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Original

A novel lighting design system in Masoumeh with an approach to improving technical and economic conditions

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Abstract: Islamic countries have many sacred places that represent the culture, identity, and civilization of them. One of the most important tools that can improve the design and architecture of these places is the proper design of lighting systems. Using simulation results in DIALux Evo software and comparing them with lighting standards, technical and operational disadvantages of the current scheme were identified. In this paper, we propose alternative lighting schemes for the courtyard of the Holy Shrine of MASOUMEH considering standards of lighting systems and related international experiences in order to eliminate disadvantages in the current lighting system and to reduce and optimize energy consumption. The results show that proposed alternative schemes not only satisfy technical indicators and standard lighting values but also save the number of lights, the amount of energy consumption, and corresponding costs.

Keywords: component: Assessment of technical and economic conditions, lighting calculations, sacred places, Holy Shrine of MASOUMEH, DIALux Evo software

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1. Introduction

Basically, light is one of the most important factors influencing the value of a space which is the most non-material but perceivable nature element of sacred places. In Islamic architecture, light is not only used to illuminate the architectural space but also has a mystical and sacred aspect and influences other aspects of space including color, texture, etc, and also emphasizes them. The rhythm of light plays an important role in explaining the evolution and sequence of space in Islamic architecture. In such a way, it can be said that the functional role of space sequencing by light in this architecture is explained in three parts: painter, movement, and emphasis. Thus, it can be stated that, in Islamic architecture, implementing sequences of a space by light, as an element of Islamic art, is highly considered. The goal of lighting of a place is one of the design issues. Obviously, the value of a historical monument is its historicity and the style of its lasting architecture. However trivial and unattractive the style of architecture is considered as the identity of an element. In addition, a lighting designer has to first try to maintain the identity of the building, because scientists and tourists are going to visit a place as it has been, and a personal idea should not be imposed to change its identity.

In Islamic architecture, particularly in Iran, lighting plays a significant role. Inside a sacred place is considered such as the light that has been shaped in form material and reminds us about the verse of Light in the Quran. In Iran, because of the bright sunlight in most parts and transparent air in highlands, the experience of having light and the need of living in bright spaces has been an important part of Iranians' lifestyle throughout history. Light is an outstanding element of Iranian architecture not only as a physical element but also as a symbol. Light is a spiritual element that penetrates a solid material, converts it into a glorious form, and makes it beautiful and worthwhile. In Islamic architecture, light has a prominent role in emphasis on the principle of manifestation. Indeed, light makes the substance transparent and reduces the hardness and coldness of the building.

Light is utilized as the manifestation of existence in the inner space of mosques to build an element of perceptual space. The illumination in the mosques and the development of the mosque's light system are considered a mystical and spiritual symbol, as well as decorations. This illumination has an important role to transmit information, and occasionally it also brings up human thoughts beyond constraints of the physical world. Light adds motility and life to Islamic ornamentation in mosques.

In today's societies, lighting is considered as one of the most important physical and psychological factors in residential, and industrial buildings, and workplaces (Uygun, Kazanasmaz, & Kale, 2015). Experience and research have shown that the implementation of a well-designed lighting system can have a beneficial influence on everyday life and improve the efficiency and quality of products. Moreover, lighting affects many aspects of life, such as health, economy, safety, and beauty. Providing good light in good conditions can prevent eye fatigue and thus its side effects and reduce the cost of energy consumption. In addition, if the lamps are appropriately chosen and arranged according to an optimized lighting system, loss of energy can be prevented. The amount of light intensity we need varies from place to place, depending on the functionality of the space. Some spaces might be used during either the day or night, so these issues should be considered when determining the intensity of light for it. In order to design a suitable lighting system, color temperature, color reflection, lighting flux, lighting intensity, lighting gain, reflection coefficient, brightness, and dazzle should be taken into account. As an example, the uniformity of surface luminance, uniformity coefficient, and general uniformity can be pointed out. The longitudinal uniformity coefficient is equal to the ratio of the minimum Intensity of light to the maximum of that at the surface (Emin / Emax) and the lowest value is 0.16. Moreover, the total uniformity coefficient is equal to the ratio of the minimum Intensity of light to the average of it at the surface (Emin/Eave), and the lowest value is 0.33. Important factors in the quality assessment of the lighting system include visual relaxation, that is to say, staying in the environment without getting tired. The factor of visual relaxation includes good color and uniform distribution of brightness. The ambient light should be in such a way that the needs of the human eyes are provided for the sight of objects.

Contemporary information and technologies may create a better climate, for instance by rationalizing it, creating better working conditions. The aim of mass digitization is to create an immersive PC device made up of models, tests, analyzes, 3D visualizations. Such methods help each other create new, simpler approaches that save time for production companies as well as a lot of financial resources. The topic of working space illumination is currently being discussed by several researchers. We concentrate on projecting and maximizing lighting systems in their study, analyzing individual variations of usable lighting simulation and measurement tools, assessing energy efficiency, etc. (Avc & Memikoğlu, 2017; Domingues do santos, Faustino Agreira, & Perdigao, 2013; Li, Li,Wang, & Liu 2012; Na, Lili, Li, & Wenhai, 2016; Salata et al., 2015; Sanchez, Garcia, Domingo, Camachob, & Sebastián, 2015; Uygun, et al., 2015). Based on a comparison of the available software, the choice of the simulation tool was made. Dialux Evo software has many advantages over available software such as compliance with standard EN 12464-2 (STN EN 12464-1), simultaneous modeling of multiple types of lighting, graphical simulation design–visualization,

summarization of results in one transparent spreadsheet, and warning to achieve the minimum required values. The Dialux Evo simulation tool was used to verify the novel lighting design system (Mangkuto, 2016; Meshkova, & Budak, 2013). in (Dupláková, Radchenko, Knapčíková, & Hatala, 2016; Dupláková, et al., 2019)the possibility of using DIALux software to evaluate the lighting quality of the work environment has been investigated. in (Fu, Chen, Qiu, & Chen, 2018) a method for constructing complex spatial light environments and in (Guerry, Gălăţanu, Canale, & Zissis 2019) Optimizing the luminous environment using MATLAB and DIALux software is presented.

This indicates from the analysis of the simulation methods that the freeware simulation light-technical program Dialux Evo is the most open and detailed method for testing lighting. This simulation framework provides a simple working environment for a regular user that, as in other situations, does not need to be managed through a hierarchical tree. A significant positive point is the potential to build a simulation system of virtual, nighttime or mixed illumination in one user experience without the need for multiple modules to be tested. This program is designed to individual rooms, streets, buildings and exterior lighting design, simulation and measurement. The software uses luminaire catalogs from different manufacturers to create artificial lighting that is either available online or on specific websites or is mounted as an effective plug-in by the consumer. With its light-technical equations, the Dialux Evo software is an effective tool for creating and analyzing various types of artifacts. Specific lighting calculation and analysis was done in the Outdoor places in line with STN EN 12464-2 Light and lighting (STN EN 12464-1).

In (Kotsarenko & Ramos, 2012) An alternative approach for diffuse lighting and specular reflections is presented, and (Din, Kim, & Kim, 2013) considers an energy-efficient utilization in lighting control systems. Based on the above issues, our study, and taking the international standards into account, the design of lighting system of the Holy Shrine of MASOUMEH is very weak, and it requires the introduction of an alternative scheme that provides the intensity required by standard according to the aesthetic discussion of sacred places and energy efficiency. Moreover, with a good visual representation, by choosing the right lighting direction and the light color, we can identify the objects in three dimensions (Ahmadian, 2015; Standards DIN EN 12464-1; Rea, 2000).

The Holy Shrine of MASOUMEH can be studied in separated parts, including The Golden Dome, Goldfish, Imam Reza Courtyard, Imam Hadi Courtyard, SHABESTAN of Holy Shrine, and SHABESTAN of NAJMEH KHATUN, as shown in Fig. 1. Therefore, Novel alternative lighting schemes for this courtyard of the Holy Shrine of MASOUMEH are presented in accordance with international standards that overcome the disadvantages of current lighting plans as well as to optimize the use of electrical energy. Initially, after collecting information and depicting parts of the Holy Shrine of MASOUMEH, the current lighting scheme is modeled and simulated by DIALux Evo software (Ekren, Dursun, & Aykut, 2007; Hu, 2017). Using the simulation results and comparing them with international lighting standards, the technical and operational disadvantages of the current scheme have been identified.

In the end, novel alternative lighting schemes based on international standards and to the current lighting system of the sacred places (Uygun, et al., 2015) are proposed. The simulation results show that the proposed alternative schemes not only satisfy technical indicators and standard lighting values but also save the number of lamps, the amount of energy consumption, and the corresponding cost. Also, in terms of price, the proposed alternative schemes cost 40 percent of the current lighting scheme in the courtyard of the Holy Shrine of MASOUMEH.

2. Modeling the courtyard of the holy shrine of MASOUMEH

In order to simulate the current lighting scheme of the Holy Shrine of MASOUMEH and provide detailed examination, and present novel alternative schemes, the architectural information including dimensions, size, height, and structure of Holy Shrine of MASOUMEH, have been calculated according to the imaging in field study, and then simulated by DIALux Evo software.

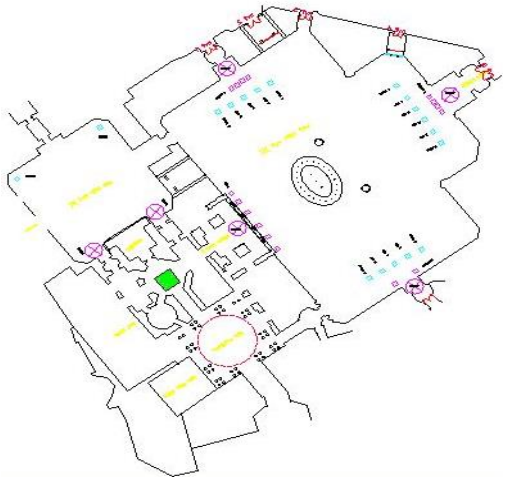

Figure 1. Parts of the Holy Shrine of MASOUMEH.

3. Evaluation the current lighting system of the holy shrine of MASOUMEH

Because of the incorrect placement of projectors (in terms of both location and installation angle) in the current design of the lighting system in the Holy Shrine of MASOUMEH, a large number of high-power projectors have been used. However, those projectors are not able to provide the minimum amount of lighting required in some parts of the courtyard of the Holy Shrine of MASOUMEH, and in some places have caused severe dazzle. The placement of projectors in the courtyard in the current system is presented in Fig. 2. The number, energy consumption, and price of the projectors used in the courtyard area are presented in Table 1. In the current design, 119 different types of 2000-watt, 1000-watt, 400-watt metal halide, and 80-watt LEDs with a total energy consumption of 97480 watts are used. This amount of energy consumption is very low and inadequate compared to the lighting intensity produced in the courtyard. Based on the final AutoCAD mapping of the current lighting system and information obtained from the field study and photography, the current lighting system of the Holy Shrine of MASOUMEH's courtyard is modeled and simulated by DIALux Evo software, as shown in Fig. 3.

Figure 2. Placement of projectors in the current lighting system of the Holy Shrine of MASOUMEH.

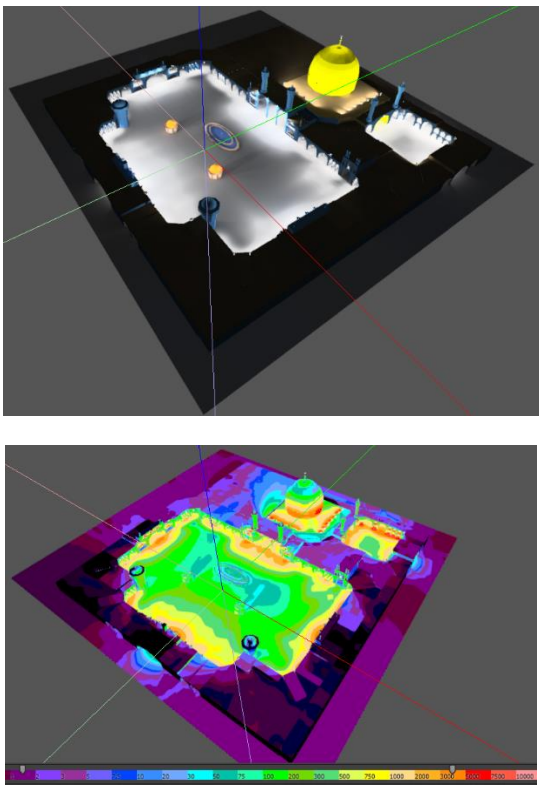

Figure 3. 3D output and false color curve of current lighting system of the HOLY SHRINE OF MASOUMEH in DIALux.

According to the simulation results (as shown in Fig. 3), the middle area of the courtyard has the least amount of lighting intensity. Moreover, the light intensity in 60% of the courtyard is less than 20 lux, which is not an appropriate and acceptable brightness set by the standards for such an area. By using the False Color curve, on the other hand, it is also observed that the high power, low-height installation, and inappropriate centralized layout of the projectors have caused strong dazzling light in some parts of the Holy Shrine of MASOUMEH. Based on the above issues, we propose alternative lighting schemes; replacing the centralized design of high-power projectors, that is, 1000 and 2000 watts ones, in limited locations with the widely distributed, low-power 400-watt projectors to provide better illumination while avoiding dazzling light in the courtyard. Also, using light towers (Fig. 4) with high-power projectors in suitable locations to provide lighting in the middle of the courtyard.

4. Novel alternative schemes for lighting system of the courtyard

Because of the high-power consumption, low-height level, and inappropriate centralized layout of projectors, the current lighting system of the Holy Shrine of MASOUMEH's courtyard causes strong dazzling light, non-uniform distribution of

Table 1. The number and the amount of energy consumption of lamps used in holy shrine of masoumeh lighting system.

Type of light	Number	Energy Consumption (*w*)	Unit price ($)	Total price ($)
2000-watt metal halide	27	54000 watts	350	9450
1000-watt metal halide	32	32000 watts	110	3520
250-watt metal halide	44	11000 watts	30	1320
80-watt LED	6	480 watts	15	90
Total energy consumption		97480 watts		

lighting intensity, and inadequate lighting intensity in some parts of the courtyard. Therefore, it is suggested to implement novel alternative lighting schemes in order to provide brighter, while avoiding dazzling light in the courtyard, by replacing 2000-watts high-power projectors, which are centralized distributed in limited locations, by 400-watts low-power widely distributed projectors. In addition, to provide lighting in the midst of the courtyard, we propose the usage of high-power light towers in inappropriate places. These proposed lighting schemes improve lighting technical conditions, such as providing minimal illumination intensity, uniform distribution of the light intensity, while eliminating dazzling lighting, which ultimately leads to improving the view of the courtyard, enriching social and cultural activities, making the signs to be readable, securing the environment, and increasing people's desire to stay in the space.

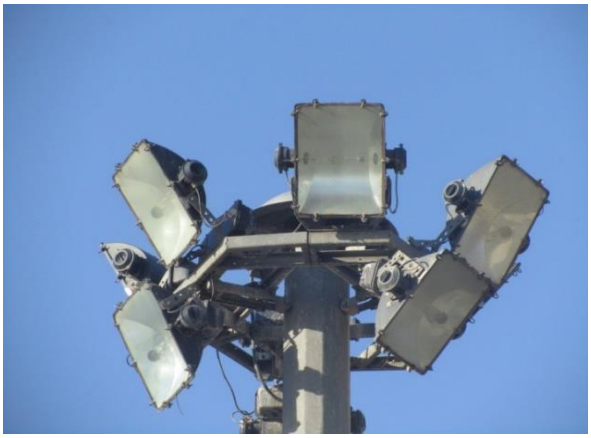

Figure 4. Light towers with high-power projectors.

In order to provide a uniform distribution of the light and reduce dazzling lighting in the proposed alternative lighting scheme and Based on the analysis of different scenarios in DIALux Evo software, we utilize twenty 1000-watt and sixteen 400-watt metal halide and 65 80-watt LED projectors. This scenario is the most optimal scenario both in terms of meeting lighting standards and economically. Also, according to a novel alternative scheme for the lighting system in the courtyard of the Holy Shrine of MASOUMEH, lighting towers are utilized to provide the minimum intensity needed in all points of the courtyard, especially in the middle, as well as having more appropriate light distribution in it. The proposed alternative scheme consists of seven lighting towers and each tower contains ten 400-watt projectors, So that six lighting towers 4000-watt with a distance of 25 meters from each other have been installed in Imam Reza Courtyard and a lighting tower has been installed in the middle of Imam Hadi Courtyard. The height of these towers varies from 15 meters to 50 meters. The 20-meter height is proposed for the towers in the courtyard of the Holy Shrine of MASOUMEH.

In the proposed alternative scheme, the distance between towers is used to satisfy the most intense lighting at all points of the courtyard. According to international standards for such area, lighting intensity varies in the range of 20 to 50 lux. In Holy Shrine of MASOUMEH's courtyard, because of religious ceremonies and the need for good lighting to study holy books, such as Quran etc, sufficient intensity of light should be adjusted according to the standards. To this end, in our second alternative scheme, the intensity of lighting is set to 30-75 lux at all points of the courtyard. The number of projectors and the amount of energy consumption along with the associated price used in the proposed scheme for the lighting of the courtyard are presented in Table 2.

Simulation results of proposed alternative schemes, including 3D image and False Color curve provided by DIALux Evo software, are presented in Fig. 5. The results confirm the improvement in technical conditions of lighting in the proposed scheme compared to those of the current scheme. These conditions include providing minimum illumination at all points in the courtyard, avoiding dazzling lighting, and uniformly distributing the light in the second alternative scheme. In addition, in the current lighting scheme of the courtyard, about 60 percent of the courtyard area has the

intensity of light less than 20 lux, which is against the standards for such an area. However, in the proposed alternative scheme, an average intensity of 50 lux is provided with six lighting towers that meet international standards. These conditions include providing minimum illumination at all points in the courtyard, avoiding dazzling lighting, and uniformly distributing the light.

According to the values provided in Table 2 (including the number of lights, the amount of energy consumption, and the cost of projectors), the total energy consumption in the proposed alternative scheme is 59600 watts, while the total energy consumption of the current plan is equal to 97480 watt watts. This confirms the fact that the proposed alternative scheme saves energy and the associated cost. Moreover, in terms of the project's cost, the proposed alternative scheme costs 40% of the price of the current lighting plan in Holy Shrine of MASOUMEH's courtyard, which reduces the initial cost of the scheme. Simulation and computational results verify that lighting towers are more appropriate than the current lighting system of Holy Shrine of MASOUMEH's courtyard, in terms of technical parameters such as minimum illumination intensity, avoidance of dazzling, and light distribution, as well as economic indicators including the initial and energy costs.

Table 2. Total number, energy consumption, and cost of projectors in the proposed alternative lighting scheme.

Type of light	Luminous intensity (*lm*)	Number	Energy Consumption (*w*)	Unit price ($)	Total price ($)
400-watt metal halid	35000	86	34400	30	2580
1000-watt metal halid	100000	20	20000	110	2200
80-watt LED	880	65	5200	15	975
Total energy consumption			59600 watts		

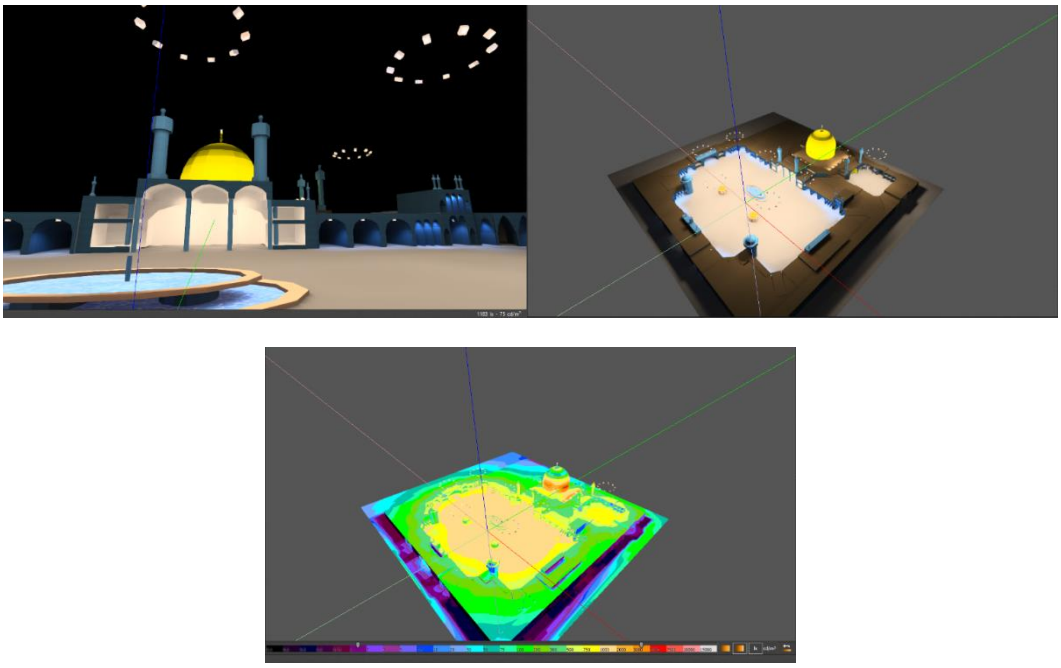

Figure 5. 3D image and false color curve of the proposed alternative lighting scheme.

5. Conclusion

Unfortunately, because of the inappropriate design of lighting systems in sacred places, the goals of their designers and architects are not properly represented, and even sometimes it has a reverse effect. In this paper, we focus on the Holy Shrine of MASOUMEH in I.R. of Iran as a sample sacred place to investigate its lighting system. After field study, information collection, as well as imaging the courtyard of the Holy Shrine of MASOUMEH, the current lighting system of it is modeled and simulated by DIALux Evo software. Using the simulation results and comparing them with international lighting standards, the technical and economical disadvantages of the current scheme have been identified. Then, proposed alternative lighting schemes based on international standards and using the points related to the lighting system in sacred places have been introduced for the courtyard of the Holy Shrine of MASOUMEH.

In a novel alternative scheme, it is proposed to use 1000-watts high-power projectors concentrated in limited locations and 400-watts low power projectors widely distributed to provide illumination and avoidance of dazzling in the courtyard of the Holy Shrine of MASOUMEH. Also, the use of lighting towers are proposed to provide the minimum intensity required in all parts of the courtyard, especially in the middle of it, and better light distribution. Simulation and computational results show and confirm that the proposed alternative schemes outperform the current lighting system of the Holy Shrine of MASOUMEH also in terms of technical indicators including minimum light intensity, unobtrusive light distribution, as well as In terms of economic indicators including initial cost and power consumption.

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