the area of the whole building exterior did not have any significant effect on the harmony-contrast assessment.

The area of hues in combination: The large area of the main color in color combination and even the hues area in ratio did not facilitate the harmony-contrast assessment of the color combination in building exteriors.

The color of opening (windows) in photographic images: The color of the opening means the whole color of the opening, i.e., the colors of the frame, the glass, and possibly the curtains behind the glass, which could be seen in photographic images. In images considered a harmonious color combination, the openings' color would affect the harmony assessment if this component had the same temperature[2] as the building exterior's color. However, if the openings' color temperature were not the same as the combination's color temperature, it would not affect the harmony assessment. Nevertheless, other factors might have affected. The color of openings was not significantly affected in images considered as a contrasting color combination.

We could classify the components of the harmony-contrast assessment of color combination into three categories based on their features: color features, formal features, and features related to size and dimension (surface area). Therefore, we could consider the difference between the hues' luminance, the difference between the hues' saturation, the number of hues in combination, and the color of openings in photographic images as components related to color features. All of which affected the harmony-contrast assessment of color combination in building exteriors. However, the harmony-contrast assessment of the color combination of building exterior was not significantly affected by the components related to the formal features of the building exterior, i.e., the form of the openings, the formal composition, and the details of the building exterior as well as the components related to the dimensional features of building exterior, i.e., the area of openings and the area of hues in combination.

The non-significant effect of the components related to the building exterior's formal features on the harmony-contrast assessment of the color combination can be explained as follows. The formal composition of building exteriors studied in the research (most of the residential building exteriors in Tehran) was plate or relief due to Tehran municipality's facade designing criteria. There was no building exterior with volumetric composition in the study. The two-dimensional photographic images of building exteriors were recorded in the times of day when shadows were minimal. Thus, the formal compositions of building exteriors in the images were less noticeable. They could not have had much effect in assessing the harmony-contrast of the color combination in the building exterior. The non-significant effect of the building exterior details can be justified based on Gestalt theory in understanding the color combination of building exterior as a whole. It means that the photographic images' totality rather than their details is seen first (Grutter, 2014). Thus, they do not affect the harmony's assessment of the building exterior's color combination; because the details are not visible at first glance. In the studied residential building exteriors, most openings were rectangular, placing repetitive symmetry on the surface. According to information theory, this similarity and repetition of the opening form reduce the information content. Furthermore, as a result, attention to it reduces at first glance.

The significant effect of the difference in luminance and difference in the saturation on the harmony-contrast assessment of the color combination can be explained based on the kinds of color contrast proposed by Itten (1961). Itten Asserted that seven kinds of color contrast exist. The contrast in terms of the difference in luminance and the difference in saturation justify the significant effect of these two components in assessing the harmony-contrast of the building exterior's color combination. The color of the openings in the image is part of the color combination in the building exterior. This component can also be explained based on Itten's proposed cold-warm contrast; that is, in terms of the notions of warm colors and cold colors. In this way, if the openings' color temperature is the same as the rest of the building exterior's color temperature, the combination is the harmony (O'Connor, 2008). As the increase in the number of colors makes it difficult to identify the background's color, it becomes difficult to assess the color combination's harmony in building exterior.

We used the color strip method[3]to analyze the colors applied to the color combinations. The photographic images of building exteriors were first simplified [4] (Figure 7). Then, each color's area was calculated into the total area and plotted in colored strips with a length of 100 units. It shows each color's percentage in the color combination of the building exterior (Figure 8).

volumetric composition.

[1] According to Van der Laan, elements with dimensions between width and height of building exterior are considered as details (Stamps III, 1999).

[2] In the HSL system, the warm color values range from 0 to 90 degrees and from 271 to 360 degrees while the values of cool colors range from 91 to 270 degrees.

[3] This method was adopted in studies run by Tadayon et al. (2018) and O'Connor (2008).

[4] Each building exterior comprises different components such as the main surface, frames, windows, details, decorations, which considering the multiplicity of colors used in them as well as the purpose of this study, only the colors of main elements of building exterior were considered.

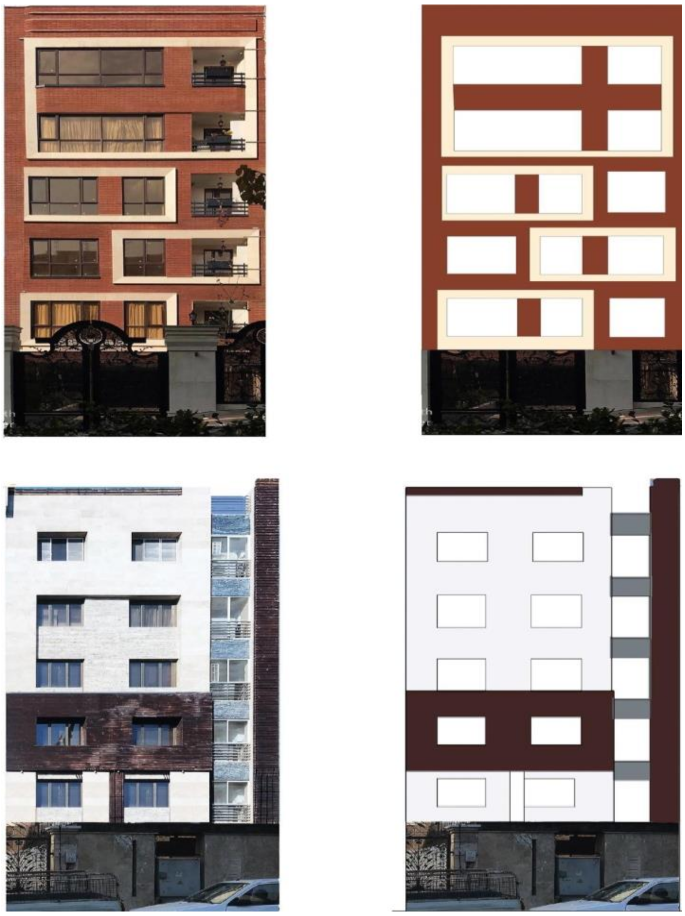

Fig 7. Simplification of the building exteriors based on main colors

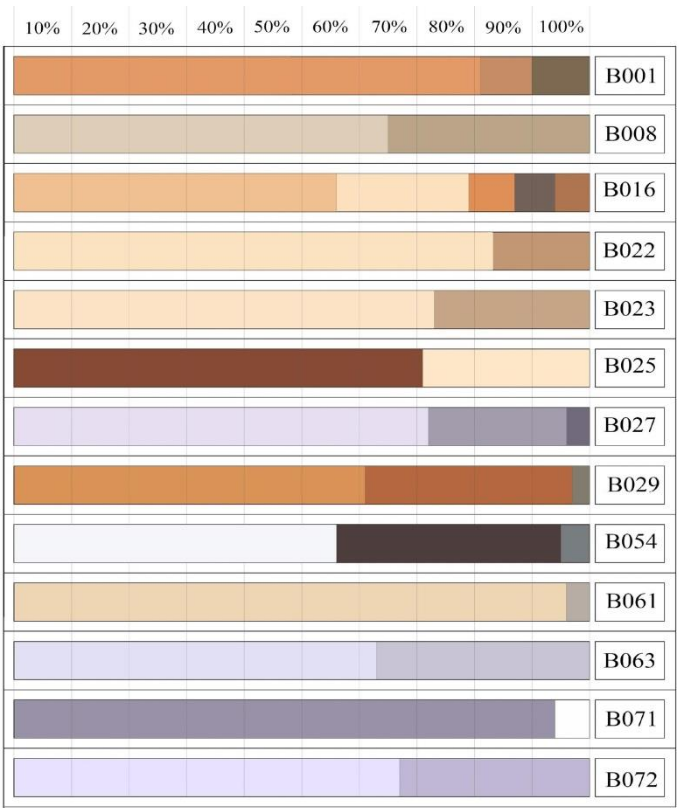

Fig 8. The color strips of selected images of building exteriors
(B001, …. are the number of building exterior's images)

We used colored strips and the HSL color system's codes to study the colors in terms of luminance difference and saturation difference. The results obtained from the analysis of colored strips and HSL codes are as follows:

The HSL codes of the images of the difference in luminance's component were analyzed (Figure 9). The findings showed that the luminance difference between the lightest hue and other hues was massive (at least 45%) in combinations considered contrasting. On the other hand, the difference in luminance between the hues of color combinations was small (maximum 20%) in combinations considered harmonious. Thus, the difference between luminance was up to 20% in combinations with two hues. There was the hue(s) with a maximum 20% difference in luminance between the lightest hue and the darkest hue in combination with more than two hues. It is noteworthy that the difference in the hues' luminance with an area of about 6% or less did not significantly affect the harmony-contrast assessment of the color combination in building exterior.

The HSL codes of images of the difference in saturation's component were analyzed (Figure 10). The finding indicated that the difference between the hues' saturation was small (maximum 15%) in combinations considered harmonious. The difference in the hues' saturation of a contrasting combination was at least 20%. Thus, the contrasting combination had a hue whose difference in saturation with the rest of the hues in combination was at least 20%. In these images, the difference in the hues' saturation with an area of about 5% or less did not considerably affect the harmony-contrast assessment of the color combination in the building's exterior.

Colour	H	S	L	Area
B001				
	25	55	89	48%
	25	48	77	33%
	32	35	49	19%
B008				
	36	19	88	65%
	32	27	76	35%
B016				
	32	45	92	56%
	34	26	99	23%
	24	62	87	8%
	11	15	45	7%
	24	54	67	%6
B022				
	36	23	97	83%
	28	39	81	17%
B023				
	33	22	99	73%
	29	32	78	27%
B025				
	17	61	52	71%
	34	21	99	29%
B027				
	240	6	100	72%
	250	11	82	24%
	258	16	58	4%
B029				
	28	60	85	61%
	20	65	71	36%
	42	16	51	3%
B054				
	228	2	98	56%
	3	22	30	39%
	210	8	51	5%
B061				
	35	24	93	96%
	28	10	72	4%
B063				
	243	8	96	63%
	257	8	84	37%
B071				
	259	13	65	94%
	240	1	100	6%
B072				
	255	12	100	67%
	257	13	83	33%

Fig 9. The HSL codes of the colors of selected images that were related to the difference in luminance (B001,… are the number of building exterior's images. H: hue, S: saturation and L: luminance)

Colour	H	S	L	Area
B001				
	25	55	89	48%
	25	48	77	33%
	32	35	49	19%
B003				
	41	13	100	40%
	36	44	53	25%
	19	59	46	18%
	27	45	76	17%
B025				
	17	61	52	71%
	34	21	99	29%
B029				
	28	60	85	61%
	20	65	71	36%
	42	16	51	3%
B054				
	228	2	98	56%
	3	22	30	39%
	210	8	51	5%

Fig 10. The HSL codes of the colors of selected images that were related to the difference in saturation (B001,… are the number of the building exterior's images. H: hue, S:saturation and L: luminance)

In both groups of the selected images, the combination's hues were considered harmonious and had the same temperature (cold hue with 91-270 degrees or warm hue with 0-90 and 271-360 degrees). In comparison, this was not necessarily the case in contrasting combinations. The color combination was necessarily considered contrasting when the temperature of the hues of the color combination was not the same. However, some photographic images were considered a contrasting combination despite the same temperature of hues.

The results of color strips and codes of the HSL system also confirm the findings of Q-method data. Thus, increasing the difference in luminance and the difference in saturation between the combination's color causes the contrast of color combination. While decreasing the difference in luminance and the difference in saturation between the combination's color and the same temperature of its hues causes the harmony of color combination.

5. CONCLUSION

According to the obtained results, the main components describing the harmony-contrast of the color combination are the difference in luminance, the difference in saturation, and the temperature difference of the hues of the color combination in building exterior. These results confirm the harmony/contrast classification of color combination in the study carried out by Sarica & Cubukcu (2018). This study was about the component of the temperature difference of the hues. Thus, if the hues' temperature were not the same, the color combination would look contrasting. However, this is not the case with harmony, which means that the same hues' temperature does not necessarily make it look harmonious. This study's results also confirm the findings of Garcia et al.'s study (2003) which is e about the difference in luminance, the difference in saturation of color combination in building exterior. The difference is that in Garcia's study, in addition to luminance and saturation, various hues, regardless of their temperature, have been used to classify the color combination.

In this way, we can define and design the color combination of building exteriors using the components described, the color combination's harmony and the quantity values. The formal and dimensional components have the non-significant effect in describing the harmony-contrast of the color combination. Therefore, the building exterior as harmonious of contrasting color combination can have any style in terms of form and dimensions of openings and any amount of color area in the combination. The combination should have a maximum of two or three hues with the same temperature to design the building exterior's harmonious color combination. The difference between the hues' luminance and the difference between hues' saturation should be less than 20% and 15%, respectively. Additionally, the openings' color temperature should be the same as other hues' temperatures in the building exterior's color combination. The combination should have a maximum of two or three hues with different temperatures to design the building exterior's contrasting color combination. The luminance difference between one hue and other hues of the combination should be more than 45%. The saturation difference between one hue and the other hues of the combination should be more than 20%.

In addition to the harmony-contrast color-emotion scales, two other color-emotion scales (temperature and weight) were considered to describe and classify the color combination in building exteriors. Due to budget and timing constraints, it is highly recommended that future studies examine these two color-emotion scales. Further research could also focus on the affective and cognitive evaluation of the color combinations in building exterior based on the present study results.

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ENDNOTES

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