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An Investigation of the Effects of Nature-Inspired Lighting Patterns On the Users*

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ABSTRACT

Today, the modern construction techniques and search for ways to achieve the desired quality of living spaces have made the quality of life in residential units and improved quality of life the way they are improved is a fundamental challenge and an ideal for the users. Of the factors affecting the quality of the human's life is the natural element of light, which, this test uses the quality-of-life indicators to evaluate the nature-inspired fractal lighting patterns for the residents. This makes sense because the natural fractal geometry is legible by the human's visual perception and whose formative processing and aesthetics can be easily adapted by the human's subjective and visual perception. The main goal of the research is to improve the residents' quality of life by explaining and evaluating its indicators using fractal geometry-based lighting patterns. Thus, the main research question is to investigate the nature-inspired effects of lighting patterns using fractal geometry on the users' quality of life. The research also uses reasoning and scientific methods. Data are collected by the Delphi and library methods. Here, the lighting patterns are regarded as independent variables and quality of life indicators of the users as dependent variables. Generally, consistent with the research findings, quality of life indicators and the factors affecting them are evaluated as research measures based on the Likert scale, while natural and unnatural lighting patterns are assigned scores 120 out of 150 and 121 out of 150, respectively. In sum, it is concluded that novelty in defining nature-based lighting patterns and the production of new mentality in the users lead to new visual and spatial quality. On the other hand, acquainting the users with the objectivity of the pattern and creating a subjective link with the users' perceptions can engender ways to change the way lighting styles are designed, as this will transform the users' quality of life perception of the space.

Keywords: Quality of Life, Skylights Patterns, Fractal Geometry.

* This article is an excerpt from the doctoral dissertation of the first author entitled "An explanation of light patterns affecting the quality of life of residents in residential complexes using fractal geometry", with the supervision of the second author and reading of the third author at the Faculty of Art and Architecture of Islamic Azad University, Tabriz Branch, which was completed in 2020.

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1. INTRODUCTION

Today, given the type of materials and modern construction methods, achieving a desirable level of satisfaction and improving the quality of life of the users of residential spaces have become an ideal issue. One of the factors which affect the human's quality of life in an architectural space is the effects of nature and light. To measure the quality of life, subjective and objective indicators or a combination of the two are used. Daylight which is a positivity, affects the residents' health, visual desirability, and creation of an appealing and rhythmic architectural space. In contrast, its conceptual features, such as creating shade and depth for the desired use of the space as in the past Iranian architecture can be used for a better life quality (Safar-Beyranvand, Mehrnoush, & Sharifi, Mehdi, 2018). In the traditional architecture of Iran and other countries, relatively effective measures and time-specific techniques were used to receive the light and lighting patterns; also, geometric shapes and girih tiles, including peepholes, were used. Today, architects, engineers, and light designers need more studies to combine design criteria and human emotional preferences when planning lighting in buildings (Castilla et al., 2018, p. 601). Here, the word pattern is used to visually and formatively systemize the way light is received because the shapes of light, which have similar formative features, can become a lighting pattern or parts of the pattern. This research uses the natural fractal geometry, which is proportionate to the human' visual perception and is processed through his subjective and visual perception. The fractal geometry is used to choose the patterns for the visual test of the lighting patterns. The evaluation of the criteria and data analysis and the proposition of relevant strategies help remove the shortcomings and improve the residents' quality of life.

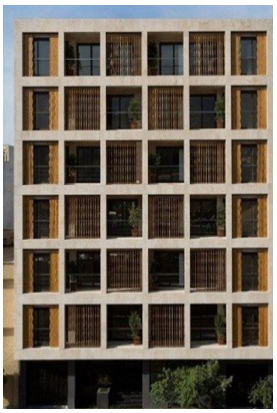
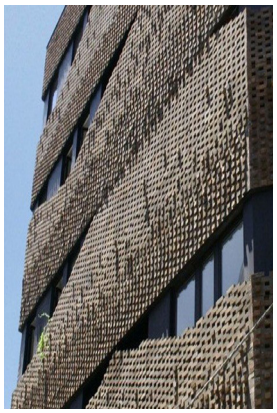
2. RESEARCH QUESTION

Given the material stated, the question posed in this research is as follows:
How do natural fractal geometry-based lighting patterns affect the users' quality of life?

3. LITERATURE REVIEW

The 2002 Architecture Competitions in Iran heightened competition among the architects to design desirable houses, which led to special fractal geometry lighting designs. The competitions also centered around light and lighting using traditional and modern materials to improve the residents' quality of life (Table 1). This research also provides new lighting patterns using nature-based fractal geometry to investigate the quality of life indicators and improve them in the Tabriz City.

Table 1. Using Fractal Geometry Approach to Design Lighting (Case Studies of Buildings Designed and Constructed in Tehran)

			
Building name: Sa'adat Abad Fractal feature: Repetition/ self-similar/ symmetry	Building name: Saba Fractal features: Repetition/ symmetry/micro-level proportions	Building name: Ajorpoush Fractal features: Repetition/ self-similar/symmetry/micro-level proportions	Building name: Chehel Gereh Fractal features: Repetition/ self-similar/dispersion

A review of both Farsi and English research on the subject matter led to a rich repertoire of articles, books, and doctoral dissertations, which are listed in the following Table 2.

Table 2. Some of the Research Conducted on the Subject Matter

Authors (year)	Research Title	Major Themes	Conclusion
Sameh & Akrami (2016)	Analyzing the development of "Quality of Life": thinking on architecture and urban development	- An introduction to the concept of "Quality of Life." - Factors affecting the quality of life thinking in architecture and urban development	- Providing three major approaches based on research about "Quality of Life," including 1. Structural and non-structural; 2. Residents' perceptual and value systems, and 3. Man-environment interaction - The interdependence of the interactive human-environment effects on the interpretation of both subjective and objective factors of the existing situation
Fakhri & Azimi (2018)	An explanation of the concept of quality of life: spatial attachment as the factor affecting the quality of the human-made environment	- Concept of quality of life in the behavioral environment - Subjective and objective dimensions of the quality of life - Architectural quality - Spatial attachment	- Effects of the sense of satisfaction on the subjective and objective aspects of quality of life - The increase of spatial attachment with a sense of belonging and continued presence through better designs
Arditi & Zanchi (2019)	Health status and quality of life of patients with diabetes in Switzerland	- Health and quality of life (QoL) status (dependent variables) - Characteristics of the participants, health, and QoL status	- Quality of life is one's perception of his situation in life in the context of cultural systems - Quality of life is associated with the individual's objectives, expectations, regulations, and attitudes
Madani et al. (2017)	Evaluation of Chahar Bagh St. walls and providing of a relevant pattern using fractal geometry	- Fractal geometry - Providing a design pattern - Conversion of a fractal dimension to a geometric structure	- Use of desirable fractals at the Isfahan's Chahar Bagh St. walls - Formulation of a formative and geometric language of the fractal structures
Behzadpour, Gorji, & Soheili (2017)	A review of the natural role on the sense of residents' happiness in residential complexes	- Factors affecting sense of liveliness - Use of nature-based design for social interaction of the users in residential complexes	- The increase of social interactions in residential complexes with increasing the level of using nature - The element of nature as a factor affecting the urban design to promote a sense of liveliness environmental comfort and reduce modernity-induced mechanization
Lyons & Dupre (2019)	Visual discomfort and evaluation of light in office settings	- Visual discomfort and ways to evaluate it - Light-induced physiological responses	- Effects of light on the human's welfare, comfort, and visual behavior - Negative effects on the visual perception from weak lighting design and visual discomfort
Taylor, Juliani, Bies, & Boydstone (2017)	Mental fractal effects on environmentalist architecture	- Fractal in art and architecture - Effects of a fractal on mental health	- Complicated systems theory (fractal geometry) as a perspective affecting the architectural sciences - Fractal model of human's visual system which indicates adaptability with one's visual characteristics and relative easiness for processing
Sereno & Taylor (2019)	Aesthetic responses to accurate fractals taken from physical complexity	- A review of symmetrically fractal dimensions and shapes in visual priorities - Linear fractal techniques along with symmetry and refraction	- Fractal dimensions, return, symmetry, and number of fragments in the patterns compose the factors which affect the complexities and preferential rules in the fractals and may extend to other pattress

4. THEORETICAL BASICS

To investigate the effects of lighting patterns on the quality-of-life indicators of the residents, the literature on quality of life, lighting effects and patterns, and fractal geometry are investigated.

4.1. Quality of Life

Quality of life refers to the manner in which residents meet their life requirements based on physical housing characteristics (Tanaphoom, Bart, 2019, p. 35). Zanchi also considers it to be beyond illness or health and introduces it as one's perception of his situation in life within the context of cultural and valuation systems, which associates with his objectives, expectations, and attitudes (Arditi & Zanchi, 2019, p. 235). Quality of life involves mental dimensions including satisfaction, happiness, cheerfulness, legibility, sense of attachment, distress, anxiety, and security. It also refers to some motivational and comfort issues which involve not only mental dimensions but also environmental dimensions of such criteria as housing, self-care, vision and landscape, dimensions and access to services, and environmental security (Fakhri & Azimi, 2018) (Table 2). The indicators affecting the quality of life include socio-cultural factors such as privacy and association with neighbors, and realization of citizens' participation in life affairs such as environmental factors, which include prevention of air pollution and the sound and efficiency of the energy consumption (Ashrafi, Zeinab & Kohzadi, Umran, 2017). A theoretical literature review reveals that quality-of-life indicators are determined based on the measures investigating the lighting patterns, as shown in diagram 1.

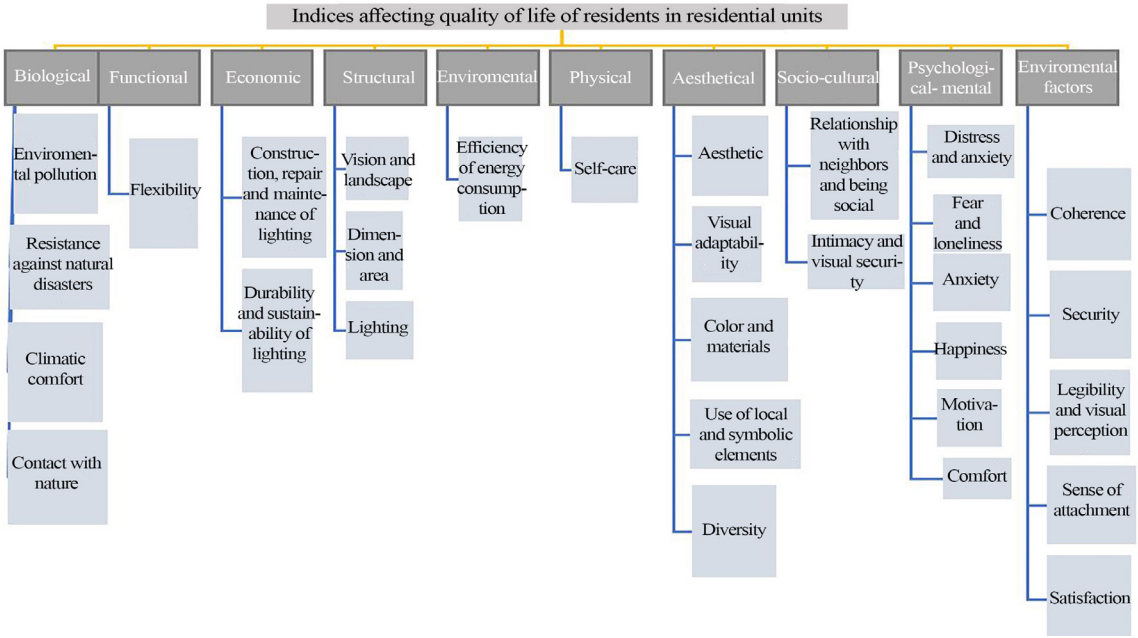


Fig. 1. Indicators Affecting the Quality of Life of Residents in Residential Units

Considering the quality of life and the effects of nature and light that contribute to man's quality of life in the architectural space, it is imperative to investigate the lighting patterns in light. This is because the basics of explaining the techniques used in girih tiles and the way lighting quality is used can be sought in its geometry and the creation of diverse lighting patterns.

4.2. Lighting Patterns

Visual comfort depends on the physiology of human's eyes, physical amounts of the description of light amount, light distribution in the space as well as a propagation of a spectrum of the light source, which is usually achieved through the evaluation of a set of factors regulating the relationship between human needs and light environments including the amount of light, uniformity of light, quality of light and prediction of light reflection (Michael & Heracleous, 2016, p. 3). Levels of lighting, light color, shadows, and alternating lighting-darkness, which affect the man's feelings and perceptions of the space, also regulate his behavior and life pace (Divandi & Bozorg-Ghomi, 2018). Consciously or unconsciously, man seeks order within disorder and tends to find patterns [1] that are made meaningful based on his perception of the world; these patterns also involve desirable relationships between parts and the whole. Pattern recognition is significant because it can help us better perceive the world around us and create transforming processes of the landscape sensory and aesthetical reactions via extending them in a descriptive-analytical context and establishing an

interrelationship between the patterns. Patterns are classified into two natural and man-made categories; the former refers to natural patterns, and the latter refers to those inspired by nature and constructed by humans (Bell, 2015). As mentioned by Stevens in the book "Patterns in nature," the fundamental patterns in nature are classified into the spiral, meander, explosion, and branching [2]. Branching is made of the connected moving points, an example of which is the tree pattern (Fig. 2).

Fig. 2. Fractal Tree Pattern with Branching Feature
(Bell, 2015)

One of the defining features of fractal dimensions from the view of perspective perception is that it is a perceived dimension, i.e., the manner in which human's eye looks at an object. It seems to be an ideal instrument for the aesthetical judgment of the patterns. Furthermore, because nature creates most of its patterns out of fractal geometry, fractal dimensions can be used to identify the natural quality of the patterns (Flynn et al., 2013). The major fractal geometry property describes the objects or patterns that are self-similar at scales of different enlargement or at symmetrically scaled levels, which help provide a complete perception of the world structure and more creativity for the designers. For this, fractal geometry will be measured for lighting and the manner in which light is received (Fig. 3).

4.3. Fractal Geometry

Fractal [3], in mathematics, is any of a class of complex geometric shapes that commonly have "fractional dimension," a concept first introduced by the mathematician Felix Hausdorff in 1918. Fractals are distinct from the simple figures of classical, or Euclidean, geometry—the square, the circle, the sphere, etc. Fractal [3] is a modern geometry that man has unconsciously used over the years via modeling nature and constructing an artificial environment. Fractal geometry is a kind of natural geometry that indicates its latent and complex order. Figures 4 and 5 illustrate the presence of fractals in nature, the adoption of nature and its geometric calculations, and the way they are used in architecture and in decorating the buildings. Artificial fractal reveals that the use of fractal has possibly aimed at reducing stress throughout history, such as the Gothic Church (twelfth era), the Eifel Tower in Paris (1889), and the Palmer's House (1950) by Lloyd Wright, among others. In architecture, buildings aim to create environments associated with physiological responses to visual stimuli. Fractals are seen as one of the distinct features of our daily visual experiences for their effects on cultures across the world and their widespread presence in nature (Taylor, 2006).

Fig. 3. Light as an Effective Factor on the Quality of Life in Residential Units
(Khat Me'mar website, 2019)

Fig. 4. An Example of Fractal Shapes in Nature
(https://bigbangpage.com)

Fig. 5. An Example of Fractal Shapes Used in Iranian Architecture
Imam Mosque of Isfahan

Fractals are infinitely complex patterns that are self-similar across different scales. The human's aesthetical response to the accurate fractal complexities is investigated by manipulating the fractal dimensions, symmetry, recursion, and the number of the fragments (Ardalan, 2015, p. 51). Compared to non-fractal light patterns, fractal light patterns increase comfort and emotions (Abushi et al., 2019) (Fig. 6).

Fig. 6. Light Radiation Patterns Through the Trees
(Abushi et al., 2019)

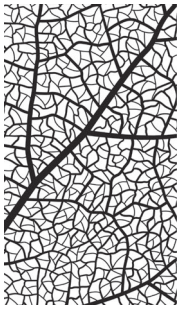
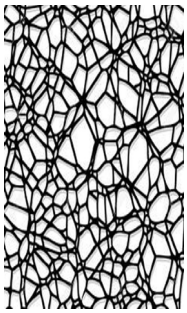
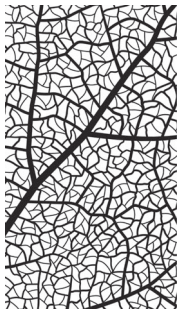
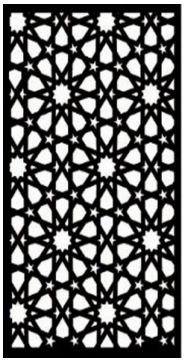
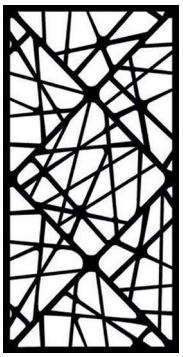
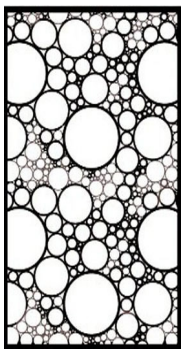
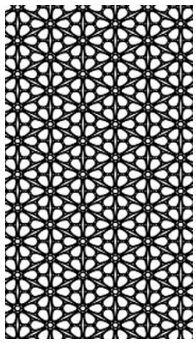
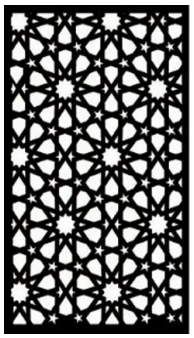
5. RESEARCH METHODOLOGY

Consistent with the objectives, the research uses rationalistic reasoning (inductive and deductive) and a scientific method. The research also addresses psychological and quality of life indicators among the users and employs a questionnaire, sums up the views, tests the hypotheses, and measures the correlations between the variables to provide findings that underlie the research. Qualitative and quantitative data are used to analyze the sample size in preliminary and final tests. The sample size is based on the purposeful sampling method, and the views of the people already familiar with the subject matter are used. Because the studied variables are based on qualitative types (ordinal scales), and the population size is unlimited, the Cochran formula [4] is used. This rate is 29.88 for the statistical population, which totals 30 people.

Data are gathered by the Delphi and library methods. In the Delphi method, the views of prominent academic professors who are experienced in the research subject are used. Also, research on the nature of fractal geometry and geometric features of the nodes in the Islamic decorations are used. Moreover, digital software in architecture is applied. Articles and M.A. and Ph.D. theses on the nature of light and lighting patterns in the Islamic architecture of mosques are also used. A questionnaire is administered to ask peoples' views of the residential units because they are seen as the users of the nature-based light. The library method also involves a review of the books, articles, credible scientific journals, relevant theses, and research taken from domestic and foreign websites.

To evaluate the new lighting patterns in the city of Tabriz, a number of the images and designs that made use of fractal geometry are gathered. Then, because the measurement components of the present research initially involved a qualitative test and pertained to quality-of-life components, the patterns derived from another classification are classified into two natural and unnatural categories by considering the nature of the fractal geometry and similar and different features of it as well as proportional and mathematical dimensions. This output of each category can thus provide more accurate results. Next, the Delphi method and the views of some academic professors are used to select 16 patterns and then eight patterns, and eventually two patterns. The visual test and the questionnaire administration selected two patterns out of 8 (Table 3).

Table 3. Selection of Patterns Based on Natural and Unnatural Fractal Geometry for Lighting

Fractal Group	Pattern 1	2	3	4	Selected
Natural					
Unnatural					

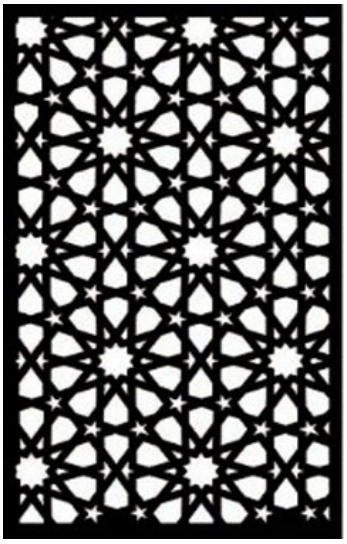
The selected patterns were installed on the window facing the sunlight in the southern direction of a fixed room with residential use (Fig. 7); also, necessary explanations were given to the respondents to provide more accurate responses. The explanations pertained to lighting patterns Nos. 1 and 2, which were covered by composite materials at a distance of 10 cm from each other, and installed on the back of the window using the accordion method, which, consistent with figure 8, could be compressed together, if necessary.

At 11 a.m., the questionnaires were evaluated by considering the sample size of 30 people. The sample answered the natural fractal lighting pattern questionnaire (Fig. 9) and the unnatural fractal lighting pattern questionnaire each once (Fig. 10). Attempts were made to only display the intended pattern by the window shade when the visual test was being administered. This removed any disturbances of the user's visual perception and could only be affected by the intended shape. It was noted that the questionnaire items were consistent with every component of the users' quality of life and composed of relevant indicators and measures which, one item was considered for each measure and its sub-measure, resulting in 30 items. Because the researcher developed the questionnaire, he used the nominal method and corrected his items by taking benefit of the academic professors' views.

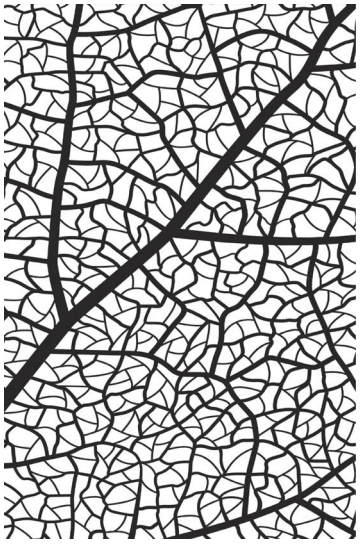
Fig. 7. Administering the Questionnaire test Based on Natural and Unnatural Fractal Light Patterns

Fig. 8. Selected Patterns and Execution of the Lighting Patterns Using the Execution Technique and its Materials

Execution Manner



No. 1 Pattern: Girih Tiles



No. 2 Pattern: Tree

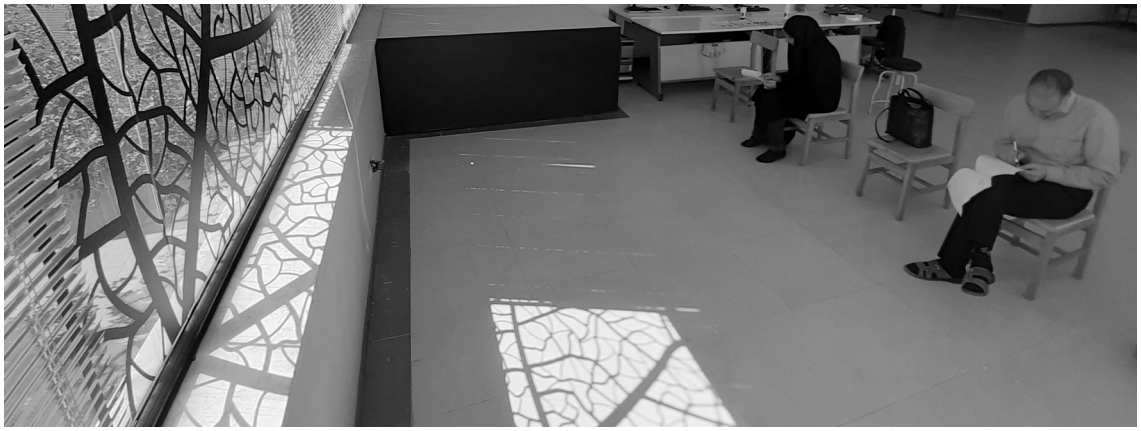


Fig. 9. Administering the Questionnaire Test Using the Natural Fractal Lighting Pattern

Fig. 10. Administering the Questionnaire Test Using the Unnatural Fractal Lighting Pattern

Data were analyzed by the SPSS statistical analysis and Excel program while fractal geometric shaped were classified by the Explorer Fractal software. A questionnaire method was used as a statistical method to analyze the data; Cronbach's alpha was also used to provide descriptive data as given in the relevant table. Then, inferential statistics of the lighting patterns were analyzed and compared, which led to answering the research items. The questionnaire assigned a relevant item for each major quality of life indicator and evaluated them using a Likert scale. This research sought to evaluate and identify the lighting patterns of fractal

geometry as independent variables and the quality of life of its users as a dependent variable (Fig. 11).

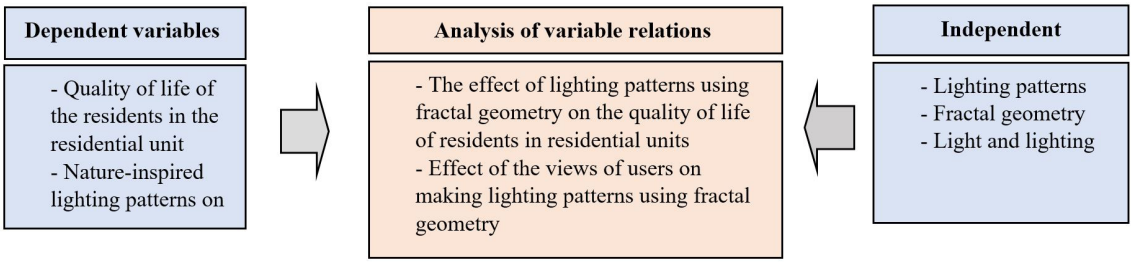


Fig. 11. Research Variables: Independent Variable and Dependent Variable

As suggested by the above theoretical literature, residents' views about lighting patterns were evaluated by a questionnaire. In the conclusion section, they were described and analyzed, which ultimately led to the research output, the conceptual model illustrated by figure 12.

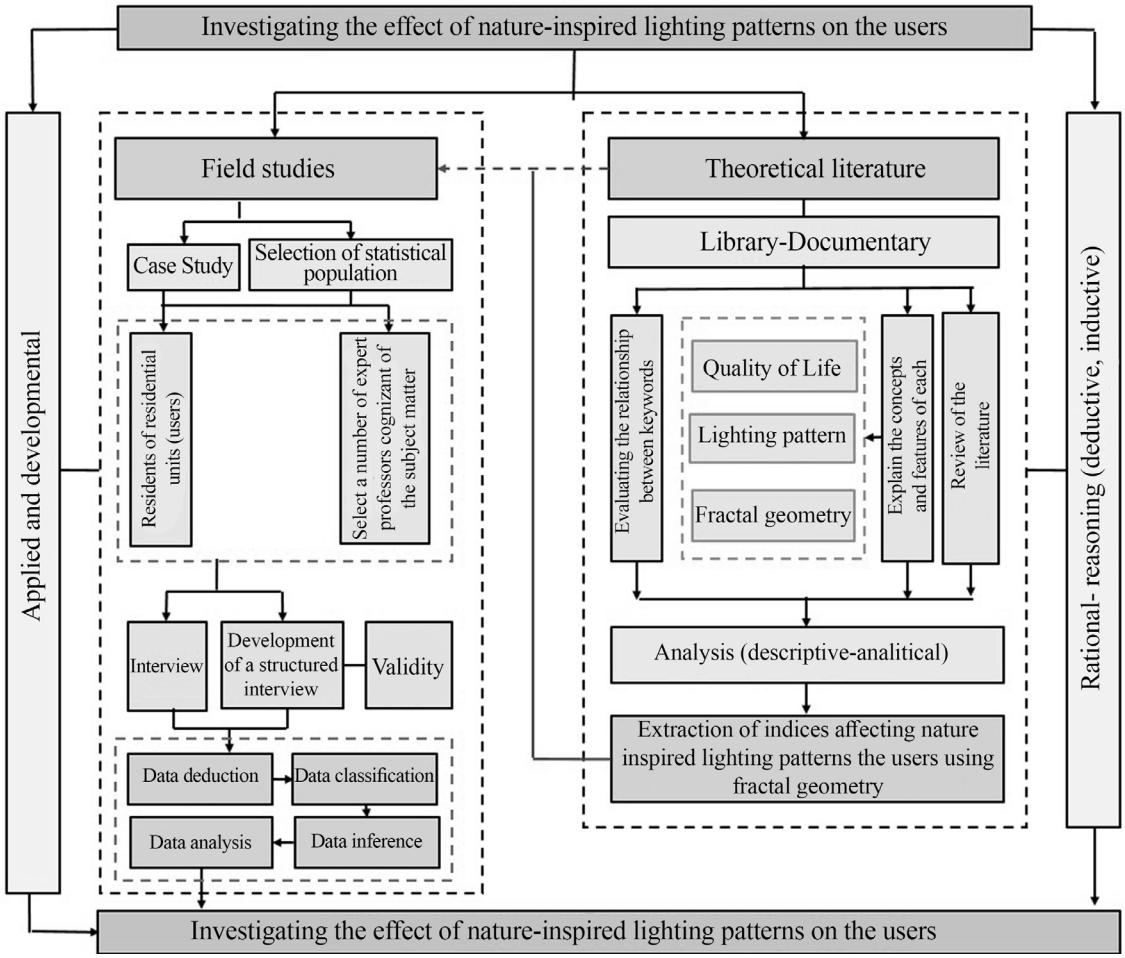


Fig. 12. Conceptual Model of Research

To investigate the quantitative content validity, the Content Validity Ratio (CVR) and Content Validity Index (CVI) coefficients were used [5]. As for the research reliability, the internal consistency suggested that the total Cronbach's alpha of No. 1 pattern and No. 2 pattern were 0.852 and 0.849, respectively. Also, all questionnaire domains enjoyed standard reliability coefficients of 0.80 to 0.91. As noted, the outcome of the validity estimates showed that the alpha coefficient of each of the components was acceptable.

6. RESEARCH FINDINGS

Generally, considering the statistical population and

sample size, research findings were analyzed by the relevant quality of life measures.

6.1. Descriptive Data

Descriptive statistics consisted of data from testing fractal lighting patterns (natural and unnatural) installed in a lab setting in the Tabriz City. In the meantime, the descriptive statistics included a questionnaire and tables and diagrams of gender, education, and age (diagram 4) using the Likert scale.

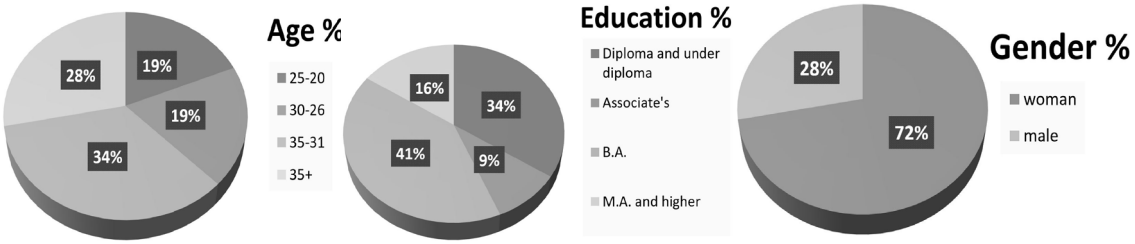
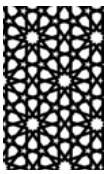
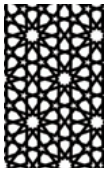
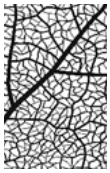


Fig. 13. Frequency of Respondents' Gender, Educational Status, and Age

The Likert scale-based mean scores for the natural and unnatural patterns, respectively, as given in Table 4. The total test index scores were higher than those of the mean of variables. Relative satisfaction was also noted in most cases.

Table 4. Evaluation of Residents' Views about Fractal Lighting Models Using Quality of Life Indices based on Likert Scale

Quality of Life Indicators	Sub-Measure of Quality of Life	 Pattern No. 1 Unnatural Fractal Pattern						 Pattern No. 2 Unnatural Fractal Pattern					
		Scores					Acquired Score/Total Indicator Score	Scores					Acquired Score/Total Indicator Score
		1	2	3	4	5		1	2	3	4	5	
Mental and Psychological Factors	Anxiety and distress					*	25 / 30				*		24 / 30
	Fear and loneliness				*						*		
	Depression				*						*		
	Liveliness and happiness				*						*		
	Motivation for daily activities				*						*		
	Comfort				*						*		
Environmental Factors	Lighting security				*		20 / 25				*		20 / 25
	Light continuity				*						*		
	Legibility and visual perception of the space through proper lighting				*						*		
	Sense of attachment				*						*		
	Peace				*						*		
Biological Factors	Lighting patterns-involved environmental pollution				*		16 / 20				*		16 / 20
	Resistance against lighting-related natural disasters				*						*		
	Climate comfort				*						*		
	Contact with nature				*						*		

Quality of Life Indicators	Sub-Measure of Quality of Life	 Pattern No. 1 Unnatural Fractal Pattern						 Pattern No. 2 Unnatural Fractal Pattern					
		Scores					Acquired Score/Total Indicator Score	Scores					Acquired Score/Total Indicator Score
		1	2	3	4	5		1	2	3	4	5	
Aesthetic Factors	Lighting aesthetics				*		20/25				*		20/25
	Light and lighting diversity				*						*		
	Visual adaptability with the type of incoming lights				*						*		
	Lighting color and materials				*						*		
	Use of native and symbolic elements for lighting				*						*		
Social-Cultural	Communication with neighbors and being social with the type of lighting			*			7/10				*		8/10
	Visual privacy and security with the type of lighting				*						*		
Functional	Flexibility to receive light				*		4/5				*		4/5
Economic	Durability and stability of the lighting				*						*		
	Cost of construction, maintenance of lighting				*		8/10				*		8/10
Structural	The proportion of dimensions and area of lighting				*						*		
	Lighting vision and landscape				*		12/15				*		12/15
	Lighting illumination				*						*		
Environmental	Energy efficiency from lighting				*		4/5				*		4/5
Physical	Self-care against lighting					*	5/5				*		4/5
Mean total scores acquired/ total indicator scores		Pattern No. 1 Unnatural fractal pattern					121/150	Pattern No. 2 Unnatural fractal pattern					120/150
Final evaluation							Positive effects						Positive effects

The total scores of quality-of-life indicators in each of the fractal lighting patterns (varying from 30 to 150) fell into three categories of positive (1111-150), neutral (71-110), and negative (30-70) effects. Scores 121 and 120 assigned to lighting patterns Nos. 1 and 2 were evaluated positively.

6.2. Inferential Data

In this section, the mean difference test of the quality-of-life indicators and the variance test were administered to measure the gender status, education, and age status, respectively (Table 5).

To test the hypothesis, the mean test of the population or T-test was used consistent with the central limit theorem. The test showed the significance level of the quality-of-life indicators to be less than 0.05. Its mean showed a significant difference with the numerical mean of 2.5, suggesting that the significance level of 0.000 reveals a significant relationship between the indicators and the fractal lighting pattern.

To calculate the mean difference of the indicators, the mean difference test was used consistent with the people's gender because gender is a two-state nominal variable while the indicators are interval variables. For example, as given by the table, as for the "mental and psychological" indicator, the T-test in lighting patterns Nos. 1 and 2 were t=2.348 and t=0.846, at significance levels of 0.026 0.405, respectively.

Data analysis of gender reveals that the said indicator was different in pattern 1, but not different in pattern 2, with women regarding the effects of "mental and psychological factors" on the quality of life to be greater in pattern one than in pattern 2, as compared to men.

The variance analysis test calculated the mean difference of education and age. As given by Table 5 and consistent with the one-way variance analysis of education, the indicator of "mental and psychological factors" in patterns 1 and 2 were F=2.219 and F=1.185, at significance levels of 0.110 0.0169, respectively. Thus, one would say that the "mental and psychological factors" indicator was not different among educational groups.

Also, consistent with the one-way variance analysis test of age, the indicator of "mental and psychological factors" in patterns 1 and 2 were F=0.725 and F=1.094, at significance levels of 0.546 and 0.369, respectively. Thus, one would say that the "mental and psychological faces" indicator was not different among age groups.

Pearson correlation coefficient is used to investigate the relationship between quality-of-life and its indicators at an interval level. The table below illustrates the significance level obtained between the quality of life and "mental and psychological factors" to be at 0.000. Pearson correlation (Pearson's r) coefficients of the two lighting patterns 1 and 2 are 0.857 and 0.792, respectively, indicating a consistently higher relationship between the two variables. The other indicators are evaluated this way.

Table 5. Pearson Difference and Coefficient test with Significance Level for Quality-of-Life Indicators and Descriptive Data

Indicators		Gender		Education		Age		The Relationship between Quality of life and Indicators	
		T-test	Sig. level	F value	Sig. level	F value	Sig. level	Correlation coefficient (Pearson's r)	Sig. level
Psychological Factors	Pattern 1	2.348	0.026	2.219	0.110	0.725	0.546	0.857	0.000
	Pattern 2	0.846	0.405	1.815	0.169	1.094	0.369	0.792	0.000
Environmental Factors	Pattern 1	2.130	0.042	1.629	0.207	0.887	0.461	0.914	0.000
	Pattern 2	0.247	0.807	2.425	0.088	1.067	0.380	0.869	0.000
Biological Factors	Pattern 1	0.514	0.611	1.881	0.158	1.882	0.157	0.715	0.000
	Pattern 2	1.759	0.089	0.541	0.659	2.343	0.096	0.668	0.000
Aesthetic Factors	Pattern 1	1.810	0.081	3.631	0.026	1.502	0.237	0.860	0.000
	Pattern 2	-0.341	0.736	2.119	0.122	1.143	0.350	0.831	0.000
Social and Cultural Factors	Pattern 1	1.791	0.084	0.740	0.538	0.649	0.591	0.733	0.000
	Pattern 2	1.975	0.058	0.101	0.959	0.587	0.629	0.660	0.000
Functional Factors	Pattern 1	1.617	0.117	0.232	0.873	0.582	0.632	0.662	0.000
	Pattern 2	2.339	0.027	1.723	0.187	0.872	0.468	0.467	0.009
Economic Factors	Pattern 1	0.555	0.584	0.080	0.970	0.005	1.000	0.417	0.000
	Pattern 2	0.549	0.588	0.955	0.428	0.416	0.743	0.643	0.000
Structural Factors	Pattern 1	1.986	0.057	0.752	0.531	0.722	0.548	0.831	0.022
	Pattern 2	0.142	0.888	1.575	0.219	0.527	0.668	0.765	0.000
Environmental Factors	Pattern 1	1.933	0.063	1.699	0.192	0.803	0.504	0.548	0.002
	Pattern 2	0.725	0.474	2.665	0.69	0.793	0.509	0.495	0.005
Physical Factors	Pattern 1	0.594	0.540	1.566	0.222	1.585	0.217	0.677	0.000
	Pattern 2	-0.170	0.866	3.677	0.025	1.413	0.261	0.692	0.000

7. CONCLUSION

As for the conclusion section, which includes the research outcomes, various dimensions of the users' quality of life were investigated by some evaluation measures as research measurement variables that can help focus on research objectives and responses. To answer the research question: What effects does fractal geometry-based lighting patterns used in residential architecture affect the users' quality of life? One needs to evaluate and compare the findings. Data collected for each lighting pattern was investigated, and mean scores were assigned for each of the measures, as shown in Figure 14.

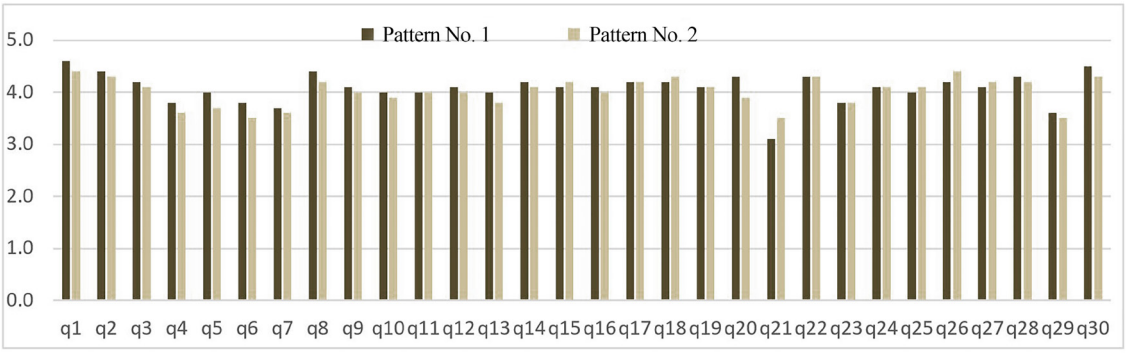


Fig. 14. Comparison of Mean Scores of the Measures for Patterns 1 and 2

The mean scores in all indicators and relevant measures are similar or very close to each other with little difference or percentage, which indicates the convergence of the research concept and similarity of the patterns. The scores obtained for all the indicators are above the mean of 2.5, suggesting a relative satisfaction rate (Fig. 15).

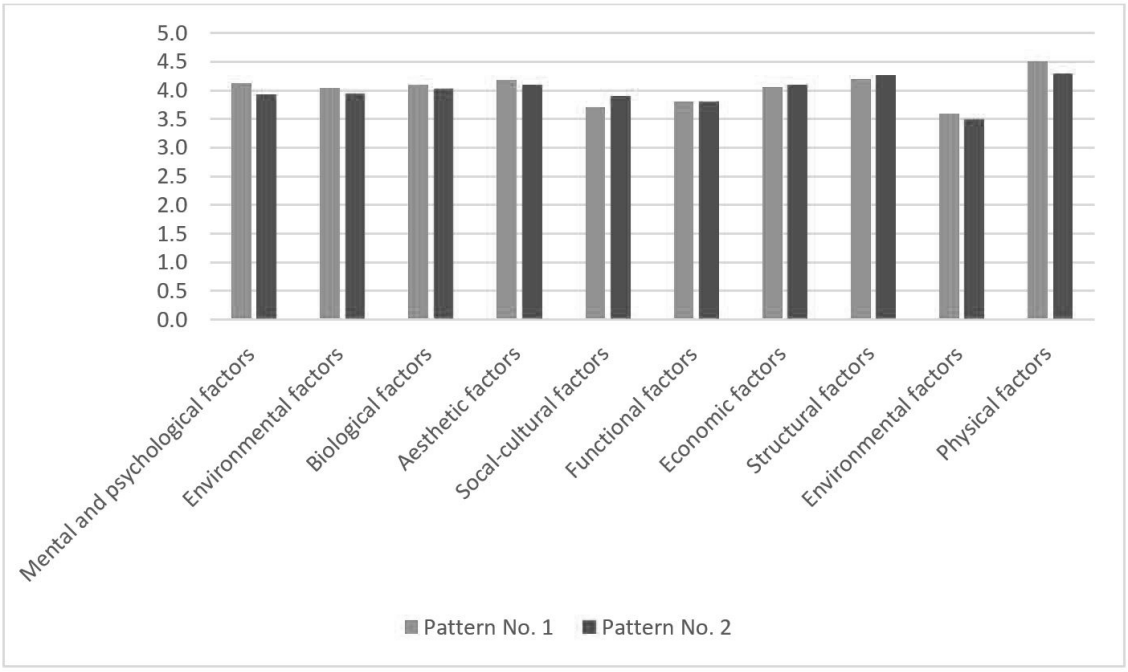


Fig 15: Comparison of Mean Scores of Patterns No. 1 and 2

The above diagram shows that physical, structural, and aesthetic indicators elicit more satisfaction than other factors. Here, as for the mental and psychological, biological, and economic factors, the respondents were assigned a score of 4, which indicates a desirable satisfaction. Moreover, environmental, functional, and social-cultural indicators elicited a relative satisfaction rate. According to diagrams 5 and 6, measures of distress and anxiety and fear and loneliness in the mental and psychological indicator, a measure of light continuity in the environmental indicator, measures of privacy and visual security with the type of

lighting in the social-cultural indicator, a measure of lighting illumination in the structural indicator, and measure of self-care against appropriate lighting in the physical indicator were assigned greater scores which suggest the greater impact of lighting patterns on the user's quality of life.

The sub-measure "communication with neighbors and sociability" in the "social-cultural" indicator had a mean score of 3, which, calculating the positive decimal number, was slightly affected by the normal mean of 2.5, suggesting an insignificant coefficient. This indicates it contrasts the other sub-measure of the same indicator; however, since it [communication with neighbors and sociability] achieves satisfaction in the sub-measure of "privacy," which itself enjoys relative satisfaction, the impacts of the residents' satisfaction will be reduced, which implies the validity of the satisfaction and improved quality of life, and finally verification of research course dimensions.

In sum, research findings, theoretical literature, and nature of the fractal geometry, as well as data from the diagrams which evaluated the quality-of-life indicators of the users regarding the lighting patterns, revealed that nature-based fractal geometric lighting patterns used in contemporary residential unit's architecture had a positive effect on the quality of life and could improve it. In the meantime, it was found that fractal geometry-based lighting patterns could be directly associated with quality-of-life components. One can also state that novelty, diversity, difference, and creativity to employ naturalistic patterns in intended lighting patterns and producing a new mindset in the users through testing those patterns can lead to a new visual and spatial quality. Thus, acquainting the users with the objectivity of the patterns and establishing a subjective link with the users' perceptions through the tests conducted would explain the spatial quality and provide solutions to transforming lighting pattern designs. This can, by itself, develop the users' perception of the space. It is concluded that the weaknesses of the research approach warrant developing strategies to both provide ways to eliminate the problems with the lighting patterns and maintain their positive dimensions.

END NOTE

1. Dictionaries have provided various definitions of pattern as follow:
   - Order of arrangement of similarly repetitive parts of decorative motifs - A decorative work
   - A style
   - A sample or scheme used as a guide to construct the objects
   - Common route of a motion or activity
   - Valuable model for imitation
   - A sample representing the whole
2. Spiral is highly uniform and fully occupies a two-dimensional space that is short in length and highly indirect. Meander is not so uniform and can be irregular and chaotic; it fully occupies the space and is relatively direct. The explosion is uniform in terms of the fixed angle between the lines and cannot occupy the space with equal density, denser, and highly direct in the center to the surrounding.
3. Fractal means fracture, rupture, and refraction. The word is taken from Latin words of Fractus and Fractum meaning broken. The following provides definitions for fractal structures: 1. The structural and geometric structures have an irregular and fragmented form at all scales and measurement states; 2. In Mathematics, it refers to studying complex shapes with self-similar characteristics; 3. Fractals are complex and irregular shapes whose complexity and irregularity are similar at different scales; 4. Fractals refer to shapes that, unlike Euclidian geometric shapes, are, by no means, regular. These shapes are wholly irregular, whose irregularity is the same across all scales. Also, their irregularity is geometrically repeated in different scales.
4. Cochran formula:

$$n = \frac{Z^2_{\frac{\alpha}{2}} * P(1-P)}{\varepsilon^2}$$

Here, alpha represents the level of confidence which is usually set at 0.05, with the denominator representing the accuracy intended by the researcher, set at 0.15. The P-value represents the success ratio, set at 0.5 for the research without the literature (Cochran, W.G. 1977).

5. For the sub-measures of each measure, degrees 1 to 5 (very low, low, medium, high, and very high) were assigned. Each table assigns 1 for the number of items and 5 for the number of items. The obtained number divided by the fraction of this set leads to three qualities of positive effects, neutral effects, and negative effects. The total score of the tables is also calculated from the number of the marked options by the total item weight (Salimi et al. 2008, pp. 55-60).
6. To determine CVR, experts were required to investigate each item by a three-part spectrum of "necessary," "useful but not necessary," and "not necessary." The responses were then calculated by the following equation:

$$Cvr = \frac{n_{E-\frac{N}{2}}}{\frac{N}{2}}$$

In this connection, the questionnaire was, at the first stage, given out to 20 experts who were cognizant of the subject matter to comment on it, and the CVR was examined for every item. Thus, the items with CVRs greater than 0.42 were held, and those with CVRs lower than that were reviewed and corrected. Upon revision, the experts rechecked the items to get to the quorum intended (Hajizadeh & Asghari, 2011). This method also helped calculate every item of the questionnaire. Later, CVI was determined for the items. A review of each item with irrelevant options must be seriously revisited, with relevant options requiring revision and completely relevant required to be responded to by the experts. The summation of the scores for each item that acquired "relevant but required revision" and "completely relevant" was divided by 20 (sum of the experts) to calculate the CIV of each item. If the score gained was higher than 0.79, the content validity could be confirmed. Otherwise, the items would be revisited and rechecked or completely removed, which confirmed the content validity of the questionnaire.

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