NOCTURNAL ARCHITECTURE OF BUILDINGS: INTERACTION OF EXTERIOR LIGHTING AND VISUAL BEAUTY

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ABSTRACT

Exterior lighting of buildings and their appearance at night is an important issue in architectural design. While the effect of natural daylight on the appearance of a building during the day is not completely under the control of the designer, exterior lighting at night is a design choice that can strongly effects the beauty of a building. The current research Delft University of Technology examined the effect of exterior lighting on the appearance of buildings at night using a questionnaire-based research methodology accompanied by in-depth statistical analysis of the results. The aspects addressed are how exterior lighting and its elements, such as luminous intensity (low vs. high intensity), colour diversity (single vs. multiple colour), lighting type (accent vs. uniform), and lighting state (harmonized vs. diversified), can affect the perception of the beauty of a building facade at night. The results confirm that exterior lighting of buildings substantially increases the beauty of the facades at night. The beauty of buildings increases with the use of single-colour accent lights in harmony with the façade and as the light intensity increases. On the other hand, the use of multi-colour or uniform lights with low intensity or not in harmony with the façade negatively impacts the beauty of the buildings. The results also indicate that light intensity and lighting types affect the perception of beauty of building facades more than colour diversity and lighting conditions.

Keywords: lighting, nocturnal architecture, visual beauty

1. INTRODUCTION

Nocturnal architecture is a concept that a viewer perceives from an architecture at night [1, 2]. As the trend for urbanization and night life in major cities increases, the need to design beautiful and eye-catching exterior lighting of building facades increases [3, 4, 5, 6]. It is evident that the aesthetic atmosphere of cities differs from day to night [7]. Consequently, the presentation of facades, objects, sculptures, and green spaces at night is tightly coupled with the type of lighting. Exterior lighting of monuments and buildings in cities is often designed to add to their attractiveness and provide a distinct identity for them [4, 8].

Because the façade of a building is the site at which it exposed and connected to the outside world, it has an effect on the surrounding area as well as on the people living nearby. The design of the exterior lighting of a building should be considered to be as important as the design of the façade of the building itself. Attractive lighting can make a unique impression about a building in the eye of the viewer and turn a normal building into a tourist attraction. On the other hand, unattractive exterior lighting could turn a beautiful monument to an eyesore at night.

The present study examined the effect of natural and artificial lighting on perceptions about the beauty of a building. Does a building seem more beautiful during the day in natural light or during the night in artificial lighting? The study examine how and to what extent the elements of artificial lighting,

light intensity, light colour, lighting method, and lighting mode, affect the perception of the beauty of the building.

The research methodology was based on field studies. A literature review on exterior lighting and its effect on the perception of beauty were first completed. A questionnaire was then designed based on the literature review to examine the effect of artificial and natural lighting on the appearance of buildings. The questionnaire was completed by groups of participants with different levels of visual literacy. The questionnaires offered photographs of the façades of a number of randomly selected buildings at night and in the day and participants were asked to rate the beauty of each building on a scale of 1 to 5. Participants were asked to rate the effect of different lighting elements on the appearance of the building. SPSS software is used to analyze the qualitative data. Semantic differentiation and bipolar adjectives were used to translate the qualitative data to quantitative values to evaluate the degree of influence of natural daylight and artificial exterior lighting on the perceived beauty of buildings and monuments.

Section 2 introduces light and its effect on human perception. Section 3 describes the research methodology and the design of the questionnaire. The analysis of the data is discussed in Section 4 and Section 5 presents the conclusions.

2. ROLE OF LIGHT IN HUMAN PERCEPTION

Light provides humans with perceptions of their surroundings. The effect of light cannot be touched, only perceived. Perceptions about an object in the mind derives from its appearance when exposed to light and individuals do not have exactly the same perception of one object [14].

Natural daylight creates the best perception of surroundings [8]. Sunlight can illuminate objects uniformly to make the light intensity on all surfaces be approximately the same. The effect is similar to the reflection of lighting from objects, which allows individuals to see them. Artificial lighting, on the other hand, can create different perceptions of an object. Artificial lighting could make part of an object seem more prominent than the other parts. The perception of that object when artificially lighted is likely different from the perception in natural daylight.

2.1. Aesthetics and effect of light on perception of beauty

The nature of lighting has both technical and artistic aspects. The artistic aspect of lighting plays a role in creating the perception of beauty. Aesthetics is a branch of philosophy that focuses on concepts such as beauty and ugliness. It is the ability to better understand objects and surroundings and can change perceptions about an object [12]. For centuries, philosophers and artists have looked at aesthetics as either natural or geometric (man-made). From the eighteenth century onward, philosophers have viewed aesthetics more from a psychological and individual perspective [18].

The aesthetic value of an object can be perceived when that object is exposed as an independent entity to the viewer and stimulates the viewer to perceive its beauty [17]. Light is a means for this and provides visual communication between the viewer and the surroundings [14]. It is light which makes objects visible to humans and enables them to perceive their environment and its elements. This is necessary to perceive the beauty of an object.

2.2. Interaction of colour and light

Similar to lighting, colours are significant in terms of aesthetics [20]. Colour is a component of visual perception that can stimulate emotional feelings [15]. The colour of light is one influence of lighting and can signify both white and coloured lights. Given the fact that lighting is a major factor in perception of surroundings, the colour of light can be used to influence this perception. The psychological effects of colour can change the conceptual specifications of an object and its elements to create relaxing and soothing conditions that accentuate beauty. The use of coloured light enables humans to see the modes and effects of objects and their elements without changing their structural forms [9].

2.3. Novel lighting technologies

Light is necessary when providing a visual perception of an environment to the observer. Lighting and architecture are inter-dependent. Light is like the spirit through which lighting design can make a building look alive [19]. Perception of the architecture of a building is often affected by

light, whether natural or artificial. Light en-hance a state or feature of architecture to provide it a unique identity in the surrounding space. Light is a tool with which to express the architecture of a building. Lighting that an architect considers fa-vourable for the building during the day and at night effects the atmosphere around the building and shapes the mental form of the building [7].

Lighting can serve to justify a space, a build-ing, or an element. It can be an endorsing or attenu-ating factor for the architectural form of a building [2]. Lighting is usually deployed to add beauty and identity to urban spaces. Vertical panels of building facades create a sense of perception in city squares and streets. Lighting the facades at night can change the atmosphere of the cities and create attractive site-scenes.

The morphological and operational characteris-tics of a building affect the lighting design for that building. Monuments with complex architecture and detailed ornamentation should be lighted such that the contrast between shadow and bright light makes visible both small and large elements and clearly highlights the ornamentation. The power of the light source should not overshadow some parts (especially details) and obscure them.

2.4. Nocturnal architecture

Exterior lighting of building façade expresses nocturnal architecture of the building [2,3]. Just as the architecture and application of buildings differ, their lighting design also differs. The lighting design depends on the architectural style of a building and its visual characteristics. Each building has its own identity that can be expressed using proper lighting design. Proper lighting should also put the building into harmony with its surroundings.

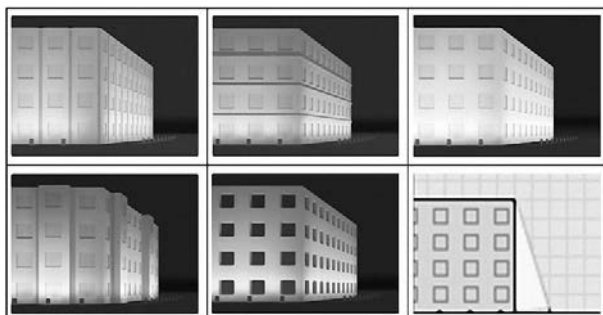Lighting of the façade of a building is affect-ed by the type of façade (rigid or glass) and the way light is projected onto the façade. The form of a façade is determined by the type and form of the material used and by the direction and colour of the light projected onto it. During the day, a façade looks different because of the change in the angle of light as well as the change in the spectrum of the light. At different moments of day, an observer will form different perceptions of the facade of the same building. At night, the façade will appear to be very different from its appearance during the day. Em-phasis on specific elements and parts of the façade and a change in the light colour, the elements of lighting design, changes the way the façade appears at night. There are three methods to consider when considering the type and detail of the façade in the design of lighting: uniform lighting of building sur-faces, emphasis on indicating elements of buildings (accent lighting), and creating attractiveness and visual variety [13].

In uniform lighting different levels of a façade are lighted uniformly. These levels can be hori-zontal, vertical, inclined, curved, or convex (e.g., domes). The level chosen for uniform lighting de-pends on the architecture and application of the building and its surroundings. Facades that are uni-formly lighted without differences in contrast at different levels seem flat and two-dimensional. To create such uniform lighting, the light must be projected from a distance with a wide angle. Such lighting makes the entire façade of the building vi-
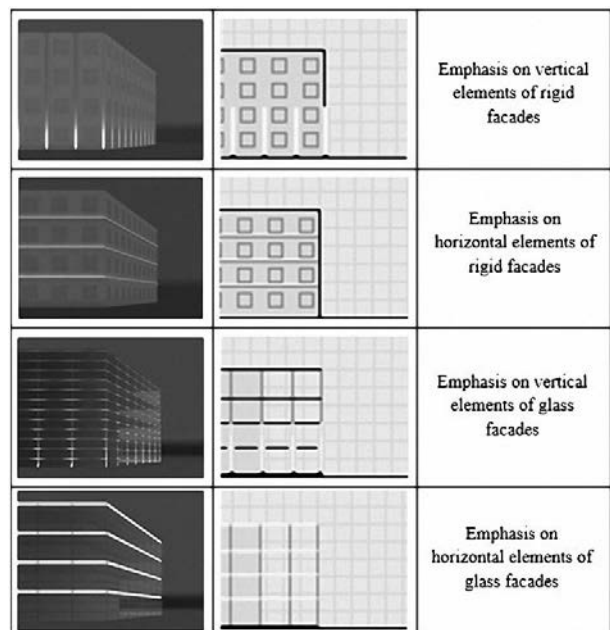

Fig. 1. Uniform lighting of facades [21]

Fig. 2. Accent lighting with emphasis on vertical and hori-zontal elements of rigid facades and glass facades [21]
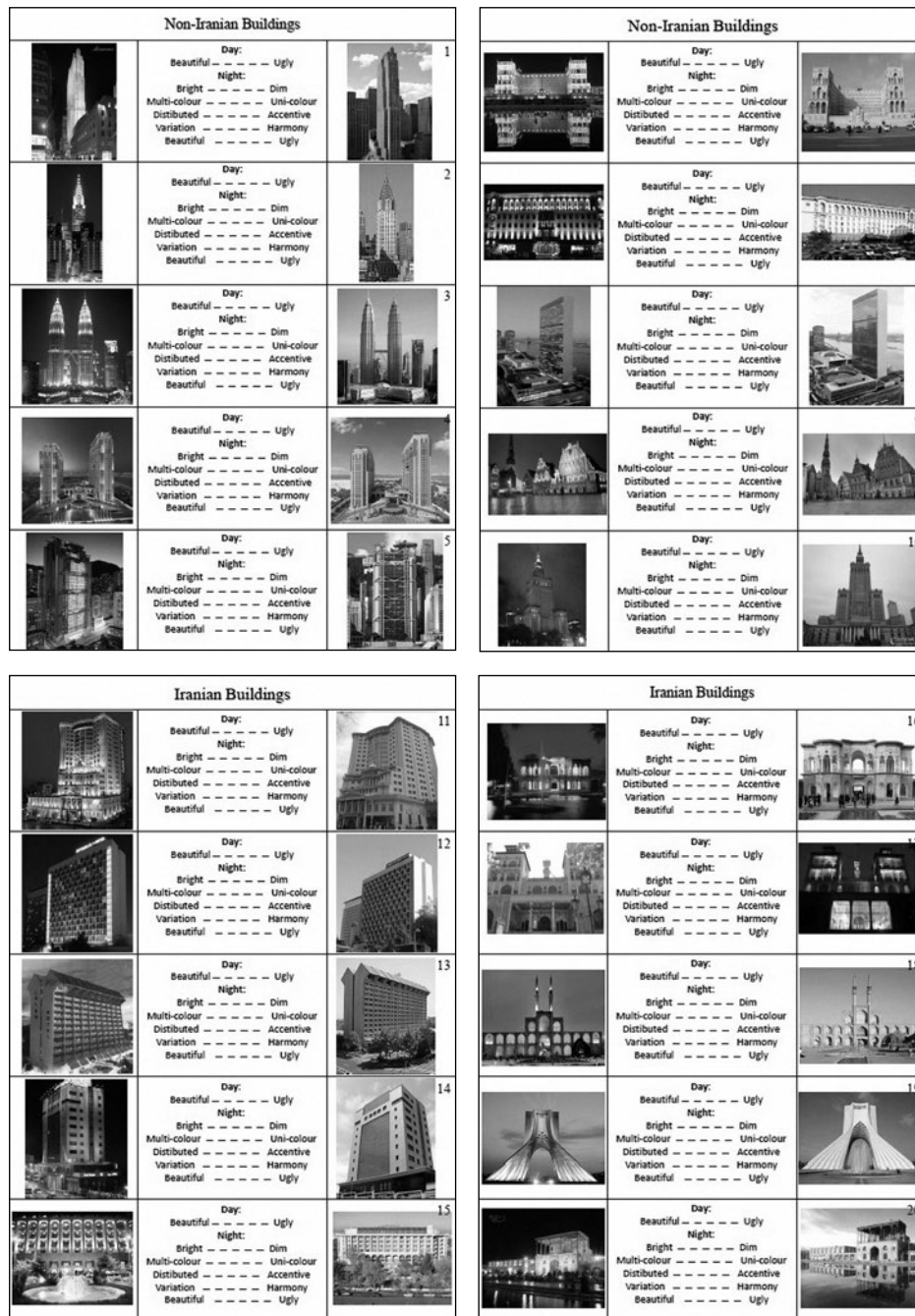
Fig. 3. The questionnaire

sible at night. Fig. 1 shows examples of uniform lighting of building facades.

Accent lighting emphasizes and highlights elements of a façade. These elements can be horizontal or vertical or specific elements of the architecture of the building such as its texture, material, structure, windows, or features such as a clock, sculpture, or ornament. To highlight an element, light is projected on that element from close up. This creates contrast between that element and the background (the rest of the façade). Another way of highlighting an element is to light the entire façade and highlight the borders of a specific element so that is stands out from the rest of the façade. Fig. **2** shows examples of accent lighting.

Attractiveness and visual variety are very important in nocturnal architecture and lighting of the considerable architectural buildings. Attractiveness and visual variety can be created by projecting colourful moving lights on the façade or by projecting patterns onto the façade. Colourful lighting, either in muted shades or primary colours, can make

Table 1. Buildings selected for study

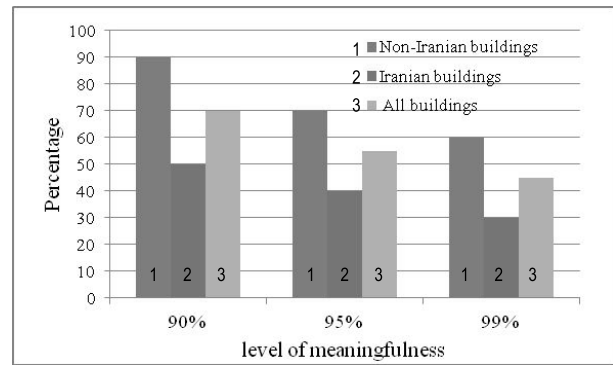| Building ID	Building Name	Location
1	General Electric Building	US
2	Chrysler Building	US
3	Petronas Towers	Malaysia
4	Habtoor Grand Beach Resort	UAE
5	John Hancock Tower	US
6	Government House	Azerbaijan
7	Sheraton Sofia Hotel	Balkans
8	United Nations building	US
9	House of the Blackheads	Latvia
10	Palace of Culture and Science	Poland
11	Ghasre Talaee Hotel	Iran
12	Esteghlal Hotel	Iran
13	Laleh Hotel	Iran
14	Abresan Shopping Mall	Iran
15	Setareh Hotel	Iran
16	Shazdeh Garden monument	Iran
17	Shamsolemareh Palace	Iran
18	Mir Chakhmagh Square	Iran
19	Azadi monument	Iran
20	Ali Qapu monument	Iran

Fig. 4. Percentage of buildings exhibiting a valid hypothesis for similarity of beauty by day and night vs. level of meaningfulness

engineering, and 25 ordinary individuals with different levels of education. The individuals in the groups will likely have different criteria for their perceptions of beauty because of the differences in education and field of study. This provides confidence about the validity of the results.

Participants were asked to rate the beauty of each building on a scale of 1 to 5 and to rate the effect of different lighting elements on the appearance of the building. SPSS software is used to analyze the collected qualitative data. We used semantic differentiation and bipolar adjectives to translate the qualitative data to quantitative values to evaluate the degree of influence of natural daylight and artificial exterior lighting on the perceived beauty of buildings and monuments.

3.1 Buildings selected for questionnaire

Twenty buildings were selected randomly as the objects of assessment in the questionnaire. These buildings are architectural monuments with different methods of lighting facade. Ten of these are in Iran and the rest are in other countries (Table 1).

These buildings are well-known due to architectural values or are monuments with different lighting designs. In addition to analyzing the effect of lighting on the beauty of the buildings at night, the effect of natural light was also examined. This allowed comparison of the effect of artificial lighting and natural daylight on the perception of beauty.

3.2. Design of questionnaire

The questionnaire featured photographs of buildings taken in daylight and at night. Participants were asked to rate the beauty of the each building

a façade more attractive. However, while the use of colourful lights (compared to white light) might increase attractiveness of a building, it may not necessarily increase the beauty of the façade [10].

3. RESEARCH METHODOLOGY

To study the effect of natural and artificial lighting on the perception of the beauty of buildings, a questionnaire was designed to perform field studies. The questionnaires offered photographs of the façades of 20 randomly selected buildings at night and in the day. This questionnaire was used to gather data from a statistical society of 50 individuals comprising three groups. The groups were 10 students of urban design, 15 students of architectural

under natural lighting and artificial lighting. The ratings were based on a five-level Likert scale (very low, low, average, high, and very high).

For nighttime artificial lighting, in addition to beauty, participants were asked to rate the elements of lighting design. These elements are the intensity, colours, prominence, and harmony of the lighting. All information was collected about the perceptions of beauty at night and in the daylight, as well as information about the effect of different elements of lighting design on the overall beauty of the building.

Fig. 3 shows the questionnaire used in the study.

4. ANALYSIS OF DATA AND STATISTICS

4.1. Validity of data

The validity of the questionnaire and the data gathered from participants was first determined using Cronbach's alpha. When Cronbach's alpha is greater than 0.7, it can be concluded that the questionnaire and data are valid. Otherwise, any conclusion drawn from the data will not be valid. The questionnaire examined six items for each building, making a total of 120 items (variables). SPSS was used to analyze the data. Cronbach's alpha was calculated to be 0.816, which indicates that the questionnaire and data collected was valid.

4.2. Beauty of façades by day and night

The Wilcoxon test was used to analyze the day and night beauty of buildings using the collected data. This is a statistical test suitable to study of the degree of correlation between variables. It can be used to determine the co-evolution factor of two variables. The absolute value of this coefficient specifies the extent to which variable are correlated and the sign denotes how the two variables are correlated. All test data should be of cardinal scale.

The validity of the hypothesis "the buildings are equally beautiful in daylight and at night" was first determined. The correctness of the hypothesis for each building was determined and the percentage of buildings for which it was valid was calculated.

The results of analysis are shown in Fig. 4 for different levels of meaningfulness. The level of meaningfulness specifies the confidence of the result. It was observed that at 99 %, more than half of the buildings were considered as beautiful at night as in the day. At 95 %, less than half of the buildings were perceived to have the same beauty. At 90 %, 30 % of buildings are considered of equal beauty. At all three levels, a small percentage of buildings have different levels of beauty during the day and night.

Fig. 5 shows the degree of similarity between perceptions of the beauty of each building in daylight and when illuminated at night. The average degree of similarity is provided for each group of buildings and for all buildings in Fig. 6. The results indicate that most participants felt that exterior lighting at night increased the beauty of most buildings over their appearance in daylight. This observation is also verified by Fig. 7, which shows the average points accrued for nighttime and daytime beauty of the individual buildings.

Fig. 8 indicates that artificial lighting at night made non-Iranian buildings appear more beautiful
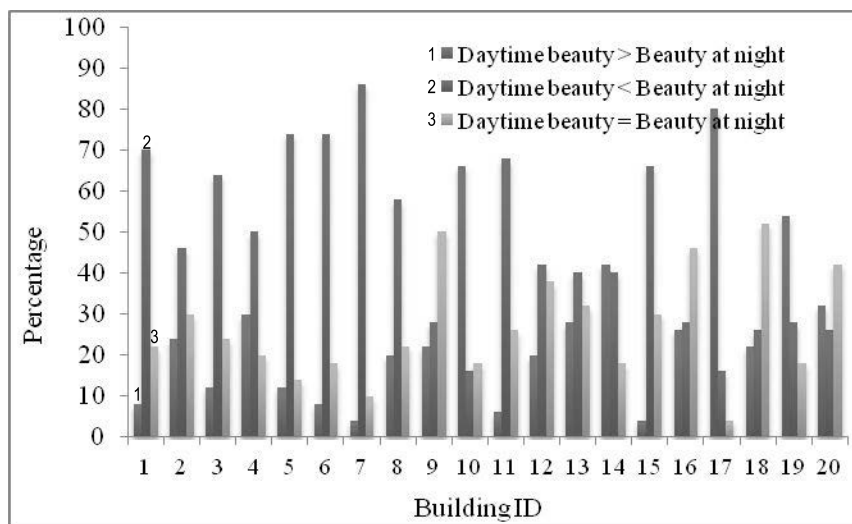

Fig. 5. Degree of similarity between perception of beauty of buildings in the daytime and at night
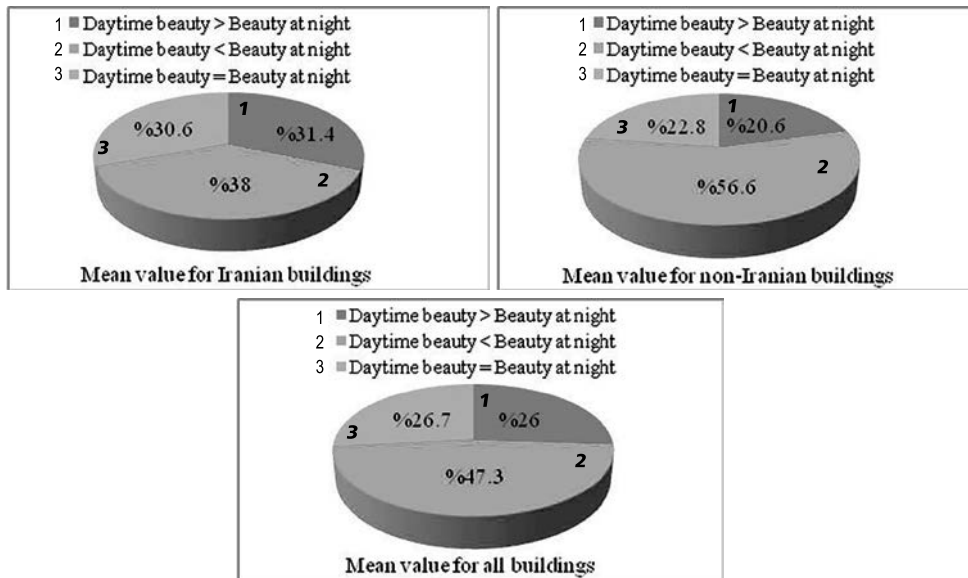
Fig. 6. Mean values for similarity of perceived beauty of buildings in the daytime and at night

than it did for Iranian buildings. Iranian buildings were perceived by the participants (which were all Iranian) to be more beautiful than non-Iranian buildings in natural daylight, but both groups were rated similarly for night lighting.

4.3. Effect of lighting elements on beauty of facades at night

At night, the beauty of a building is effecting by lighting elements. These elements are lighting intensity, colours used, accentuation, and the harmony of the lighting with the building. The results established a meaningful relation between the perception of beauty of buildings and each element; 90 % agreement was considered to denote a meaningful relationship.

The Spearman coefficient was used to determine the existence of such a relation for individual buildings. This coefficient shows the degree of correlation between two random variables. It takes a value between –1 and 1. When the Spearman coefficient for two variables equals 1, those two variables are directly related to each other. If one variable increases, the other will increase as well. When the coefficient takes a value of –1, it means that the two variables are inversely related; if one increases, the other will decrease. A value of zero means the two variables are not correlated.

Table 2 lists the results of this test and shows that the correlation between the elements of lighting and beauty of a façade at night varied from building to building. Because a meaningful correlation had been established using the Spearman coefficient,
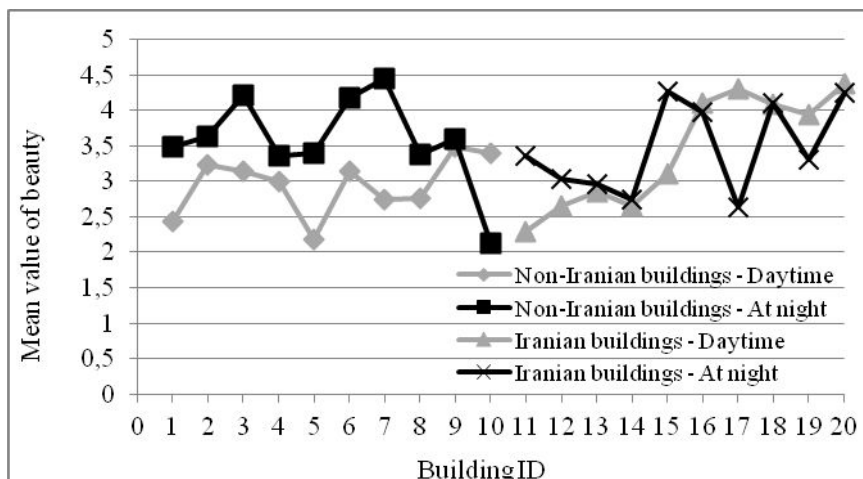

Fig. 7. Average points for perception of beauty of buildings in the daytime and at night

Table 2. Spearman's coefficients for elements of lighting and degree of perceived beauty of buildings; empty rows denote no meaningful relation for a level of meaningfulness of 90 %

Building ID	Lighting intensity	Colour diversity	Lighting uniformity	Lighting harmony
1	0.265	0.240		
2	0.241		−0.317	
3	0.283			
4				−0.262
5			−0.296	
6		−0.369		
7	0.453			
8				
9			0.241	
10	−0.315			
11			−0.364	
12				
13	0.455		−0.286	
14			−0.292	
15	0.440			
16		−0.269		−0.405
17		−0.303		−0.435
18		−0.584		−0.461
19				
20				
Average Spearman coefficient	0.260	−0.257	−0.219	−0.390

it could be concluded that the beauty of the façade was more closely correlated to the lighting method (uniform or accent lighting) than to lighting colour or harmony between the lighting and building. This was concluded because the correlation between the beauty of a façade and lighting method was observed for a majority of buildings.

The average correlation coefficient indicates that the perceived beauty of a façade had a direct relationship with lighting intensity. When the light intensity increased, the building was perceived as being more beautiful. The perceived beauty of a façade was found to be inversely proportional to lighting colour. If the single colour lighting was used, the
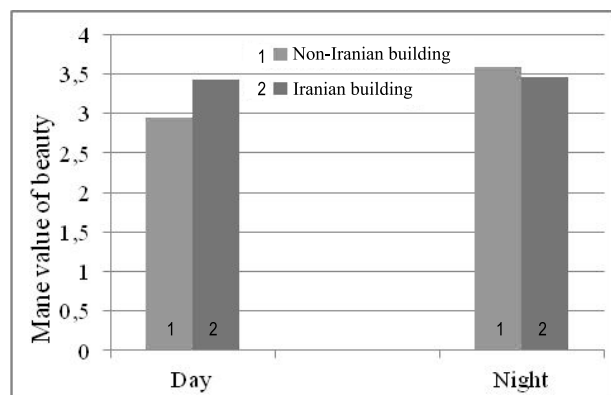

Fig. 8. Mean value for perceived beauty of Iranian and non-Iranian buildings in the daytime and at night

perceived beauty of the building increased compared to when multiple colours were used. In terms of lighting types, accent lighting increased the perception of beauty of the façade over the effect of uniform lighting. With respect to lighting condition, harmony between the lighting and the building also increased the perception of beauty of the façade at night over the lack of harmony.

5. CONCLUSION

The present study examined the effect of novel lighting techniques and its elements on perceptions about the beauty of facades of buildings at night. The elements studied were light intensity (low vs. high intensity), colour diversity (single vs. multiple colour), lighting type (accent vs. uniform), and lighting state (harmonized vs. diversified). The study was conducted using a questionnaire that was completed by 50 participants. The groups were 10 students of urban design, 15 students of architectural engineering, and 25 ordinary individuals with different levels of education. The questionnaire required the participants to rank the beauty of 20 buildings during the day (natural lighting) and at night (artificial lighting) along with the effect of each lighting element on the perceived beauty of the facades at night. The buildings selected were a group of Iranian and a group of non-Iranian buildings. The results were analyzed using SPSS to draw meaningful and scientific conclusions.

Analysis indicated that artificial lighting at night made a building appear more beautiful than it did in natural daylight. This was more recognizable in non-Iranian buildings than in Iranian buildings. Iranians buildings were perceived by the Iranian participants to be more beautiful than non-Iranian buildings in natural daylight, but both groups were rated similarly for night lighting. This study also suggests that as light intensity increased or when single-colour lights were used, buildings were perceived to be more beautiful at night. Accent lighting is where elements and levels of a façade are highlighted selectively rather than uniform lighting of the whole facade, and harmony between the lighting and building increased the perception of beauty of the facade at night as well. Lighting intensity and method (accent or uniform) had more influence on the perceived beauty of the façade than the other two elements.

The results of this research indicate the perceived beauty of buildings can be strongly effecting by proper lighting design. Although the design of façades and their appearance at daytime is important for the architect, the appearance of the façades at night is of high importance as well. This requires scientific and novel design of the exterior lighting of the buildings.

ACKNOWLEDGMENT

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Fig. 3. The questionnaire