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Investigation of daylight performance in traditional residential buildings in the context of EN- 17037 standard - Sivas Hubiyar Korucu Mansion

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Abstract

Daylight is an integral part of our lives as the most important element in places. Efficient and appropriate use of daylight reduces the need for adequate illumination of the volumes and artificial lighting. Today, windows that are not designed correctly cause energy waste by increasing the use of artificial lighting instead of natural lighting. The seriousness of this situation is increasing today and regulations and standards regarding daylight use are published. The disappearance of this traditional Turkish architecture has also reduced the effective use of natural light. Study is focused on daylight penetration in traditional Turkish houses in the context of EN-17037 and a traditional Turkish house evaluated as case study. Natural lighting measurements of the selected building were calculated using the daylight simulation program, at 09:00, 12:00 and 15:00 for the months of March 21, June 21, September 21, and December 21 under average sky conditions. In line with the results obtained from the simulation program, the illumination levels (Lux), daylight factor (DF) and daylight performance classification (%) of the spaces are presented. As a result of the evaluation made in the context of EN 17037 standard, attention was drawn to the importance of openings as windows in traditional Turkish houses. And additionaly, architectural similarities and differences with the contemporary building is highlighted in results.

Keywords: daylight, daylight performance evaluation, EN 17037, natural lighting, traditional Turkish houses.

1. Introduction

Daylight is the most basic natural resource used to illuminate living spaces from the past to the present (Kazanasmaz, 2009). The relationship between space and daylight was the most important concept that architects focused on before the electrical lighting of living spaces (Arpacıoğlu et al., 2020). In terms of visual comfort and efficient use of living spaces, natural lighting is given priority in the designs. The design setup was made by improving the light quality and perceptibility of the spaces over time (Kazanasmaz, 2009). Daylight also affects people psychologically and physiologically (Kutlu, 2019). Its positive effects on human performance have also been proven in studies (Garris, 2004; Arpacıoğlu et al., 2020). As a result of studies conducted for many years, it has been proven that natural light has a significant effect on human physiology and that the external view from the windows can positively affect human health (Tuaycharoen & Tregenza, 2007). For

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this reason, considering all kinds of effects on people, the importance of the predominance of natural light in all spaces is emphasized in many studies (Sevinç & Altın, 2021).

Spaces that are adequately illuminated and have sufficient visual comfort are naturally preferred by people (Bülow-Hübe, 2001). For this reason, the luminous effect created by daylight attracts more attention than the unnatural image formed in the electrically illuminated space (Arpacıoğlu, 2012). At this point, an increase in the lighting quality of the space by including daylight values in the design process in the early phase of the design should be aimed. Thus, the overall quality of the project can be increased, and project costs can be reduced (Arpacıoğlu et al., 2020). This interaction between quality and cost is also an important factor in design that reduces the need for artificial lighting and saves energy. The productive and stimulating environments created in the spaces illuminated by daylight increase the comfort of the people and significantly reduce the building energy costs (Kutlu, 2019).

Tezel (2007) emphasized the necessity of accepting natural light as a building element in the design of architectural spaces in his doctoral thesis. He also stated that natural light makes important contributions to gaining different visual meanings in the space. The effect of daylight is undeniable as much as the importance of the material effect in the shaping of the spaces. For residences at the design stage, setting up parameters such as orientation and location with predetermined correct lighting systems and predicting the lighting requirement in advance play an important role in reducing energy consumption (Sümengen & Yener, 2015). In this case, it is very important to use lighting systems designed with the right techniques. The role of natural light in mass and facade design is critical. The use of these architectural elements with high performance in terms of energy saving should be preferred at this point (Kutlu, 2019). The most known and traditional of these systems are the methods used as windows and skylights. At the same time, there are alternative usage methods such as light tubes, which are developed with today's technology and increase the dominance of daylight in spaces (Sevinç & Altın, 2021).

2. The importance of natural lighting in buildings

The windows of the buildings play the biggest role in taking natural light into the interior. Through the windows, natural light can be brought in vertically or horizontally. The natural light entering the building from different directions affects the facade design and identity of the space; guides the determination of the number, size, design, and location of windows (Tezel, 2007). Windows openings are the most important facade element that allows daylight to be taken into the interior and to establish eye contact with the exterior. The analysis and design of these openings is very important for both increasing the quality of the space and user satisfaction (Kılıç & Yener, 2018).

Bülow-Hübe (2001) states that if daylight is designed and used correctly, it can replace artificial lighting and be considered as renewable lighting. *Trengenza & Mardaljevic* (2018) argued in his study that windows affect much more than daylight. For example, in building design, windows affect not only energy use, but also conditions such as acoustics, thermal balance, ventilation and viewing angles. The main function of windows is to provide sufficient natural light to enter the space and to establish visual contact with the external environment (Bülow-Hübe, 2001). In the past, the purpose of these window openings was only to take natural light into the interior, but later on, they were shaped according to the needs of the residents in terms of comfort and psychology, and the functionality (Yıldırım et al., 2018). *Ayssa* (1996) emphasizes that features such as vision, lighting, ventilation, protection and privacy are functions of the window. In the study, *Ayssa* (1996), also argued that these functions are shaped according to needs and vary according to cultural, social and environmental factors, and these variations are even caused by floor differences in buildings. As time progressed, window designs began to be created according to their aesthetic appearance rather than their functions. This situation prevents adequate sunlight to be taken indoors (Murt, 2006). The fact that the number and dimensions of windows are not designed in accordance with energy use also causes a decrease in the heat energy gained by the buildings from the sun (Turkish

Ministry of Environment and Urbanization, 2016). While the number and dimensions of the designed windows increase the daylight efficiency in the space, the extra designed windows bring glare problems in the space (Arpacıoğlu et al., 2020). For this reason, it is recommended to use daylight simulations to make these indoor illuminances analyzes at the early stage of the design (Alhagla et al., 2019). Window designs created with aesthetic concerns instead of making maximum use of daylight in residential designs prevent natural light from entering the volumes sufficiently and cause an increase in the use of artificial lighting. This situation increases energy use and creates a negative situation in terms of energy saving (Gezinmez, 2019). When the important examples in history are examined, many details, from window designs to the orientation of the building, are considered important to benefit from daylight as much as possible. Unfortunately, this situation lost its importance later on (Kutlu, 2019).

3. Standards used in evaluation of daylight performance in buildings

Over the last century, the active use of natural light in spaces has decreased with the increase in the number of residences and the energy use opportunities in buildings (Mardaljevic & Christoffersen, 2013). With the decrease in the use of natural light, the sustainability perception of the building has improved and the need for studies involving changes in the concept of architectural space has emerged (Sevinç & Altın, 2021). For this reason, directives regulating the correct use of daylight in buildings have been prepared (Şener & Ünnü, 2011). The minimum conditions of daylight suitable for building occupants, together with public controls, are defined by mandatory standards (Trengenza & Mardaljevic, 2018). The use of renewable energy has been widely accepted in the world, and recommendations, standards and regulations encouraging the design of energy-saving buildings have begun to be published (Mardaljevic et al., 2009; Mardaljevic & Christoffersen, 2013). These standards and regulations aim to realize the potential of energy conservation in buildings, develop energy efficient policies and increase the demand for these designs. At the same time, it aims to protect and increase the satisfaction quality and well-being of those who use the spaces (Erlalelitepe et al., 2011). Considering the conditions of each country and region, the requirements for minimum or maximum values of lighting energy are determined (Turkish Ministry of Environment and Urbanization, 2016). EU countries have conducted studies on energy efficient designs in buildings and published the Energy Performance Regulation in Buildings (2002/91/EC) in 2002. According to this regulation, the required amount of energy has been determined and a common method has been adopted for the evaluation of energy performance in buildings (2002/91/EC; Sümengen & Yener, 2015). Following this regulation, the EN 15193 "Energy Performance in Buildings – Lighting Energy Requirements" standard is published, and the energy performance of the building is calculated over various variables (EN 15193, 2006; Şener & Ünnü, 2011). "EN 12464-1 European Standard" was approved by the European Standards Committee (CEN) in 2002 in order to provide the required illumination level in interior spaces with different functions (EN 12464-1, 2011; Baskan & Aş, 2021). The standard (AS/NZS 1680.2.3, 2008), which was prepared jointly by Australia and New Zealand in 2008, is accepted due to the indication of the illuminance levels needed in the buildings. In the standard (DIN 5034-4 standard, 1994) put into effect in Germany, the illumination levels are adjusted according to the functionality of the spaces (Bayram et al., 2020). Moreover, according to the IES handbook used in the USA, the illuminance levels in buildings are regulated depending on many parameters such as the ages of the people using the space (Arpacıoğlu et al., 2020).

Turkey, on the other hand, follows EU countries and implements regulations on energy use by bringing new legal regulations with similar approaches (Turkish Ministry of Environment and Urbanization, 2016). This regulation is the Energy Performance Regulation in Buildings (BEP-TR, 2010), which was prepared in accordance with the country's conditions in 2008 in line with the "EN 15193 Standard". In this regulation, lighting energy performance is calculated by proposing a general calculation method for residential buildings (Sümengen & Yener, 2015). Adhering to the "EN 12464-1 Standard" published in 2002, TS EN 12464-1 standard was accepted by the Turkish

Standards Institute in 2013, and definitions and limits were expressed regarding indoor lighting (TS EN 12464-1, 2013; Arpacıoğlu et al., 2020). This standard is valid for buildings with different functions such as educational buildings and is for artificial lighting conditions. In addition, it covers the rules that meet the visual comfort and performance needs for indoor users (Bayram et al., 2020).

With the increasing interest in healthy design practices and the need to raise standards, the fact that daylight has become a more standard practice has enabled the EU to develop EN 17037. For the use of passive systems, namely natural lighting, in buildings, EN 17037:2018 European Union Standard was put into effect in 2019 (EN 17037:2018). This standard includes the necessary criteria and methods to meet the needs for visual comfort in buildings (Yılmaz, 2019). According to the standard, the daylight performance in the space depends on the building design as well as the climatic conditions of the area where the building is located (Christoffersen et al., 2017). The TS EN 17037:2019 standard has also been developed according to the conditions of Turkey, and it is aimed to provide sufficient daylight level in residential buildings (TS-EN 17037, 2019). This proposed standard presents daylight evaluations with two different evaluation methods as 'daylight factor' and 'detailed daylight modeling' (Yılmaz, 2021).

4. Natural lighting in traditional houses

Various contemporary methods have been developed to reduce the energy used and to bring natural light to indoor spaces where daylight is insufficient. Variables such as the orientation of the building, climate and usage hours can be designed with the right strategy and energy savings can be achieved (Yener, 2007). Although it is not difficult to benefit from daylight at the desired level, it is also necessary to integrate many factors together for the use of natural lighting in spaces (Kutlu, 2019).

The effects of daylight on humans and the body's need for sunlight are a well-known fact. There are the necessary daylight calculation and measurement tools in order to make all the necessary arrangements in the spaces. However, since the measurements are not made by experts, they cannot be calculated correctly, causing the buildings not to receive enough daylight (Trengenza & Mardaljevic, 2018). This situation not only has negative effects on human health, but also increases energy consumption in a country. Of course, this situation depends on different cultures, climates, solar activity, lifestyle, etc. varies according to the variables and can affect the architectural design of the building (Murt, 2006). For example, the effect of daylight on spaces can be controlled with the help of architectural elements in some traditional Turkish houses (Yüksek & Esin, 2009). In her thesis of traditional Gaziantep mansions, Gezinmez (2019) discussed that most of the lighting is provided from the window openings and the moonlight can be taken into the interior at night through the pigeon window. Another variant of this architectural element in the thesis, which is used depending on the culture and geography variable, is seen in traditional Yemen windows. There is the lower part (Taqah) defined as the window opening and the fan light (Cabin) which has a similar function to the pigeon window. This window element provides a small amount of daylight to the living space when the shutters of the lower part are closed (Ayssa, 1996). Ayssa (1996) states that the number of windows on the south facades of these traditional buildings has been increased in order to benefit adequately from daylight. In this way, natural lighting and ventilation needs can be met without energy consumption. At the same time, the intake of natural light indoors throughout the day also reduces the amount of energy required for heating of the volumes (High & Esin, 2009). For example, this situation is seen in the traditional Gaziantep mansions that Gezinmez (2019) examined in her thesis. The window layouts of the two mansions chosen within the scope of this study vary according to the floors. Accordingly, it was determined that the size and number of windows on the upper floors were higher than those on the lower floors. This difference is due to the increase in the need for natural light for the upper floors, as the lower floors are the service floor, and the upper floors are the living areas. In the thesis, thanks to this feature seen in Anatolian traditional houses, natural light is taken in according to the functions of the spaces. In other words, it is important to determine the functionality between the building spaces according to the intensity of natural light while designing the design. A similar situation is encountered in some traditional Yemeni dwellings. Ayssa (1996) examined the components of the traditional Yemeni window and the interior comfort. For the local residence examined in this study, Ayssa (1996) argued that only small windows with small slots providing ventilation were placed on the ground floor. On the contrary, Ayssa (1996) observed the windows reached the maximum size in order to provide ventilation, lighting and vision on the upper floors. In other words, window sizes vary according to the functionality of the spaces.

4.1. Sivas traditional Mansions

It is possible to define Sivas traditional mansions selected within the scope of this study as Turkish houses. They are the Ottoman heritage houses that have survived from the 17th century. The one-floor housing type with an outer sofa in the 15th century developed into traditional duplex houses with an inner sofa (Sivaslıoğlu, 2015). According to the cultural and geographical differences of the Turkish people, plan type, overhang, building material, number and dimensions of windows etc. Differences can be seen in many architectural formations. Despite these differences, the architectural language and character of Turkish houses are clearly evident (Sagın, 2014). When we look at the facade setup of Turkish houses, it is seen that the ground floors consist of shallower walls compared to the upper floors, on the contrary, the gaps in the upper floors increase in order to establish a view with the external environment (Küçükerman, 1995; Sivaslıoğlu, 2015). The facades have been enlivened by the overhangs on the upper floors and the increasing number of windows. The window forms formed on the facades over time ensured the formation of integrity with the urban texture. These window models, designed in double rows, can be opened and closed with the large opening at the bottom, and the small spaces at the top are skylights designed for lighting and decoration. Windows are mounted on the outer surface of the walls in order to expand the space (Sivaslıoğlu, 2015). Accordingly, the Sivas traditional houses' architecture are also shaped in line with these interactions (Figure 1).

Figure 1 Examples of traditional Sivas houses (Source: Author Archive)

The development of Sivas houses started in the 19th century, and they were generally built on a basement as a single or duplex building. Through the overhangs on their facades, the upper floor spaces are enlarged, and enough sunlight can be taken into the volumes. Since the living spaces are on the upper floors, the rooms have been expanded and bright spaces have been obtained through the cantilevers (Şimşek, 2021; Bilget, 1992). Traditional Sivas houses are buildings that are designed according to the functionality of the spaces.

5. Method

The structure in which the study was conducted is located in Sivas province at 39° 75° North latitudes and 37° 01° East meridians (URL-1). There is no natural or artificial obstacle that will affect the daylight illuminance level around the building. Simulation calculations were made by assuming that there are no sunshades and shading elements in the windows. According to the reference study, the earth reflectance coefficients for Sivas province were determined as minimum 1990 lx and maximum 7000 lx (Sayın, 2014). According to these determined values, the availability of the illuminance levels determined in the spaces in the volumes is given in Table 1-8 at the rate of %. The selection of the sky model to be considered in the simulation calculations in accordance with the local characteristics of the region where the examined structure is located is very important in terms of the accuracy of the numerical data to be obtained from the program. At this point, considering the meteorological data of Turkey, the average sky conditions for Sivas Province have been accepted. In the study, simulation calculations were made according to 09:00, 12:00 and 15:00 hours for 21 March, 21 June, 21 September and 21 December at certain location and average sky conditions. The ground height to be calculated in the simulation was taken to be approximately h: 0.85 m, as specified in the EN 17037 Standard (EN 17037:2018). The simulation results obtained were evaluated according to the reference EN 17037 standard. According to the standard, evaluation steps have been created for the need for light level in the volume as low, medium and high. In the standard, the minimum illuminance levels targeted for spaces with vertical openings are classified as 100 lx ≤, 300 lx ≤, 500 lx ≤ and these lighting levels are required to be provided in 95% of the space (EN 17037:2018). The simulation results of the obtained Traditional house have been evaluated according to the conditions of the reference standard, whether it is provided for certain days and time zones of the year.

There are many simulation programs used today for the design of lighting projects, observing the parameters that affect the result, and reviewing the effects of the lighting systems before the design. These; *Dialux, Relux, Velux Visualizer, Europic, Agi32, Calculux, Siteco* etc. (Yılmaz, 2007). Velux Daylight Visualizer is a professional computer program created for the analysis of daylight conditions in buildings (Velux Daylight Visualizer 3.0.22 Beta). Modeling of three-dimensional spaces designed with the program, the design of window openings with the help of catalogs and a visual analysis of the effect of daylight on the space are presented (Kazanasmaz, 2009). In this study, the evaluation of the mansion spaces in terms of lighting was made with the Velux Daylight Visualizer 3.0.22 Beta program.

5.1. Field study- traditional Hubiyar Korucu Mansion

Considering the studies in the literature, studies examining natural lighting in traditional Turkish houses are quite limited. In this context, the study has a remarkable and original feature. With this study, it is expected to contribute to the traditional Turkish house works as an addition. Sivas traditional mansions are also unexamined at this point. The natural lighting performance of the selected Hubiyar Korucu Mansion was examined in this study. In this study, it was determined whether the mansion spaces have the appropriate illuminance level according to the reference standard.

In this part of the study, there is information about the Hubiyar Korucu Mansion located on Höllüklük Street in Sivas Province. The floor plans, site plan and views obtained by the Agency of the mansion are shown in Figures 4 and 5. Although the building is not far from Sivas city center, it is located on Höllüklük Street, where the traditional texture is tried to be preserved (Figure 2).

Figure 2 Location of Hubiyar Korucu Mansion and its relationship with other registered mansions (Source: The Author)

The historical building in ruins was purchased by the Oran Development Agency in 2010 and its restoration was completed in 2014. The agency has revived the registered structure, which is one of the historical symbols of Sivas. Many studies and planning such as investment, support, training, and promotional activities in the city are now continuing in the historical Hubiyar Korucu Mansion (Figure 3) (ORAN Development Agency Activity Report, 2016).

Figure 3 The south and north facades of the mansion after restoration (Source: Author Archive)

The building has 3 floors: basement, ground floor and first floor (Figure 4). There is an adobe walled garden near the entrance to the south of the building. There are double-winged wooden garden gates opening to the street in the east and north of the garden. The basement of the building is filled with stone, and the upper floors are filled with mud brick between the timber frame (URL-2). The site floor plan of the building was examined, and no natural or artificial obstacles were found outside the building that would affect the daylight illuminance level (Figure 4).

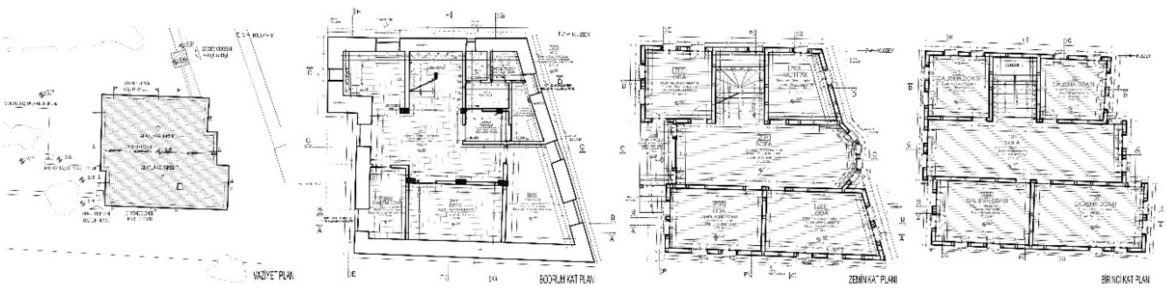

Figure 4 Floor plans of the mansion (Source: ORAN Development Agency, Photo archive)

The ground floor entrance door is reached by stairs from the garden courtyard. After the entrance door, the sofa with an area of approximately 30 m² is encountered first. There are 4 rooms numbered Z02, Z03, Z05, Z06, which can be reached from the sofa numbered Z04. Space Z03 on the floor is used as a kitchen. The wooden bench in the north of the sofa is used as a raised and sitting area. This elevated area allows for visual contact with the outdoors through the windows. When the old functions of the ground floor are examined, there are living areas, kitchen and divan room. Its current function is in the form of study rooms, kitchen and waiting area. There are windows in every room of this mansion, which is an interior sofa type. The average floor heights of the spaces are 3.54 m. When the ground floor facades are examined, there are 7 windows located at different angles in the north and south, and 4 windows in the east and west (Figure 5). All floors of the building are accessed by wooden stairs. From the ground floor to the basement floor is accessed with the help of wooden stairs. There are B01, B02, B03 and wet areas on the basement floor. Although there are small skylights in the basement floors, daylight cannot illuminate the volumes. The basement floor was used as a cellar, service, and storage area in its original function, but today it has been renovated as wet volume and storage areas. There are 3 small windows on the north side of the basement floor and 2 small windows on the south side. There are no windows on the east facade of this floor. There is a small window on the west side and a door opening to the garden. The basement floor was excluded from the study. The first floor is accessed by a wooden staircase from the ground floor and a larger sofa is encountered compared to the ground floor. Along with the projections on the facades, there was a volumetric expansion in the sofas and rooms. On the first floor, there are 4 rooms numbered 101, 102, 104, 105 opening to the sofa numbered 103. The original function of the ground floor is bedrooms-living areas. Its functions today are in the form of study and meeting rooms. When the floor plans of the building are examined, all window sizes are the same. The ground and first floor Windows are 0.90 m wide and 1.55 m high. The sofa windows on the north facade of the ground floor are 0.70 m wide on average. There are 2 small windows in the north and south directions between the roof (Figure 5).

Figure 5 Facade views of the mansion (Source: ORAN Development Agency, Photo archive)

The building has a hipped roof and is covered with eternit material. The roofs are wooden cladding with wide eaves and under eaves profile. Door and window jambs are made of wood. In addition, it has double wings and iron fingers. Between the floors, wood should be wiped (URL-2).

5.2. Building daylight performance analysis

The visuals of the results obtained from the Velux Daylight Visualizer 3.0.22 Beta program are placed on the plan drawings of the building. The results obtained for the ground and first floor plan on March 21 at 09:00, 12:00 and 15:00 are shown in Figure 6-8; the illumination levels (Lux), daylight factor (DF) and daylight performance classification (%) of the spaces are presented in Tables 1-2.

Looking at the data on March 21 at 09:00 (Figure 6); in the south facade spaces on the ground and first floors, it is seen that the illumination level of 300 lx ≤ is present in approximately 90% of the spaces. Although the illumination level of 300 lx ≤ in the northern facades is less than the other places, it is seen that the illumination level of 100 lx ≤ is present in 95% of the relevant space and it can be said that it is sufficient according to the standard.

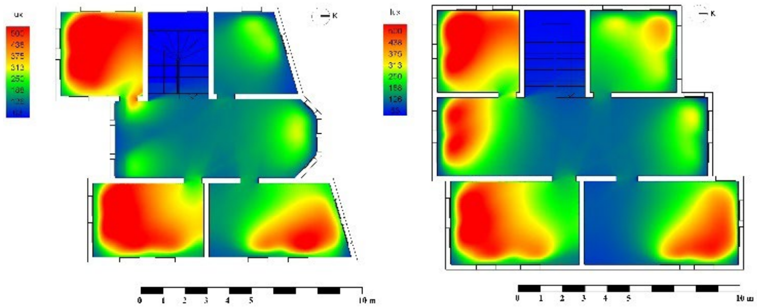

Figure 6 Lighting levels of ground and first floor plans for 21 March at 09:00

Looking at the data of March 21 at 12:00 (Figure 7); spaces Z02, Z05, 101, 104 on the ground and first floors have maximum daylight intake with illumination levels of 500 lx ≤ present in 25%-50% of the spaces. Half of some spaces and nearly all of others are adequately illuminated.

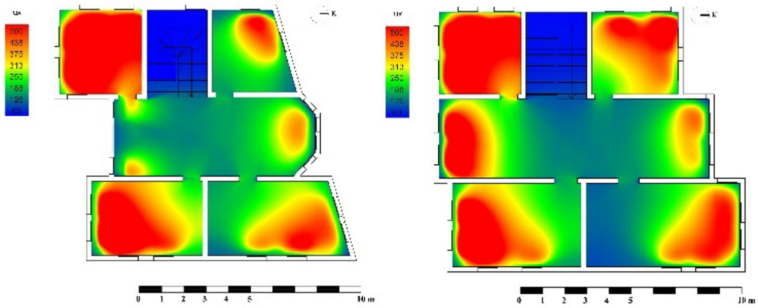

Figure 7 Lighting levels of ground and first floor plans for March 21st at 12:00

Looking at the data on March 21 at 15:00 (Figure 8); in the late afternoon, natural light intensity tends towards the south and north spaces. These spaces are Z02 on the ground floor; on the first floor are rooms 101 and 102. In approximately 40%-75% of the spaces, a lighting level of 300 lx ≤ is provided. In other facades, the illumination level of 100 lx ≤ is available in an average of 95% of the spaces.

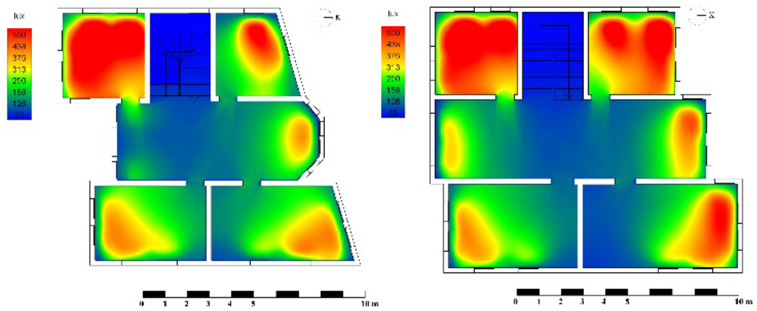

Figure 8 Lighting levels of ground and first floor plans for March 21 at 15:00

The results obtained for the ground and first floor plan on June 21 at 09:00, 12:00 and 15:00 are shown in Figures 9-11; the illumination levels (Lux), daylight factor (DF) and daylight performance classification (%) of the spaces are presented in Tables 3-4. Looking at the data on June 21 at 09:00 (Figure 9); the lighting levels of the rooms on the south and east facades are above 500 lx ≤. Approximately 50% of the spaces are illuminated with an illumination level of 300 lx ≤. Lighting levels of 100 lx ≤ are provided in 100% of the rooms.

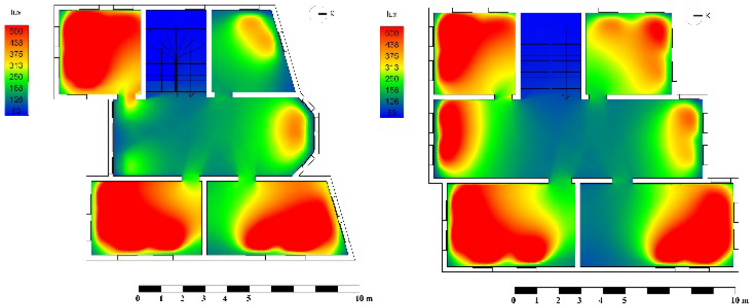

Figure 9 Lighting levels of ground and first floor plans for 21 June at 09:00

Looking at the data on June 21 at 12:00 (Figure 10); all spaces on the ground floor receive sufficient daylight according to the standard. 23%-77% of Z01, Z05 spaces have illumination levels above 500 lx ≤. According to the results of the first floor, 500 lx ≤ lighting levels are sufficient according to the standard in 8%-83% of spaces 101, 102, 104 and 105 on the south and north facades. Looking at the other rooms on the floors, approximately 58-90% of the spaces are at 300 lx ≤ lighting levels.

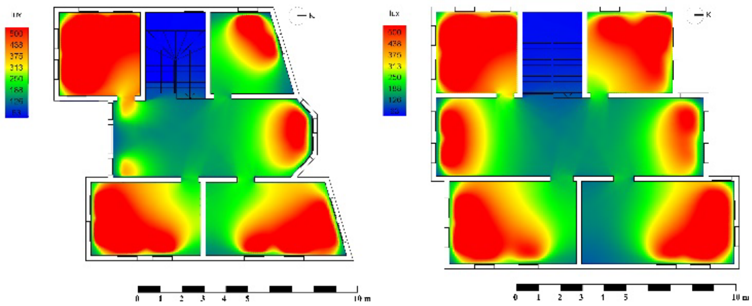

Figure 10 Lighting levels of ground and first floor plans for 21 June at 12:00

Looking at the data on June 21 at 15:00 (Figure 11); although the natural lighting decreases in the afternoon, it continues to be effective. The illumination levels of 500 lx ≤ in rooms Z02, 101, 102 on the ground and first floors are more than 50% of the spaces. In the eastern facade spaces, this illumination is effective at 300 lx ≤ levels and in 30-60% of the space.

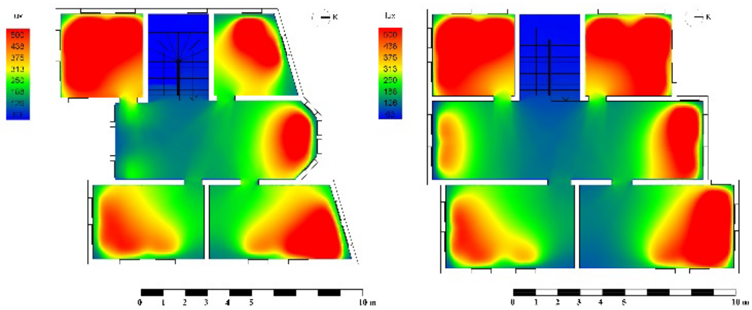

Figure 11 Lighting levels of ground and first floor plans for 21 June at 15:00

The results obtained for the ground and first floor plan on September 21 at 09:00, 12:00 and 15:00 are shown in Figures 12-14; the illumination levels (Lux), daylight factor (DF) and daylight performance classification (%) of the spaces are presented in Tables 5-6. Looking at the data on September 21 at 09:00 (Figure 12); with the sunrise, the intensity of natural light is effective in the south and east places. These spaces are Z02, Z05 and Z06 on the ground floor; on the first floor are rooms 101, 104 and 105. Lighting levels ≤ 500 lx in these rooms are available in approximately 8%-40% of the spaces. On the other hand, the daylight level of 300 lx ≤ in the spaces on the other floors varies between 0% and 94% of the spaces.

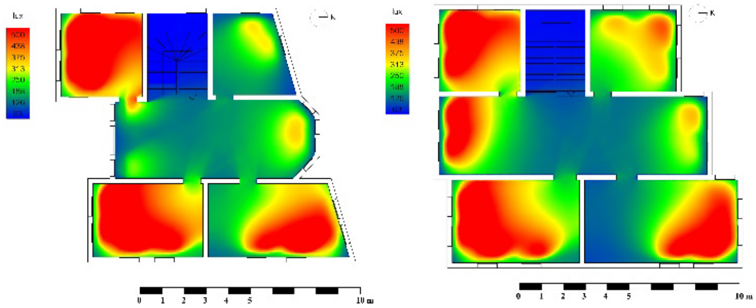

Figure 12 Lighting levels of ground and first floor plans for September 21 at 09:00

Looking at the data of September 21 at 12:00 (Figure 13); more than half of the spaces have above-average illumination. Illumination levels ≤ 500 lx vary between 11% and 73% in spaces Z02, Z05, 101,102, 103 and 104. In 70%-96% of the spaces, there are lighting levels of 300 lx ≤. In other rooms, illumination levels of 100 lx ≤ are provided in 95% of the spaces on average. This level is sufficient for daytime use according to the referenced standard.

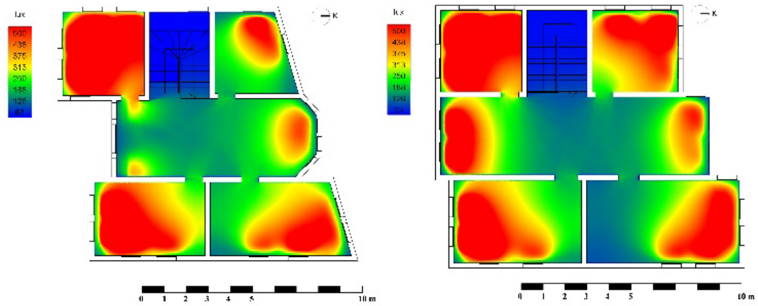

Figure 13 Lighting levels of ground and first floor plans for September 21 at 12:00

Looking at the data on September 21 at 15:00 (Figure 14); in the afternoon, natural light activity decreases in the south and east facades. Rooms Z02, 101, 102 on the ground and first floors receive more natural light compared to rooms on other facades. Lighting levels of 500 lx ≤ vary between 8% and 40% of the rooms. At the same time, the illumination level of 300 lx ≤ is available between 88% and 96% of the spaces. The lighting levels of 300 lx ≤, which are effective between 0% and 92% in other places, were not sufficient according to the standard.

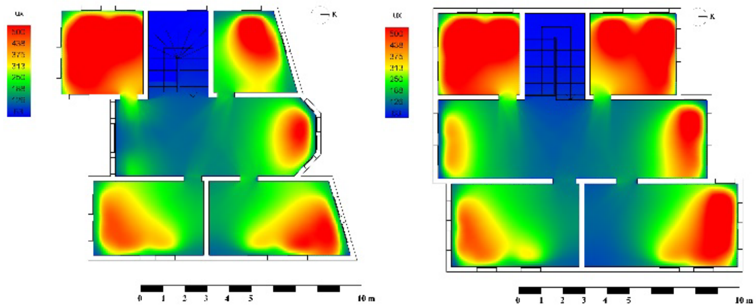

Figure 14 Lighting levels of ground and first floor plans for September 21 at 15:00

The results obtained for the ground and first floor plan on 21 December at 09:00, 12:00 and 15:00 are in Figures 15-17; the illumination levels (Lux), daylight factor (DF) and daylight performance classification (%) of the spaces are presented in Table 7-8. Looking at the data on December 21 at 09:00 (Figure 15); with the decrease in solar activity, the lighting performance of the spaces is also affected. Lighting levels ≤ 300 lx are not measured in many rooms and are insufficient compared to the reference standard. According to the standard, 100 lx ≤ illumination level of the rooms on the south and east facades is provided in 100% of the spaces.

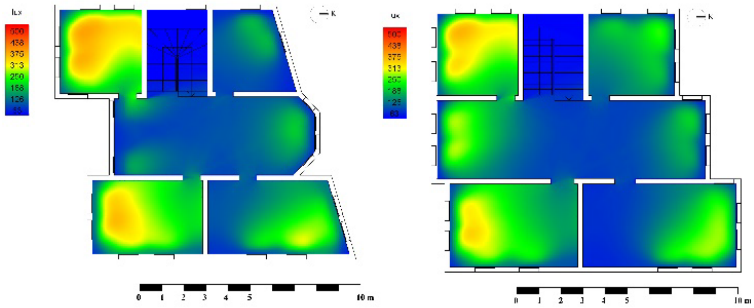

Figure 15 Lighting levels of ground and first floor plans for 21 December at 09:00

Looking at the results of the ground floor at 12:00 on December 21 (Figure 16); the lighting levels of the places on the south facades are the highest compared to other times of the day. Lighting levels of 500 lx ≤ are calculated only in rooms Z02 and 101 and this rate is 20%. Looking at the results of the ground and first floor spaces, the illumination level of 300 lx ≤ varies between 0% and 91%. Again, 100 lx ≤ lighting levels are provided at an average of 95% in all spaces. Average daylight performance is exhibited according to the reference standard throughout the spaces.

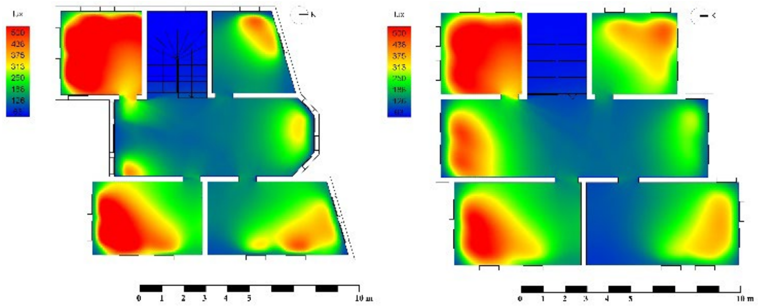

Figure 16 Lighting levels of ground and first floor plans for December 21st at 12:00

Looking at the data on December 21 at 15:00 (Figure 17); the intensity of natural light decreases in all spaces with the decrease of solar activity in the afternoon and the seasonal situation. Daylight has reduced its intensity in the spaces on the south and east facades and most of the spaces have lighting levels ≤ 300 lx. Lighting levels of 100 lx ≤ were achieved at an average of 85% in all spaces. However, it was insufficient according to the reference standard.

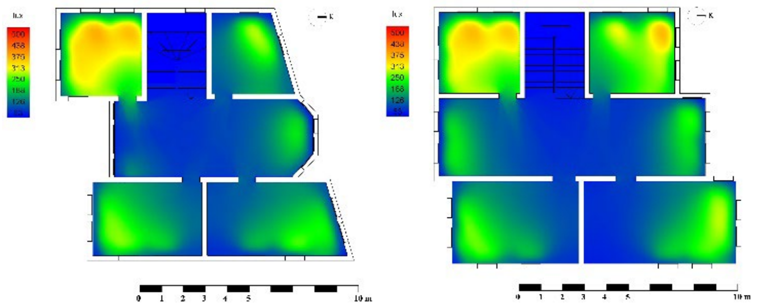

Figure 17 Lighting levels of ground and first floor plans for December 21st at 15:00

6. Building daylight performance evaluation

Necessary simulation measurements for all spaces on the ground and first floor of the mansion were determined with the Velux Daylight Visualizer program at approximate values. By using the program, the minimum, maximum and average values of the illumination level (lx) were found in each place, according to the specified dates and times. The percentages (%) of achieving the "targeted illuminance level for vertical openings" in the spaces, in accordance with the EN 17037 standard, were calculated. Percentage results were calculated according to three different illumination levels, (100 lx ≤), (300 lx ≤) and (500 lx ≤). The values on the ground and first floors for the specified dates of 21 March, 21 June, 21 September and 21 December are calculated and presented in tables.

When the ground floor spaces for March 21 are examined (Table 1), rooms Z02 and Z05, which are the southern spaces, showed a high level of daylight performance throughout the day compared to the average lighting level values. The illumination level of 300 lx ≤ in these places during the day was observed in 96% of the rooms. The illumination level of 500 lx ≤ in the same places at 12:00 reaches up to 54% of the rooms. Lighting efficiency changes according to the hours of the day in rooms Z03, Z04 and Z06 on the northern facades. While the daylight efficiency of 100 lx ≤ dominates 95% of the spaces, the lighting level of 300 lx ≤ did not occur for every hour of the spaces. At the same time, the overhangs built on the upper floor affected the lighting levels on the lower floor compared to those on the upper floor. On the other hand, the lighting levels and percentage values of the southern facade spaces are higher than the other facade spaces.

Table 1 Daylight performances of the ground floor spaces for March 21st

		The Illumination Level (Lx)			Daylight Factor (DF)			Daylight Performance Classification (%)		
	Hour	**Mean**	**Min**	**Max**	**Mean DF**	**Min DF**	**Max DF**	**100 lx ≤**	**300 lx ≤**	**500 lx ≤**
Z02	9:00	392.2 lx	224.2 lx	521.6 lx	8.72%	11.27%	7.45%	100%	79%	8%
	12:00	549.3 lx	319.2 lx	756.9 lx	12.21%	16.04%	10.81%	100%	67%	54%
	15:00	371.7 lx	225.1 lx	509.1 lx	8.26%	11.31%	7.27%	100%	69%	5%
Z03	9:00	103.5 lx	65.7 lx	154.2 lx	2.30%	3.30%	2.20%	50%	0%	0%
	12:00	219.3 lx	101 lx	296.1 lx	4.87%	5.08%	4.23%	100%	0%	0%
	15:00	226 lx	89.2 lx	326 lx	5.02%	4.48%	4.66%	98%	5%	0%
Z04	9:00	93.8 lx	62.3 lx	125.9 lx	2.08%	3.13%	1.80%	35%	0%	0%
	12:00	122.6 lx	83.7 lx	173.4 lx	2.72%	4.21%	2.48%	81%	0%	0%
	15:00	184.9 lx	136.6 lx	216.8 lx	4.11%	6.86%	3.10%	100%	0%	0%
Z05	9:00	400.4 lx	263.7 lx	485.6 lx	8.90%	13.25%	6.94%	100%	90%	0%
	12:00	438.7 lx	310.8 lx	623.5 lx	9.75%	15.62%	8.91%	100%	96%	25%
	15:00	223.8 lx	179.4 lx	276.5 lx	4.97%	9.02%	3.95%	100%	0%	0%
Z06	9:00	253.7 lx	168.8 lx	356.1 lx	5.64%	8.48%	5.09%	100%	21%	0%
	12:00	264.4 lx	162.8 lx	367 lx	5.88%	8.18%	5.24%	100%	29%	0%
	15:00	209.9 lx	123.3 lx	278.2 lx	4.66%	6.20%	3.97%	100%	0%	0%

When looking at the first-floor spaces for 21 March (Table 2), an increase in the lighting values of 300 lx ≤ and 500 lx ≤ is observed compared to the ground floor. In addition to south-facing spaces, there has been an increase in the average daylight level in spaces on north facades. At 12:00, lighting levels of 300 lx ≤ were observed in all rooms of the first floor. A lighting value of 100 lx ≤ is provided in almost all of the spaces. Except for the values measured at 15:00 in rooms 103 and 104, there are 300 lx ≤ lighting levels varying between 21% and 96%. On the other hand, for rooms 101, 102 and 104 facing south at certain times, the level of 500 lx ≤ is sufficient according to the standard. With the sunrise at 09:00, an average of 300 lx ≤ values are seen in the eastern and southern facades, while an average of minimum 200 lx lighting is provided on the northern and western facades. With the change of the angle of the sun at 15:00, the average values and the lighting percentages in the spaces vary according to different facades. In rooms 101, 102, 104 and 105, sufficient daylight levels required for living spaces are observed at 15:00.

Table 2 Daylight performances of the first-floor spaces for March 21st

		The Illumination Level (Lx)			Daylight Factor (DF)			Daylight Performance Classification (%)		
	Hour	**Mean**	**Min**	**Max**	**Mean DF**	**Min DF**	**MaxDF**	**100 lx ≤**	**300 lx ≤**	**500 lx ≤**
101	9:00	369.4 lx	224 lx	449.9 lx	8.21%	11.26%	6.43%	100%	85%	0%

	12:00	545.8	lx	319	lx	706.9	lx	12.13%	16.03%	10.10%	100%	96%	58%
	15:00	367.3	lx	195.4	lx	489.5	lx	8.16%	9.82%	6.99%	100%	73%	0%
102	9:00	197.9	lx	144.3	lx	229.9	lx	4.40%	7.25%	3.28%	100%	73%	0%
	12:00	363.3	lx	229.7	lx	426.6	lx	8.07%	11.54%	6.09%	100%	90%	0%
	15:00	346.8	lx	195.9	lx	416.9	lx	7.71%	9.84%	5.96%	100%	75%	8%
103	9:00	231.6	lx	93.1	lx	324.4	lx	5.15%	4.68%	4.63%	98%	21%	0%
	12:00	321	lx	118.9	lx	491.5	lx	7.13%	5.97%	7.02%	100%	58%	0%
	15:00	187.9	lx	79	lx	266.2	lx	4.18%	3.97%	3.80%	94%	0%	0%
104	9:00	353.5	lx	256.3	lx	438.8	lx	7.86%	12.88%	6.27%	100%	77%	0%
	12:00	368.6	lx	247.4	lx	607.4	lx	8.19%	12.43%	8.68%	100%	75%	13%
	15:00	189.6	lx	142.9	lx	258.1	lx	4.21%	7.18%	3.69%	100%	0%	0%
105	9:00	269.4	lx	172.7	lx	355.3	lx	5.99%	8.68%	5.08%	100%	31%	0%
	12:00	314.9	lx	233.6	lx	398.4	lx	7.00%	11.74%	5.69%	100%	54%	0%
	15:00	288.2	lx	183	lx	356.9	lx	6.40%	9.20%	5.10%	100%	40%	0%

When the ground floor spaces for 21 June are analyzed (Table 3), the highest values have emerged throughout the year. The illumination levels in rooms Z02, Z05 on the south facade and Z06 on the north facade were at the maximum level for each hour determined. Average minimum levels of 400 lx are the highest measured during the year. For other places, there is an increase in the limit values of 300 lx ≤ and 500 lx ≤ according to the specified hours. In all areas of the ground floor, the lighting level at 12:00 is on average 300 lx ≤. In this hour, 300 lx ≤ illumination level is provided at a rate of 16% to 98% of all spaces. Illumination level ≤ 100 lx is available in most rooms. 500 lx ≤ illumination level only for rooms Z02, Z05 and Z06. A maximum of 83% lighting is provided in these rooms. At 09:00, while 300 lx ≤ illumination values are observed in approximately 95% of the spaces in the east and south facades, these percentages vary between 20% and 45% in the other facades. At 15:00, the activity of the sun decreases. As of this hour, the average value measured in all spaces and the percentage of the rooms illuminated vary according to the facades, and the average lighting values are minimum 295 lx and maximum 550 lx.

Table 3 Daylight performances of the ground floor spaces for June 21

		The Illumination Level (Lx)						**Daylight Factor (DF)**			**Daylight Performance Classification (%)**		
	Hour	**Mean**		**Min**		**Max**		**Mean DF**	**Min DF**	**Max DF**	**100 lx ≤**	**300 lx ≤**	**500 lx ≤**
Z02	9:00	522.2	lx	309.5	lx	635.7	lx	11.60%	15.55%	9.08%	100%	96%	60%
	12:00	586	lx	135	lx	756	lx	13.02%	6.78%	10.80%	100%	98%	77%
	15:00	558.4	lx	314.8	lx	731.6	lx	12.41%	15.82%	10.45%	100%	96%	63%
Z03	9:00	143.9	lx	93.4	lx	221.4	lx	3.20%	4.69%	3.16%	94%	0%	0%
	12:00	296	lx	105	lx	404	lx	6.58%	5.28%	5.77%	100%	19%	0%
	15:00	295.6	lx	128.4	lx	461.8	lx	6.57%	6.45%	6.60%	100%	48%	0%
Z04	9:00	109.5	lx	74.1	lx	136.8	lx	2.43%	3.72%	1.95%	73%	0%	0%
	12:00	234	lx	118	lx	351	lx	5.20%	5.93%	5.01%	96%	16%	0%
	15:00	355.8	lx	208.8	lx	452.9	lx	7.91%	10.49%	6.47%	100%	88%	0%
Z05	9:00	571.4	lx	414.1	lx	662.9	lx	12.70%	20.81%	9.47%	100%	96%	83%
	12:00	477	lx	147	lx	626	lx	10.60%	7.39%	8.94%	100%	94%	56%
	15:00	297.3	lx	241.9	lx	365.9	lx	6.61%	12.16%	5.23%	100%	44%	0%
Z06	9:00	420.6	lx	239.2	lx	648.4	lx	9.35%	12.02%	9.26%	100%	75%	23%
	12:00	398	lx	91	lx	527	lx	8.84%	4.57%	7.53%	100%	86%	23%
	15:00	365.2	lx	193.3	lx	507.8	lx	8.12%	9.71%	7.25%	100%	71%	5%

When the first-floor spaces for the date of 21 June (Table 4), the highest values are emerged throughout the year as well. At 12:00, rooms 101, 102 and 104 provided an average of minimum

450 lx illuminance level. 500 lx ≤ illumination levels are provided for the rooms of 101, 102, 104 and 105 at 8% to 83% of their spaces. However, the percentage of illumination in the rooms varies depending on the time of day and the facades. Room 103 on this floor cannot reach an illuminance level of 500 lx ≤. Illumination percentages at 300 lx ≤ in rooms range from 12% to 100%. In all spaces, the illumination level of 300 lx ≤ maximum at 12:00. Again, illumination values of 100 lx ≤ dominate in all hours examined in all rooms. At 09:00 and 15:00, average minimum 290 lx and maximum 540 lx values were measured in all spaces of the first floor. In general, all floor spaces perform above the average according to the standard in the hours examined.

Table 4 Daylight performances of the first-floor spaces for June 21

		The Illumination Level (Lx)						Daylight Factor (DF)			Daylight Performance Classification (%)		
	Hour	Mean		Min		Max		Mean DF	Min DF	Max DF	100 lx ≤	300 lx ≤	500 lx ≤
101	9:00	463.9	lx	309.9	lx	562.9	lx	10.31%	15.57%	8.04%	100%	96%	27%
	12:00	588	lx	165	lx	726	lx	13.07%	8.29%	10.37%	100%	100%	83%
	15:00	541.7	lx	258.4	lx	695	lx	12.04%	12.98%	9.93%	100%	92%	61%
102	9:00	283.6	lx	213.6	lx	328	lx	6.30%	10.73%	4.69%	100%	35%	0%
	12:00	448	lx	120	lx	527	lx	9.96%	6.03%	7.53%	100%	100%	35%
	15:00	543.7	lx	300.8	lx	705.4	lx	12.08%	15.12%	10.08%	100%	96%	66%
103	9:00	291.1	lx	119.6	lx	416.9	lx	6.47%	6.01%	5.96%	100%	52%	0%
	12:00	160	lx	79	lx	447	lx	3.56%	3.97%	6.39%	91%	12%	0%
	15:00	319.9	lx	125.2	lx	499.5	lx	7.11%	6.29%	7.14%	100%	56%	0%
104	9:00	505.9	lx	365.6	lx	602.2	lx	11.24%	18.37%	8.60%	100%	96%	54%
	12:00	489	lx	106	lx	625	lx	10.87%	5.33%	8.93%	100%	93%	66%
	15:00	253.6	lx	189	lx	339.3	lx	5.64%	9.50%	4.85%	100%	13%	0%
105	9:00	486.9	lx	330.1	lx	626.7	lx	10.82%	16.59%	8.95%	100%	96%	46%
	12:00	195	lx	83	lx	576	lx	4.33%	4.17%	8.23%	100%	13%	8%
	15:00	466.4	lx	243.8	lx	638	lx	10.36%	12.25%	9.11%	100%	92%	46%

When the measured lighting levels on the ground floor rooms as of September 21 are examined (Table 5), the presence of the sun's activity in most of the spaces is argued. Average minimum 260 lx and maximum 610 lx values were calculated for all hours in places Z02 and Z05 facing south. The intensity of 500 lx ≤ illumination level in these spaces varies between 8% and 69% depending on the hours. In the same rooms, the intensity of 300 lx ≤ illumination level in the rooms reaches approximately 90%-95%. The illumination levels of rooms Z02, Z03, Z04 and Z06 on the north and west facades are minimum 120 lx and maximum 330 lx. Maximum 300 lx ≤ illumination level provides illumination in the space up to 96%. While the illumination levels of 100 lx ≤ 100 lx in the rooms are between 95% and 100% in general, this percentage decreases at different times in some places and remains insufficient compared to the standard. At 09:00 and 15:00 hours, the illumination levels and illumination percentages of the rooms change and decrease depending on the direction of sunlight.

Table 5 Daylight performances of the ground floor spaces for September 21st

		The Illumination Level (Lx)						Daylight Factor (DF)			Daylight Performance Classification (%)		
	Hour	Mean		Min		Max		Mean DF	Min DF	Max DF	100 lx ≤	300 lx ≤	500 lx ≤
Z02	9:00	479.8	lx	269.8	lx	623.1	lx	10.66%	13.56%	8.90%	100%	94%	40%
	12:00	617.3	lx	367	lx	814.7	lx	13.72%	18.44%	11.64%	100%	96%	69%
	15:00	467.5	lx	269.4	lx	651.4	lx	10.39%	13.54%	9.31%	100%	92%	33%
Z03	9:00	122.3	lx	79.7	lx	184.1	lx	2.72%	4.01%	2.63%	71%	0%	0%
	12:00	206.8	lx	112.1	lx	338.1	lx	4.60%	5.63%	4.83%	100%	6%	0%

	15:00	268.1	lx	108.1	lx	424.3	lx	5.96%	5.43%	6.06%	100%	31%	0%
Z04	9:00	104.9	lx	69.8	lx	136.3	lx	2.33%	3.51%	1.95%	67%	0%	0%
	12:00	127.3	lx	86.6	lx	173.1	lx	2.83%	4.35%	2.47%	85%	0%	0%
	15:00	252.5	lx	181.8	lx	298.9	lx	5.61%	9.14%	4.27%	100%	0%	0%
Z05	9:00	505.6	lx	334.9	lx	597.8	lx	11.24%	16.83%	8.54%	100%	13%	8%
	12:00	484.5	lx	358.6	lx	659.6	lx	10.77%	18.02%	9.42%	100%	94%	56%
	15:00	261.5	lx	209.6	lx	322.2	lx	5.81%	10.53%	4.60%	100%	13%	8%
Z06	9:00	332.9	lx	206.5	lx	475.9	lx	7.40%	10.38%	6.80%	100%	60%	0%
	12:00	310.9	lx	186.8	lx	434.8	lx	6.91%	9.39%	6.21%	100%	52%	0%
	15:00	271.1	lx	155.4	lx	364.2	lx	6.02%	7.81%	5.20%	100%	38%	0%

When the first-floor rooms are examined for the date of September 21 (Table 6), the natural lighting reaching to the rooms on this floor is higher compared to the ground floor. Looking at the rooms 102 and 103, daylight performance is significantly increased even at the same hours compared to rooms on the ground floor. This is due to the existence of overhangs builted on the upper floor. On the other hand, the lighting level on the ground floor is sufficient for the functionality of these spaces. In rooms 101, 102, 103 and 104 on this floor, the illumination level of 500 lx ≤ vary as of 11% to 73% of the rooms and varies according to the determined hours. These levels were not found in other places. While the illumination values of 300 lx ≤ in most of the rooms reach a maximum at 12:00, this situation changes depending on the facade orientation of the spaces at 09:00 and 15:00. In rooms 101, 102, 104 and 105 and at different hours, the average lighting values of 220 lx and maximum 600 lx were measured. In general, at 12:00, there is daylight activity at the level of 300 lx ≤ between 71% and 96%. Lighting values of 100 lx ≤ 100% are available in all spaces.

Table 6 Daylight performances of the first-floor spaces for September 21st

		The Illumination Level (Lx)						Daylight Factor (DF)			Daylight Performance Classification (%)		
	Hour	**Mean**		**Min**		**Max**		**Mean DF**	**Min DF**	**Max DF**	**100 lx ≤**	**300 lx ≤**	**500 lx ≤**
101	9:00	442.3	lx	268.4	lx	549	lx	9.83%	13.49%	7.84%	100%	93%	21%
	12:00	607.4	lx	356.1	lx	777	lx	13.50%	17.89%	11.10%	100%	96%	73%
	15:00	460.5	lx	229.7	lx	611	lx	10.23%	11.54%	8.73%	100%	88%	40%
102	9:00	237.1	lx	175.7	lx	283	lx	5.27%	8.83%	4.04%	100%	0%	0%
	12:00	410.9	lx	263.6	lx	477.5	lx	9.13%	13.25%	6.82%	100%	92%	0%
	15:00	446.1	lx	241.8	lx	561.9	lx	9.91%	12.15%	8.03%	100%	88%	23%
103	9:00	280.9	lx	110.5	lx	402.6	lx	6.24%	5.55%	5.75%	100%	50%	0%
	12:00	352.5	lx	132.3	lx	527.3	lx	7.83%	6.65%	7.53%	100%	71%	11%
	15:00	249.6	lx	100	lx	364.6	lx	5.55%	5.03%	5.21%	100%	40%	0%
104	9:00	449.5	lx	333.1	lx	547.8	lx	9.99%	16.74%	7.83%	100%	96%	19%
	12:00	410.8	lx	266.5	lx	639.7	lx	9.13%	13.39%	9.14%	100%	90%	21%
	15:00	221.5	lx	166.5	lx	300.9	lx	4.92%	8.37%	4.30%	100%	2%	0%
105	9:00	369.2	lx	257.8	lx	475	lx	8.20%	12.95%	6.79%	100%	85%	0%
	12:00	373.1	lx	235.5	lx	467.3	lx	8.29%	11.83%	6.68%	100%	85%	0%
	15:00	367.9	lx	197	lx	476	lx	8.18%	9.90%	6.80%	100%	77%	0%

Looking at the ground floor rooms for the date of 21 December (Table 7), the lowest illumination values are available throughout the year. With the decrease in the effect of sunlight and the duration of sunlight in the city together with the climate, the level of illumination in the spaces of natural light has also decreased. Maximum daylight to the spaces during the day was measured at 09:00 and 12:00 only on the south and east facades. When looking at these spaces, the lighting levels in the Z02 and Z05 rooms at the specified hours are between a minimum of 130 lx and a maximum of 400 lx on average. The illumination level of 500 lx ≤ in the rooms was measured as 20% at 12:00 only in the Z02 room. The average availability of day lightening for 300 lx ≤ values in these rooms is 75%. In Z03, Z04 and Z06 venues, on the other hand, due to their west and north orientation, they vary between the minimum 60 lx and maximum 135 lx levels according to the hours. For this reason, 500 lx ≤ and 300 lx ≤ levels, which should be found in these places according to the standard, could not be achieved. Expanded overhangs at certain rates on the upper floors also directly affected the lighting performance.

Table 7 Daylight performances of the ground floor spaces for December 21st

		The Illumination Level (Lx)						Daylight Factor (DF)			Daylight Performance Classification (%)		
	Hour	Mean		Min		Max		Mean DF	Min DF	Max DF	100 lx ≤	300 lx ≤	500 lx ≤
Z02	9:00	210.2	lx	128	lx	276	lx	4.67%	6.43%	3.94%	100%	0%	0%
	12:00	408	lx	111	lx	517	lx	9.07%	5.58%	7.39%	100%	77%	21%
	15:00	197.6	lx	129.7	lx	258.4	lx	4.39%	6.52%	3.69%	100%	0%	0%
Z03	9:00	61.7	lx	38.4	lx	91.6	lx	1.37%	1.93%	1.31%	0%	0%	0%
	12:00	135	lx	55	lx	203	lx	3.00%	2.76%	2.90%	96%	0%	0%
	15:00	115.3	lx	49.6	lx	151.1	lx	2.56%	2.49%	2.16%	84%	0%	0%
Z04	9:00	56.8	lx	38.6	lx	75.7	lx	1.26%	1.94%	1.08%	0%	0%	0%
	12:00	131	lx	78	lx	166	lx	2.91%	3.92%	2.37%	84%	0%	0%
	15:00	91.5	lx	70.2	lx	108.4	lx	2.03%	3.53%	1.55%	23%	0%	0%
Z05	9:00	199.9	lx	137.8	lx	240.4	lx	4.44%	6.92%	3.43%	100%	0%	0%
	12:00	326	lx	71	lx	427	lx	7.24%	3.57%	6.10%	100%	73%	0%
	15:00	136.1	lx	109	lx	167	lx	3.02%	5.48%	2.39%	100%	0%	0%
Z06	9:00	128.3	lx	86.9	lx	179.2	lx	2.85%	4.37%	2.56%	81%	0%	0%
	12:00	193	lx	63	lx	251	lx	4.29%	3.17%	3.59%	100%	0%	0%
	15:00	112.6	lx	66.7	lx	153.1	lx	2.50%	3.35%	2.19%	71%	0%	0%

Looking at the first-floor spaces for 21 December (Table 8), the lowest illumination values of the year were also measured. In this floor, a slight increase in values is observed compared to the ground floor. While the 500 lx ≤ illumination level in the spaces is taken as 20% only for the room 101, the 300 lx ≤ values are observed to vary between 6% and 91% of the rooms 101, 102, 103 and 104 at different times and are valid for all places at 12:00. This performance could not be achieved for other times. Looking at the rooms on the floor, the highest sun light activity was reached at 12:00 in rooms 101 and 104 on the south side. It averages between a minimum of 110 lx and a maximum of 380 lx. It varies between a minimum of 90 lx and a maximum of 200 lx in these venues for 09:00 and 15:00. Considering the daylight performances in other rooms, 300 lx ≤ values cannot be achieved, but 100 lx ≤ illumination levels vary according to hours. The values of 100 lx ≤ in the spaces show an efficiency between 46% and 100% depending on the facades and are insufficient compared to the standard.

Table 8 Daylight performances of the first-floor spaces for December 21st

		The Illumination Level (Lx)						Daylight Factor (DF)			Daylight Performance Classification (%)		
	Hour	Mean		Min		Max		Mean DF	Min DF	Max DF	100 lx ≤	300 lx ≤	500 lx ≤
101	9:00	200.4	lx	128.2	lx	246.3	lx	4.45%	6.44%	3.52%	100%	0%	0%
	12:00	380	lx	95	lx	477	lx	8.44%	4.77%	6.81%	100%	91%	20%
	15:00	194.9	lx	114.8	lx	248.5	lx	4.33%	5.77%	3.55%	100%	0%	0%
102	9:00	117.1	lx	83.9	lx	136.8	lx	2.60%	4.22%	1.95%	88%	0%	0%
	12:00	252	lx	69	lx	287	lx	5.60%	3.47%	4.10%	100%	18%	0%
	15:00	176.8	lx	109.7	lx	213	lx	3.93%	5.51%	3.04%	100%	0%	0%

103	9:00	118.8	lx	50.4	lx	158.9	lx	2.64%	2.53%	2.27%	73%	0%	0%
	12:00	115	lx	57	lx	371	lx	2.56%	2.86%	5.30%	62%	6%	0%
	15:00	92.2	lx	41.7	lx	126.5	lx	2.05%	2.10%	1.81%	46%	0%	0%
104	9:00	172.9	lx	124.5	lx	216.6	lx	3.84%	6.26%	3.09%	100%	0%	0%
	12:00	296	lx	73	lx	383	lx	6.58%	3.67%	5.47%	100%	58%	0%
	15:00	114.7	lx	87.5	lx	154.8	lx	2.55%	4.40%	2.21%	84%	0%	0%
105	9:00	144.2	lx	103.9	lx	183.2	lx	3.20%	5.22%	2.62%	100%	0%	0%
	12:00	106	lx	40	lx	272	lx	2.36%	2.01%	3.89%	62%	0%	0%
	15:00	145.2	lx	91.8	lx	180.8	lx	3.23%	4.61%	2.58%	98%	0%	0%

7. Results

The traditional Hubiyar Korucu Mansion is one of the important examples of Sivas civil architecture. At the same time, it is an exemplary building where the correct design decisions are made in terms of natural lighting and mostly positive results are obtained according to the reference standard. The importance of correct window designs has emerged in this mansion structure, which bears the traces of traditional Turkish houses. In this study, the traditional Turkish architectural structure is analyzed with the Velux Daylight Visualizer Simulation program and evaluated according to the "EN17037 Standard". Considering the annual analyzes, the visual comfort criteria related to daylight are mostly met in every space, except for some days and hours.

In the first evaluation, average daylight is dominant in all spaces of the ground and first floor. The daylight level of the spaces on the south facades is higher than on the north facades. This value on 21 June is the highest compared to other dates. On December 21, the lighting level of the places is the lowest compared to other dates. According to the EN 17037 standard, the lighting level of the places are insufficient and below the limit on December 21. South facade spaces mostly provided an average of 300 lx lighting levels and have high performance compared to the reference standard. The daylight level on the northern facades is insufficient compared to the standard value of some dates. Daylight illumination values in all places are at the highest level at 12:00. At 09:00 and 15:00, these values decrease. Lighting level of 100 lx ≤ in all rooms of the building is provided in approximately 95% of the spaces. For 21 December, the illumination levels of 500 lx ≤ and 300 lx ≤ do not dominate the spaces due to climatic conditions. In this case, the appearance of this illumination level in 95% of the space is insufficient compared to the reference standard. Illumination level ≤ 300 lx is available in more than half of the rooms in the south-facing rooms and on 21st June in the north-facing rooms. On the other hand, 500 lx ≤ illumination level is provided at an average of 50% on 21 June in the south facades. The minimum, maximum and average percentage values of the daylight factor are calculated according to the illumination levels obtained from the simulation. According to the reference EN 17037 standard, although the necessary visual comfort conditions for the mansion spaces cannot be provided in some days and hours, mostly natural light is at average levels in every space. At the same time, the ceiling height of the spaces, the number of windows in the rooms and their dimensions directly affect the natural lighting levels of the mansion spaces. Large windows designed even in the small rooms of the building provide high levels of illumination to the spaces. The absence of a shading element such as blinds outside the window and obstacles that directly block the daylight around the building are also other factors affecting the level of illumination.

Architectural designs and parameters that increase daylight in traditional houses differs from contemporary buildings. In Table 9, the similarities and differences between the Hubiyar Korucu Traditional Mansion and the Sivas Cumhuriyet University Residences according to architectural parameters are discussed (Table 9). The measurements in the table are evaluated in the smallest units of the structures compared.

Table 9 Comparison of the main differences/similarities between contemporary and traditional architecture with architectural parameters

Parameters / **Buildings**	Window Dimensions (width x height)	Window Above Ground	Number of Windows in the Space	Total Span in Space	Floor Height of the Space	Space Dimensions (width x length)	Spatial Depth	Extension	Structural Barriers
Hubiyar Korucu Traditional Mansion	0.9 m x 1.70 m	0.9 m	4	6.12 m2	3.54 m	3.70 m x 3.75 m	13.8 m2	0.6 m	No
Cumhuriyet University Housing	2.0 m x 1.30 m	0.8 m	1	2.6 m2	2.66 m	2.85 m x 4.0 m	11.4 m2	No	No

According to the reference rooms, there are 4 windows in the traditional residence and 1 window in the contemporary lodging structure. Depending on the width and height of the windows, the total opening in the spaces changes. Compared to contemporary one it is seen that the window sizes in the traditional house are smaller. However, the large number of windows in the traditional mansion space has increased the total window opening in the room approximately 2.5 times compared to the contemporary building. Although the spatial depth dimensions of the two compared rooms are like each other, it is likely that the total window opening difference significantly affects the daylight performance in the space. This deficiency seen in contemporary buildings can cause negative results in terms of both psychological comfort and energy saving.

By this study and the results of the analysis, it is revealed that traditional design principles can be a guide in contemporary building design process, especially in residential buildings. Because the studies that examine the natural lighting in traditional Turkish residences are limited, this study has a remarkable and original contribution to the existing Traditional Turkish House studies.

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