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Article

The effect of building height and street width on indoor daylight performance according to the town planning code – office buildings for the case of Istanbul and Adana

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ABSTRACT

Due to the concept of sustainability, it has become increasingly important to reduce the energy burden of lighting by promoting the use of natural light. In daylighting design, there are several variables that affect the performance of daylight indoors. "External obstructions," which is one of the variables that significantly affect daylight penetration into the volume, are often limited by legislation such as the zoning plan/ordinance, etc. of the city/settlement. In this article, non-structural obstructions at different heights and distances were first determined for attached office buildings within the scope of the "Planned Areas Type Zoning Regulation" in force in Türkiye. The daylight performance of these spaces in the attached structures of office spaces of 2-storey (B2), 5-storey (B5), and multistorey buildings in Istanbul and Adana were investigated according to TS EN 17037, considering the four window directions (K – North, D – East, G – South, and B – West), three light transmission factors (0.8, 0.6, and 0.4), and a transparency ratio of 0.3. Among the optimal options identified for the office buildings considered in the study, the most positive situations were identified among those with appropriate daylight and luminance according to the function, according to the criteria of TS EN 17037. For the scenarios without negative daylight criteria, suggestions were made to improve integrated lighting systems where natural and artificial lighting coexist. Thus, the performance of the daylight entering the volume would be determined at the design stage and the energy to be spent on artificial lighting could be reduced.

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INTRODUCTION

Sustainability and green design concepts have become increasingly important in recent years due to the decreasing cost of energy resources and the negative impact of energy consumption (Çelik, 2018; Uyan, 2010). The concept of sustainability in lighting design is defined as meeting the visual environment needs with the least impact on the natural environment (Yılmaz, 2019).

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Physical comfort conditions, sustainability, and efficient energy use should also be considered in the design of offices that are actively used during daylight hours. The aim should be to reduce the energy burden of lighting by encouraging the use of natural lighting (Sakınç, 2006). The standard TS EN: 17037:2021, which defines performance criteria for the use of daylight as a passive system in buildings, includes the criteria established to evaluate the performance of daylight in buildings and the methods established to evaluate the performance of daylight (Yener, 2007).

In TS EN 17037:2021 daylighting in buildings, for the whole year is considered, and the idea is that daylight illuminates volumes for a significant part of the year. Daylighting design should therefore be carried out at three successive levels: Settlement scale, building scale, and volume scale (Altuğ-Turan, 2010). Variables that affect daylighting within volumes within the volume scale are listed as follows:

- Type and power of natural light sources
- Characteristics of non-volume obstructions (size, location, light reflectance factor, light reflectance pattern, etc.)
- Ground cover characteristics (light reflectance factor and light reflectance pattern)
- Characteristics of daylight openings (windows) (size, position, number, light transmission factor of the glass, type of light transmission, contamination of the glass, and effective glass area [thickness of the glazing])
- Characteristics of the volume (size, location of observation point, light reflectance of surfaces and shape of surfaces, and contamination of interior surfaces) (Yılmaz, 2019).

One of the variables that have a significant impact on the amount of daylight entering a space is "external obstructions," which, depending on their size and position, reduce the amount of daylight by preventing direct sunlight and skylight from entering the space, while at the same time contributing to the brightness of the interior to some extent by reflecting light from the sun, sky, and earth (Yılmaz, 2019). The size and location of the building in which the volume is located (Özkaynak, 2005), and the size and location of the structures that create the artificial barriers around it, are often limited by laws such as the zoning plan/ordinance, etc. of the city/settlement. In terms of natural lighting design, it is not possible to design or control obstructive features (Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2022).

The aim of this study is to determine the effect of external obstructions at different heights and distances on the performance of daylight entering the volume and to reveal the data that can be used in natural lighting design. It would provide appropriate solutions in terms of both visual comfort and efficient use of energy through sustainable design proposals in terms of changes in features such as the dimension and location of external obstructions and space together. In this way, the effect of the variables that affect the daylight entering the volume and the daylight existing within the volume would be determined at the design stage.

The article discusses the issue of daylighting, the characteristics of which are defined in the TS EN 17037:2021 daylight in buildings standard, in the context of office spaces in Istanbul and Adana according to the "Planned Areas Zoning Regulation/Adjacent Building" (Üzmez, 2009; Kayacı, 2015; Arslan-Çinko & Eres, 2018; Şahin & Saban, 2020). The office spaces in question were analyzed according to the criteria of the standard. In this context, a brief explanation of the daylight standard is given first, followed by the postulates of the study, the findings, and suggestions.

TS EN 17037:2021 DAYLIGHT STANDARD IN BUILDINGS

TS EN 17037:2021 Standard contains the established criteria for the evaluation of daylighting performance in buildings and methods that can be used in the evaluation of daylighting performance. According to the standard, the criteria for the use of daylight in spaces that are used for long periods and visual tasks performed in all types of buildings, including dwellings, are discussed under four subheadings:

- Daylight Provision
- Protection from Glare
- Assessment for View Out
- Exposure to Sunlight.

Brief explanations of these criteria are given below.

Daylight Provision

As far as possible, daylight should be used to meet lighting requirements within the volume. In this context, barriers outside the volume should be designed to ensure that sufficient daylight enters the volume throughout the year, as required by the regulations.

TS EN 17037 2021 "Daylight Standard in Buildings" recommends three different levels of illuminance minimum, medium, and high (Table 1). Two methods are suggested for calculating daylight illuminance in volume. The first is to use the daylight factor. The second calculation method is based on calculating the illuminance at the calculation points defined on the reference plane in hourly steps throughout the year, using the climatic data of the region where the building is located. The results obtained using this approach are analyzed to check that the required illuminances are achieved at ≥50% and ≥95% of the reference plane for ≥2190 h of the year (Öztürk, 2018).

Table 1. Recommended Degrees in Terms of Illuminance Level for TS EN 17037 Daylight Benefit (TS EN 17037+A1:2021, 2021)

Recommendations for daylight provision in a space	Required level	
	≥50% of the reference plane	≥95% of the reference plane
Minimum	≥300 lux	≥100 lux
Medium	≥500 lux	≥300 lux
High	≥750 lux	≥500 lux

Protection from Glare

Glare is defined as the discomfort caused by the intrusion of high-luminance surfaces into the visual field (Öztürk, 2018). Glare in a room can be caused by direct sunlight entering through a window as well as by the high luminance difference between the high-luminance sky visible from the window and the work area.

Daylight glare is assessed by the daylight glare probability (DGP) in TS EN 17037. The recommended "DGP Thresholds (DGPt)" for the three levels of glare control are given in Table 2. The reference occupancy period is defined as the period during which the area of the room is predominantly occupied throughout the year. This period is assumed to be 8:00–18:00, five working days a week throughout the year.

The maximum allowable threshold for the possibility of daylight glare should not exceed 5% of the reference period. For example, the defined minimum protection level of 0.45 can be exceeded in a maximum of 130 h of the annual reference period – i.e., 2600 h (52 weeks×5 days×10 h) (Öztürk, 2018).

Table 2. TS EN 17037 Recommended Degrees of Glare Protection (TS EN 17037+A1:2021, 2021)

Criterion DGP	
Glare is mostly not perceived	DGP≤0.35
Glare is perceived but mostly not discomfort	0.35<DGP≤0.40
Glare is perceived and often discomfort	0.4<DGP≤0.45
Glare is perceived and mostly intolerable	DGP≥0.45

Assessment for View Out

Visual contact with the outside world fulfills human needs such as information about the location and surroundings of the building, monitoring weather conditions and the passage of time during the day, as well as providing physiological relaxation by resting the eyes and psychological relaxation. The quality of the image entering the field of vision depends on the size of the window, the distance of the person from the window, the number of visible layers, and the content of the perceived environment. Depending on the use of the volume, the windowpane at the eye level of a seated or standing person should be transparent and neutral in color. The image within the field of vision can include three different layers: Sky, natural and/or artificial landscape, and ground (Öztürk, 2018).

In terms of the quality of the visual connection with the outside environment, three levels were defined as minimum, medium, and high (Table 3).

Exposure to Sunlight

For the evaluation of sunshine duration, 21 March was chosen as a reference and it is stated that the volume should receive at least 1.5 h of sunlight on that day. Assuming cloudless sky conditions three degrees of sunshine duration are suggested as minimum, medium, and high as shown in Table 4.

METHOD OF WORK AND ASSUMPTIONS

One of the most important parameters influencing the level of illuminance inside the volume is the "outside obstructions," which is one of the variables that significantly affect the amount of daylight entering the volume. Natural or artificial obstacles outside the volume can be considered

Table 3. TS EN 17037 Recommended Degrees for Visual Connection with the Outdoor Environment (TS EN 17037+A1:2021, 2021)

Variables	Degree of visual connection		
	Minimum	Medium	High
The angle of vision based on the window width	≥14°	≥28°	≥54°
Distance of external obstructions	≥6 m	≥20 m	≥50 m
Layers required to be seen more than 75% of the used area sky, andscape, and ground	Including landscape layer	At least two layers included	All layers included

Table 4. TS EN 17037 Recommended degrees for sunshine duration (TS EN 17037+A1:2021, 2021)

Level of recommendation for exposure to sunlight	Sunlight exposure
Minimum	1.5 h
Medium	3 h
High level of sunshine duration	>4 h

uncontrollable factors in natural lighting design. This is because the size and location of the building in which the volume is located, and the size and location of the structures that create the artificial obstructions around it, are often determined by legal constraints such as the zoning plan/ordinance, etc. of the city/settlement.

While the "Planned Areas Type Zoning Regulation" in force in our country limits the height of the obstruction and the width of the road, it does not give any information about the length of the obstruction. According to the "Planned Areas Type Zoning Regulation," the relationship between the maximum road width and the maximum building height is given in Table 5.

In this study, the effect of two street widths and two building heights on the amount of daylight entering the volume was evaluated by TS EN 170307-2021 for the office spaces assumed to be in Istanbul and Adana according to the "Planned Areas Type Zoning Regulation."

The methodology of the study could be listed as follows.

- To determine the size and location of out-of-volume obstructions using the street width and building heights given in the zoning regulation
- Limiting characteristics such as the size of office space and light reflection factor of the interior surface

Table 5. According to the "Planned areas type zoning regulation" maximum road width maximum building height ratio (Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2022)

Max. Road Width (m)	Max. Coefficient	Max. Building Height (m)
≤7.00	2	7.2
7.00 <Road W.≤10.00	3	10.8
10.00 <Road W.≤12.00	4	14.4
12.00 <Road W.≤15.00	5	18
15.00 <Road W.≤20.00	6	21.6
20.00 <Road W.≤25.00	8	28.8
25.00 <Road W.≤35.00	10	36
35.00 <Road W.≤50.00	14	50.4
50.00 <Road Width	18	64.8

- To define the orientation and characteristics of the windows in the office space
- To analyze the daylighting performance in the room according to the four criteria given in the standard "TS EN 17037:2021 Daylighting in Buildings" for the assumptions made by the determination, restriction, and definitions.
- Identify the situations with optimal performance according to the results of the analysis
- To make suggestions for improving situations that do not meet the necessary conditions in terms of the daylighting criteria given in the standard.

The assumptions made in the study regarding the analysis of the presence of daylight belonging to a space in the office structure in question are presented in Table 6, and the abbreviation and coding information are presented in Table 7 (Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2022).

RESULTS OF CALCULATION

The issue of daylighting, which is defined in the TS EN 17037:2021 standard of daylight in buildings, is discussed in the context of the office function for Istanbul and Adana sky conditions by the "Planned Areas Zoning Regulation/adjacent buildings."

- Daylight Provision
- Assessment for ViewOut
- Exposure to Sunlight
- Protection from Glare.

A review of office spaces included in the standard for the above criteria is given below.

Daylight Provision

Natural illumination levels in the volume for 2-storey (B2) and 5-storey (B5) adjacent buildings in Istanbul and Adana are calculated for four window directions (N, W, S, and E), three light transmission factors (LTF 0.8, 0.6, and 0.4) and TR 0.3, using the Rhino/Climate Studio simulation program, which takes into account the meteorological data of Istanbul and Adana. For IST-B2, IST-B5, ADN-B2, and ADN-B5, the minimum and desired illuminance levels for four directions (N, E, S, and W) and three light transmission factors (LTF 0.8, 0.6, and 0.4) the annual ensuring times (%) at the workplaces were calculated. The obtained results are presented in Figure 1-4.

Assessment for View Out

Within the scope of TS EN 17037:2021 standard, the visible layer of external environment properties is evaluated in three different categories as sky, artificial/natural environment. Ground and external view evaluation is

Table 6. Basic Assumptions Accepted in the Study

Basic assumptions used	City	Istanbul, Adana	Solar control element	YOK	Floor light reflectance factor	0.3
	Obstruction height	**7.2 m, 18 m**	**Room Height (OH)**	3 m	**Ceiling Reflection Factor**	0.7
	Direction	North, South, East, and West	**Transparency Rate**	0.3	**Wall Reflection Factor**	0.5
	Obstruction distance	7m, 15m	**Window Height**	1.5 m	**Light Transmission Factor**	0.8, 0.6, and 0.4 (6 mm double glass+13 mm air gap.)
	Obstruction light reflection factor	0.3	**Window Width**	3 m	**Glass Pollution Factor**	0.8
	Ground cover light reflection factor	0.2	**Parapet Height**	0,85m	**Working Plane Height**	0.85 m, 1.2 m
	Room Width/Depth	**5 m×3 m**	**Lintel Height (lh)**	0,65 m	**Working Plane Grid Spacing**	0.67 m×0.44 m
	Wall Thickness	**0.2**	**Joinery Thickness Factor**	0.85	**Internal Surfaces Pollution Factor**	0.9

Table 7. Abbreviations and coding accepted in the study

City	**Direction (D)**	**Light transmission factor (LTF)**	**Transparency rate (TR)**	**According to the number of floors, distance, and height of the building**		**Floor location code**	
ISTANBUL	NORTH	0.8	0.3	2-STOREY BUILDING: 7m Road Width/7,2 m Obstruction Height	B2	GROUND FLOOR	F0
ADANA	SOUTH EAST WEST	0.6 0.4		5-STOREY BUILDING: 15m Road Width/18 m Obstruction Height	B5	FIRST FLOOR	F1
						SECOND FLOOR	F2
						THIRD FLOOR	F3
						FOURTH FLOOR	F4

Example scenario related to coding IST-K-LTF 0.8-S0 0.3-B2-K0: Istanbul-Northern Facade-Light Transmission Factor 0.8-Transparency Rate 0.3-2 Storey Building B2-Ground Floor K0; ADN-D-LTF 0.4-S0 0.3-Y5-K4: Adana-Eastern Facade-Light Transmission Factor 0.4-Transparency Rate 0.3-5-Storey Building Y8 Fourth Floor K4

carried out according to the qualities of the layers that are seen from at least 75% of the used space.

In the study, based on the "Planned Areas Zoning Regulation" for IST-ADN -B2 and B5, attached office spaces are shown in the section in Figures 5-7. Layers falling into the visual space of IST-ADN-B2 and B5 adjacent office spaces were determined, and the horizontal visual connections were evaluated.

To determine the illumination distribution within the volume, a grid system according to TS EN 12464-1 was used on the horizontal working plane at a height of 0.85 m above the floor for the location of observation points. For glare control, observer points were used at a height of 1.2 m above the floor in the occupied area of the volume. They are illustrated in Figures 5-7.

In the study, in the scope of "Planned Areas Zoning Regulation," the layers of the office space – which is inspected as IST-ADN-B2 and B5 adjacent buildings and shown in section in Figures 5, 6, and 7 entering the visual field determined and summarized in Table 8 by evaluating the horizontal visual connection.

Sun Exposure Time

According to the TS EN 17037:2021 standard stated that for the sunshine duration criterion, at least 1.5 h of sunlight on 21st March should be received. The solar orbit diagram for Istanbul on 21st March (41° N latitude and 29° longitude) and Adana (37° N latitude and 35° longitude) is presented in Figure 8.

Figure 1. Annual Ensuring Time of Minimum and Desired Illuminance Levels for IST-B2-N,E,S,W -LTF 0.8,0.6,0.4 and TR 0.3 in Work Spaces on Each Floor (%).

Using the diagram given in Figure 8, the sunshine durations of the building for Istanbul conditions were calculated for four directions (K – North, G – South, D – East, and B – West) and different times (sunrise, 09.00, 12.00, 15.00, and sunset). They are shown in Figure 9.

It has been observed that there is a 26-min difference between sunrise and sunset times for Istanbul (sunrise, co-rise: 07.06, and sunset: 19.16) and Adana (sunrise:

Figure 2. Annual Ensuring Time of Minimum and Desired Illuminance Levels for IST-B5-N,E,S,W-LTF 0.8,0.6,0.4 and TR 0.3 in Work Spaces on Each Floor (%).

06.40 and sunset: 18.50). If the building in the example of Istanbul was in Adana, it would not make a difference in terms of total sunshine duration for 21 March. When the windows of the office space of cases B2, and B5 are evaluated according to Figures 8 and 9 for 21st March below results are reached:

- It is seen that the building is not exposed to direct sunlight on the north façade

Figure 3. Annual ensuring time of minimum and desired illuminance levels for ADN-B2 N,E,S,W-LTF 0.8,0.6,0.4 and TR 0.3 in workspaces on each floor (%).

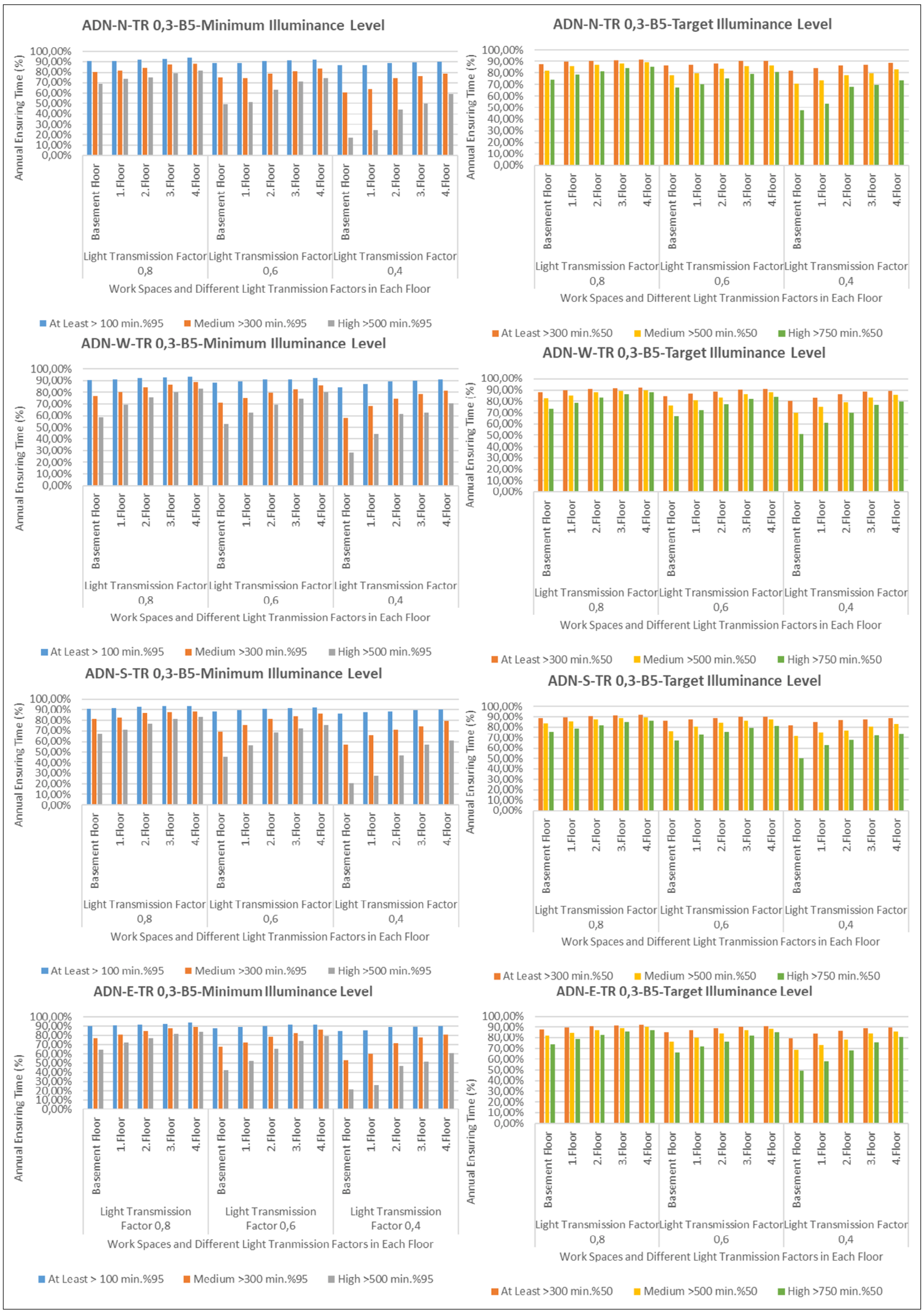

Figure 4. Annual ensuring time of minimum and desired illuminance levels for ADN-B5 N,E,S,W-LTF 0.8,0.6,0.4 and TR 0.3 in workspaces on each floor (%).

- On the southern facade of B2, B5, and each floor receives direct sunlight approximately between 11.00 and 15.00
- On the western facade of B2, B5, and each floor receives direct sunlight effectively from 15.00 in the afternoon until sunset
- On the eastern facade B2, B5, and each floor receives direct sunlight approximately from sunrise to 12.00–12.30.

Protection from Glare

In this study, the four window orientations (N, E, S, and W) and three light transmittance factors (0.8, 0.6, and 0.4) of adjacent 2 (Y2), 5 (Y5) buildings in Istanbul and Adana

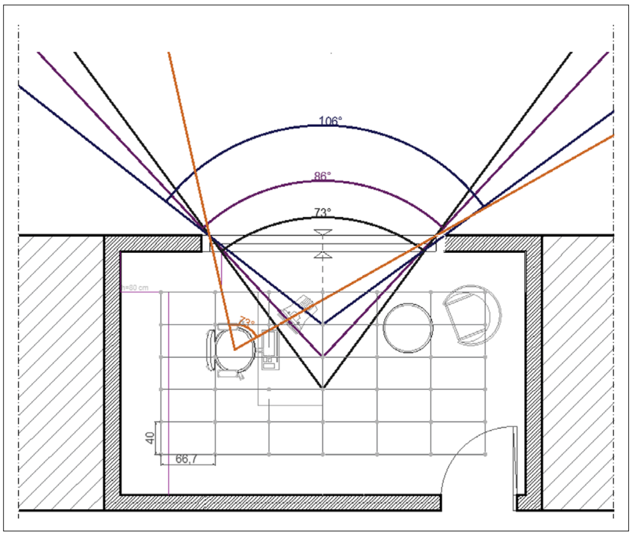

Figure 5. Observer Positions in the Horizontal Plane for IST-ADN-B2 and B5.

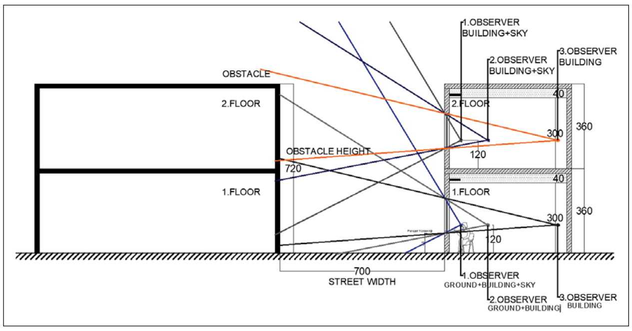

Figure 6. Determination of İST-ADN B2/visual layers

were considered and the DGP values were calculated using the Rhino/Climate Studio simulation program, taking into account the meteorological data of Istanbul and Adana. The graphs of the change (%) of the determined annual DGP values according to the annual supply time in the workspaces on each floor for the North, South, East, and West light transmittance multipliers of 0.8, 0.6, and 0.4 are presented in Figure 10 for İstanbul (IST) and Adana (ADN).

Evaluation of Figure 10 gives the following results.

- On the North-facing facade, discomfort glare is observed for less time than on the other facades
- The glare on the South and West facades is quite high for the reference clocks taken
- The entrance and lower floors of the buildings were found to have less discomfort glare in all directions compared to other floors
- The presence of barrier structures was effective in reducing the glare observed on the ground floor
- As the light transmittance decreases, so does the glare. In particular, when the light transmission rate is 0.4, there are situations with a high level of glare control
- Discomfort glare is observed for a longer period in Adana than in Istanbul.

EVALUATING RESULTS OF CALCULATION

Considered under the same conditions for Istanbul and Adana, the attached office structure has been compared for the parameters of providing sufficient daylight illumination, establishing a visual connection with the

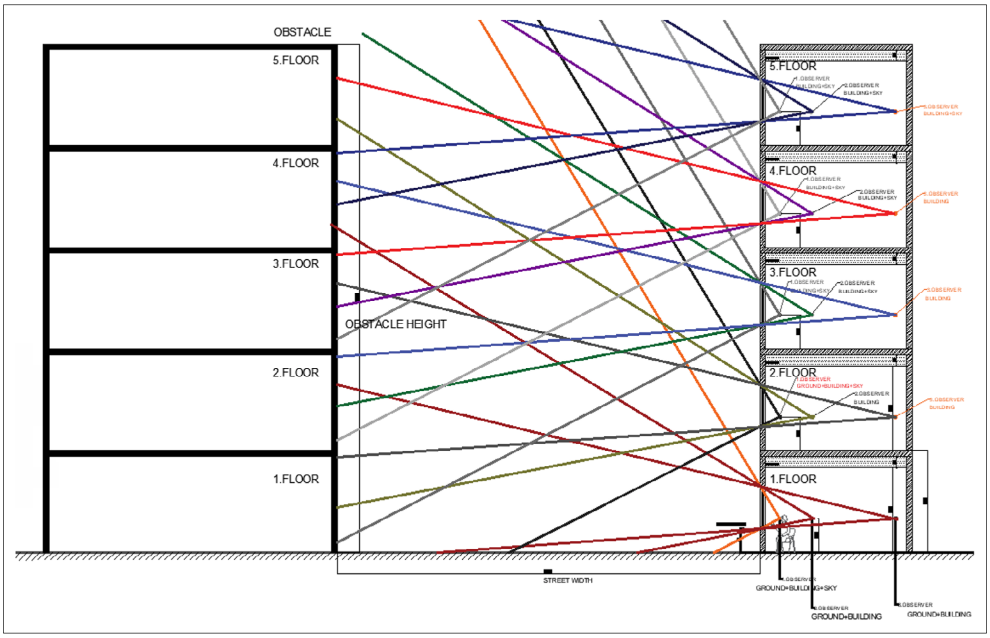

Figure 7. Determination of İST-ADN B5/visual layers.

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Table 8. Layers according to observer points in IST-ADN B2 and B5

Visible layers-IST-ADN	1st OBSERVER	2nd OBSERVER	3rd OBSERVER
B2 Obstruction Height 7.2 m/Road Width 7 m			
BASEMENT FLOOR	GROUND+BUILDING+SKY	GROUND+BUILDING	BUILDING
FIRST FLOOR	BUILDING+SKY	BUILDING+SKY	BUILDING
B5 Obstruction Height 18.8 m/Road Width 15 m			
BASEMENT FLOOR	GROUND+BUILDING+SKY	GROUND+BUILDING	BUILDING
FIRST FLOOR	BUILDING+SKY	BUILDING+SKY	BUILDING
SECOND FLOOR	BUILDING+SKY	BUILDING+SKY	BUILDING
THIRD FLOOR	BUILDING+SKY	BUILDING+SKY	BUILDING
FOURTH FLOOR	BUILDING+SKY	BUILDING+SKY	BUILDING+SKY

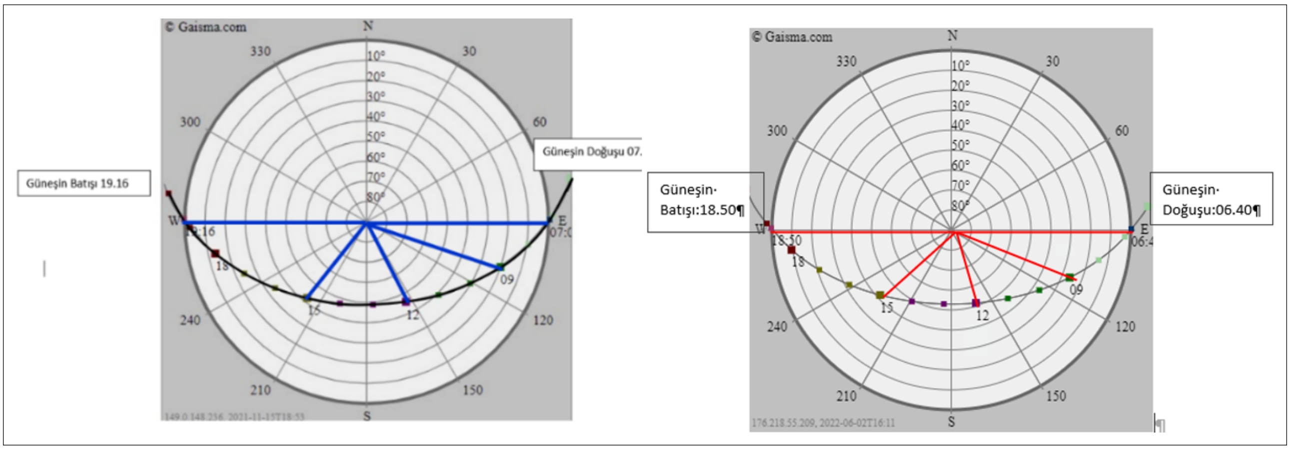

Figure 8. Istanbul and Adana 21 March Solar Orbit Diagram (Gaisma, 2023).

external environment, sun exposure time, and control of daylight-related glare by TS EN 17037. Relative evaluation results are evaluated for below cases,

- Obstruction height, road width, transparency rate, direction, light transmission factor are fixed, and cities change
- Obstruction height, road width, city, and transparency rate are fixed, and window directions change
- Obstruction height, road width, city, and transparency ratio are fixed, and window glass light transmission factor change
- Obstruction height, road width, transparency rate, direction, light transmission factor are fixed, and cities change.

Sufficient daylight is provided in Adana at a higher rate than in Istanbul. It has been observed when similar conditions occurred illuminance level of the target is usually medium in Istanbul – especially for the ground floor – however, for the same conditions lighting level of the target is high in Adana.

It has been observed that glare is higher in Adana than glare in Istanbul.

The fact that the sun has a 26-min difference between the sunrise and sunset times for Istanbul and Adana did not make a difference in the total sunshine duration. The sun exposure time is the same for each floor of the two buildings. The case of handling different cities did not make any difference in terms of visual connection.

Obstruction height, road width, city, transparency rate are fixed, window directions change

Since the northern facade does not receive direct sunlight, the lighting levels are rated as insufficient functionally, while the glare values are lower than the other facades. While the illuminance levels in the reference plane considered on the Southern, Eastern, and Western facades are sufficient for the functionality, results for discomfort glare are negative.

As the Northern facade does not receive direct sunlight, the sunshine duration is minimal.

As the Southern facade is exposed to direct sunlight most of the day, it has a high degree of sun exposure. While there is generally a high level of sun exposure on the Eastern and Western facades, this situation decreases to the middle level only on the ground floors.

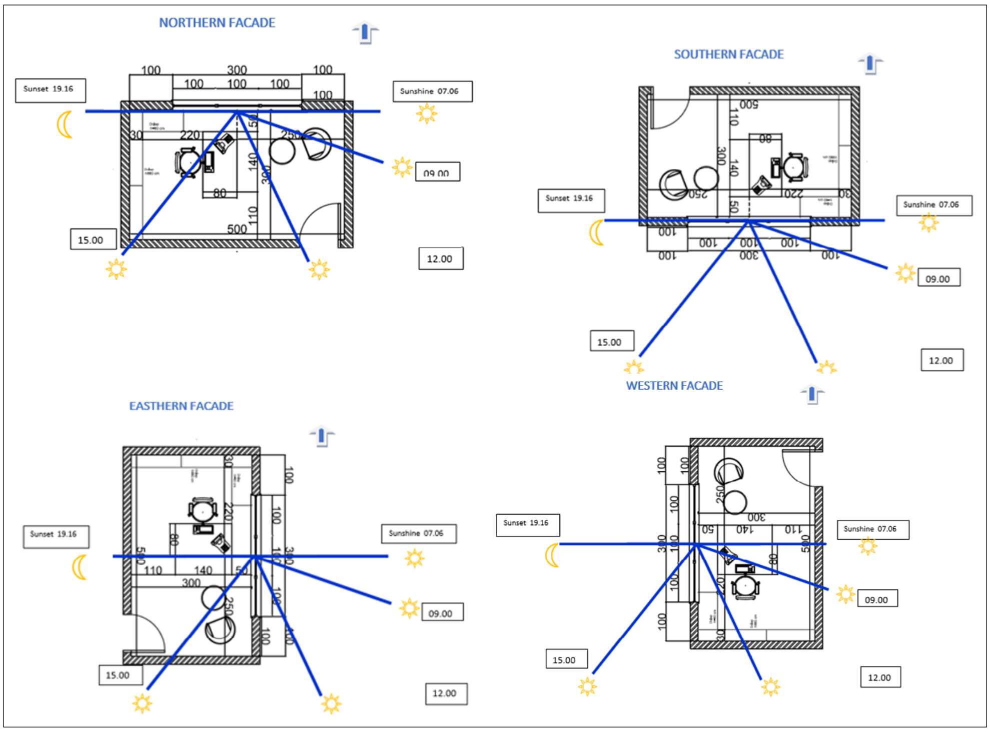

Figure 9. IST/four cardinal points/B2 and B5/obstruction height 7.2, 18 m/road width 7 and 15 m/h sun exposure status on 21 March.

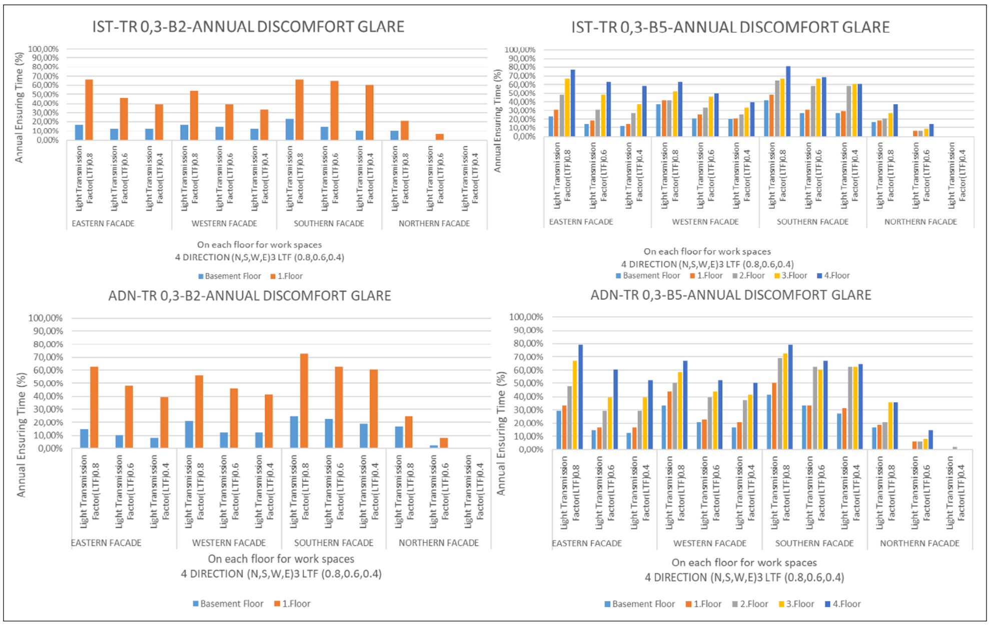

Figure 10. Available duration of annual daylight glare probability values for İST-B2 and B5 and ADN-B2 and B5-N,W,E,S-LTF 0.8,0.6,0.4 at workspaces on each floor (%).

Obstruction height, road width, city, transparency ratio are fixed, window glass light transmission factor change

As the light transmission factor of the window glass decreases, the lighting level and daylight glare values decrease. While this situation produces positive results for glare, it causes negative consequences for the level of lighting required for the function. Especially for lower floors, integrated lighting is needed for cases where the light transmission factor is 0.6 and 0.4.

The matter of establishing a visual connection with the external environment has the same evaluation for all conditions with road width, obstruction height, and floor height.

EVALUATION AND RECOMMENDATION

In line with the assumptions made in the article study, the daylighting performance of the office spaces under consideration was examined and evaluated according to the parameters of the TS EN 17037 standard. In evaluating the results of this review,

- Adequacy of minimum, medium, and high minimum illuminance levels
- Adequacy of medium and high target illuminance levels
- High-level glare control
- Medium and high sun exposure time
- Minimum and medium assessment for viewing out situations.

Of the 168 scenarios created for Istanbul and Adana, the ones with the most suitable daylight and illuminance for the office function according to the TS EN 17037 criteria were filtered in Excel and identified as 10. As the Northern facade does not receive direct sunlight on 21st March, and therefore the sunshine duration criterion cannot be evaluated, it is not included in this determination. The optimal options determined are presented in Table 9.

Then, 15 scenarios that are positive in accordance with the standard were ranked by one of the decision support systems – the Analytical Hierarchy Process (AHS) method – and the optimum option was determined for Istanbul and Adana. Of the TS EN 18037:2021 standard parameters, the weight scores determined by the AHS method (Saaty, 1994; Dağdeviren, Akay, and Kurt, 2004) and the determined interval values multiplied, and the total score of each scenario were determined by the results for Istanbul and Adana are presented in Table 10.

When the numerical values of the total score in Table 15 are analyzed, it is seen that IST-W-LTF 0.4-TR 0.3-Y5-F2, IST-W-LTF 0.4-TR 0.3-Y5-F3 with the highest total score, ADN-E-LTF 0.4-TR 0.3-Y5-F0 and ADN-W-LTF 0.6-TR 0.3-Y2-F0 options appear to be the most suitable options in terms of sequencing parameters. According to the natural illumination evaluation results of B2 and B5 buildings standing inside the Istanbul and Adana conditions discussed in the article, new arrangements and lighting designs should be done to improve inspected working spaces, especially the Southern facades of them.

Because for these working spaces, there is a negative situation in terms of discomfort glare while adequate lighting is provided in the current situation. Of the inspected office space working places which detected not having suitable lighting conditions, improvement advice is given for the IST-S-LTF 0.8-TR 0.3-Y5 -F0 and F1 (Southern facade-light transmittance factor 0.8-Transparency Ratio 0.3-15m Road Width/18 m Obstruction Height - Ground Floor and 1st Floor of the 5-Storey Building) scenarios.

In these improvements, to provide glare control, a vertical

Table 9. Positive scenarios for Istanbul and Adana office buildings according to TS EN 17037 parameters

Suitable Scenarios After Evaluation	Daylight Provision/ Min.Illuminance Level	Daylight Provision/ Target Illuminance Level	Glare	Assessment for View Out	Exposure to Sunlight
IST-G-LTF 0,4- TR 0.3-Y2-F0	Min. Level	Medium Level	<0.35	Building	High
IST-D-LTF 0,6- TR 0.3-Y2-F0	Medium Level	High Level	<0.35	Building	Medium
IST-D-LTF 0,4- TR 0.3-Y2-F0	Min. Level	Medium Level	<0.35	Building	Medium
IST-B-LTF 0,6- TR 0.3-Y2-F0	Medium Level	Medium Level	<0.35	Building	Medium
IST-B-LTF 0,4- TR 0.3-Y2-F0	Min. Level	Medium Level	<0.35	Building	Medium
IST-B-LTF 0,4- TR 0.3-Y2-F1	Medium Level	High Level	<0.35	Building+Sky	High
IST-B-LTF 0,4- TR 0.3-Y5-F0	High Level	High Level	<0.35	Building	Medium
IST-B-LTF 0,4- TR 0.3-Y5-F1	High Level	High Level	<0.35	Building	Medium
IST-B-LTF 0,4- TR 0.3-Y5-F2	High Level	High Level	<0.35	Building	High
IST-B-LTF 0,4- TR 0.3-Y5-F3	High Level	High Level	<0.35	Building	High
ADN-G-LTF 0,4-TR 0.3-Y2-F0	Min. Level	Medium Level	<0.35	Building	High
ADN-D-LTF 0,4-TR 0.3-Y2-F0	Min. Level e	Medium Level	<0.35	Building	Medium
ADN-D-LTF 0,4-TR 0.3-Y5-F0	Medium Level	High Level	<0.35	Building	Medium
ADN-B-LTF 0,6-TR 0.3-Y2-F0	Medium Level	High Level	<0.35	Building	Medium
ADN-B-LTF 0,4-TR 0.3-Y2-F0	Min. Level	Medium Level	<0.35	Building	Medium

Table 10. Total scores of scenarios suitable for AHS evaluation in Istanbul and Adana office buildings

Weight values	0.214	0.36	0.285	0.0708	0.0708	Total Points
Parameters	**Daylight Provision/ Min.Illuminance Level**	**Daylight Provision/ Target Illuminance Level**	**Glare**	**Assessment for View Out**	**Exposure to Sunlight**	
IST-S-LTF 0.4-TR 0.3-Y2-F0	0.1	0.3	0.6	0.1	0.6	0.350
IST-D-LTF 0.6-TR 0.3-Y2-F0	0.3	0.6	0.6	0.1	0.3	0.480
IST-D-LTF 0.4-TR 0.3-Y2-F0	0.1	0.3	0.6	0.1	0.3	0.329
IST-W-LTF 0.6-TR 0.3-Y2-F0	0.3	0.3	0.6	0.1	0.3	0.372
IST-W-LTF 0.4-TR 0.3-Y2-F0	0.1	0.3	0.6	0.1	0.3	0.329
ISTWB-LTF 0.4-TR 0.3-Y2-F1	0.3	0.6	0.6	0.3	0.6	0.515
IST-W-LTF 0.4-TR 0.3-Y5-F0	0.6	0.6	0.6	0.1	0.3	0.544
IST-W-LTF 0.4-TR 0.3-Y5-F1	0.6	0.6	0.6	0.1	0.3	0.544
IST-W-LTF 0.4-TR 0.3-Y5-F2	0.6	0.6	0.6	0.1	0.6	0.565
IST-W-LTF 0.4-TR 0.3-Y5-F3	0.6	0.6	0.6	0.1	0.6	0.565
ADN-S-LTF 0.4- TR 0.3-Y2-F0	0.1	0.3	0.6	0.1	0.6	0.350
ADN-E-LTF 0.4-Y2- TR 0.3-F0	0.1	0.3	0.6	0.1	0.3	0.329
ADN-E-LTF 0.4-Y5- TR 0.3-F0	0.3	0.6	0.6	0.1	0.3	0.480
ADN-W-LTF 0.6-Y2- TR 0.3-F0	0.3	0.6	0.6	0.1	0.3	0.480
ADN-W-LTF 0.4-Y2- TR 0.3-F0	0.1	0.3	0.6	0.1	0.3	0.329

and movable solar control element consisting of three parts of 1 m × 1.5 m shown in Figure 11 is proposed.

Each part of the designed solar control element has 11 motionless lamellas that make an angle of 90° with the vertical axis. The wooden solar control element, which has a light reflection factor of 0.40, is postulated to have a specular reflecting surface and isotropic diffuse (matte) light reflection type, a lamella width of 7 cm, a distance of 5 cm between lamellas, the thickness of 3 cm, and distance of 10 cm from the facade (Figure 11).

In the TS EN 17037 2021 "Daylight Standard in Buildings," the maximum allowed threshold for the possibility of daylight glare should not exceed 5% of the reference period.

The South facade with high glare values was chosen for the improvement proposal carried out in the study. Thus, it is aimed to provide sufficient lighting levels for office workplaces as well as the glare value levels specified in the standard. In this context, the calculations for the situation in which the proposed solar control element is added are made in Rhino/Climate Studio. The results are shown in Table 11.

As seen in Table 11, a high degree of protection from glare can be achieved when all three of the solar control elements are closed. However, a decrease in the desired and minimum lighting level of the working space was calculated. For this reason, it has been determined that the lighting level that is observed over the target in IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR0.3-B5-F1 at the lowest level should

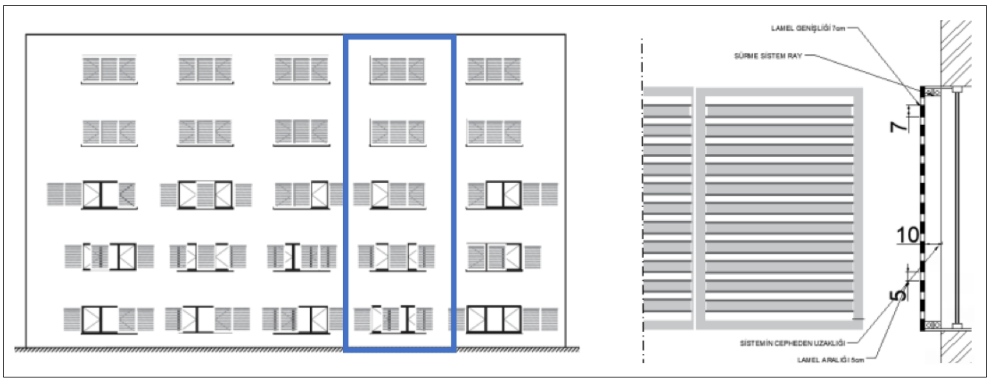

Figure 11. View and section of the suggested sun control element.

Table 11. IST-S-LTF 0.8- TR 0.3-Y5 - Vertically Driven Sunshade Proposal-Providing Sufficient Lighting Level

Min. Illuminance Level			Duration (Provided Percentage of Daylight Time (4380 Hours)				
Provided Degree	Illuminance Level (Lux)	Area	Light Transmission Factor (LTF) 0.8				
			Basement Floor	1. Floor	2. Floor	3. Floor	4. Floor
Minimum	>100	Min. %95	79,47%	80,80%	83,65%	85,14%	86,10%
Medium	>300	Min. %95	28,70%	33,42%	48,97%	59,75%	63,81%
High	>500	Min. %95	0,00%	0,00%	4,70%	20,78%	31,32%
Target Illuminance Level							
Minimum	>300	Min. %50	68,04%	72,03%	74,32%	77,63%	79,47%
Medium	>500	Min. %50	34,89%	45,68%	56,58%	61,92%	68,84%
High	>750	Min. %50	0,09%	3,74%	20,84%	37,28%	47,03%
İST-G-IGÇ 0.8- SO O.3-Y5- Sugesstion for Vertical Sun Control Element- Annual Discomfort Glare (Based on Thime Spent Per Year)			0,00%	0,00%	0.00%	0,00%	0,00%

be improved to provide a minimum horizontal 300 lux lighting as recommended in TS EN 12464-1: 2021 "Indoor Work Areas Lighting" in terms of artificial illumination for office workspace. The information about the artificial illumination design created for the improvement proposal, and the location and characteristics of the lighting devices used are presented in Figure 12.

Design of artificial illumination with natural illumination having solar control element (integrated lighting) for IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR 0.3-B5-F1 again calculated in Rhino/Climate Studio simulation program. Considering sustainability and energy issues, two different lighting scenarios called D1 and D2, which could be controlled independently of each other, were created (Table 12).

For natural illumination, the Rhino/Climate Studio simulation program uses the measured typical

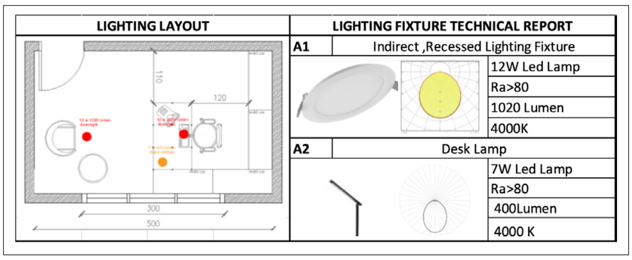

Figure 12. IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR 0.3-B5-F1 artificial illumination design and technical information of lighting devices.

Table 12. Lighting scenarios

1. Daylighting + Only Table Lamp On	D1
2. Daylighting + Table Lamp + Led Lighting Fixture	D2

meteorological year (TMY) data measured between 2004 and 2018. For the integrated lighting calculations to be performed for IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR 0.3-B5-F1, the days to be considered and the appropriate sky models for these days have been determined. In a study conducted in 2008, it was concluded that the day that characterizes a month is the 15th day of that month as a result of natural light calculations for the province of Istanbul (Güvenkaya, 2008). It was decided to use this result in the study.

Calculations regarding to integrated lighting for IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR 0.3-B5-F1 are made according to 08.00, 12.00, and 16.00 h of 15 December, 15 March, 15 June, and 15 September and national time zone of Türkiye – GMT+3 (Iğdır). The sky models determined for the discussed dates are given in Table 13.

To provide a 300 lux minimum desktop lighting level over the target using minimum energy, different lighting scenarios are applied for different cases. Lighting scenarios for IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8-TR 0.3-B5-F1 at 08.00, 12.00, and 16.00 h of 15 December, 15 March, 15 June, and 15 September are shown in Table 13, and scenarios of average lighting levels over desktop are shown in Table 14.

According to Table 15, for IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR 0.3-B5-F1 during referential time (08.00–18.00) in order to provide target desktop lighting level 300 lux as maintained by TS EN 12464-1:2021[1], it is enough to use D1 scenario which table lamp usually open along natural light. It is sufficient to use the D2 scenario only in the evening in March and all-day during winter months. In summer, the level of lighting provided by natural illumination is sufficient at noon.

Table 13. Sky models determined for the calculation dates considered (Şener & Yener, 2012)

Istanbul	15 March	15 June	15 December	15 September
08.00	OVERCAST	INTERMEDIATE	OVERCAST	INTERMEDIATE
12.00	INTERMEDIATE	CLEAR	INTERMEDIATE	INTERMEDIATE
16.00	OVERCAST	INTERMEDIATE	OVERCAST	INTERMEDIATE

Table 14. Applied lighting scenarios

	08.00	12.00	16.00
15th June			
IST-S-LTF 0.8- TR 0.3-B5-F0	D1	DAYLIGHT	D1
IST-G-LTF 0.8- TR 0.3-B5-F1	D1	DAYLIGHT	D1
15th December			
IST-S-LTF 0.8- TR 0.3-B5-F0	D2	D1	D2
IST-G-LTF 0.8- TR 0.3-B5-F1	D2	D1	D2
15th March			
IST-S-LTF 0.8- TR 0.3-B5-F0	D1	D1	D2
IST-G-LTF 0.8- TR 0.3-B5-F1	D1	D1	D2
15th September			
IST-S-LTF 0.8- TR 0.3-B5-F0	D1	D1	D1
IST-G-LTF 0.8- TR 0.3-B5-F1	D1	D1	D1

Table 15. Average illuminance level results (Lux)

	08.00	12.00	16.00
15th June			
IST-S-LTF 0.8- TR 0.3-B5-F0	413,6 lux	445,6 lux	440,2 lux
IST-G-LTF 0.8- TR 0.3-B5-F1	436,1 lux	513,5 lux	489,4 lux
15th December			
IST-S-LTF 0.8- TR 0.3-B5-F0	316,8 lux	366,8 lux	396,5 lux
IST-G-LTF 0.8- TR 0.3-B5-F1	333,7 lux	415,5 lux	423,1 lux
15th March			
IST-S-LTF 0.8- TR 0.3-B5-F0	346,9 lux	461,6 lux	360,3 lux
IST-G-LTF 0.8- TR 0.3-B5-F1	368,5 lux	535,3 lux	393,1 lux
15th September			
IST-S-LTF 0.8- TR 0.3-B5-F0	371,6 lux	463,8 lux	447,6 lux
IST-G-LTF 0.8- TR 0.3-B5-F1	397,5 lux	506,6 lux	486,8 lux

CONCLUSION

Office buildings, that are used for a long time and have a high artificial energy consumption, should be structures that provide visual comfort conditions, use energy effectively and efficiently, and cause the least damage to nature/environment (Yücel, 2019). In each space, it is possible to provide the necessary minimum visual comfort conditions with a precise lighting system design that responds to the requirements where energy is actively used. Making use of natural lighting in the lighting design phase to provide the required amount of lighting will contribute to a significant reduction in the energy used for artificial lighting.

This paper presents the first results of a study aimed at evaluating the daylighting performance of offices used during the day according to the "Planned Areas Type Zoning Regulation" in force in our country, based on the criteria of TS EN 17037: 2021 "Daylight Standard in Buildings."

The regulation includes basic data with limitations such as street width, building height, etc. In cases where these data are used, it will be beneficial to consider the variables of daylighting performance in the volume: Window orientation, window light transmittance, and the hours of use of the volume during the day and the days of use in the year in the context of the function of the building, while designing the lighting system with a view to reducing the use of artificial lighting energy using natural lighting as much as possible. As a result, the performance of the daylight entering the volume would be determined at the design stage and the results will contribute to sustainable lighting design while reducing the energy spent on artificial lighting.

NOTE

[1]TS EN 12464-1:2021, T. E. (2021). Işık ve Aydınlatma: Çalışma Yerlerinin Aydınlatılması - Bölüm 1: Kapalı Çalışma Alanları (Light and Lighting - Lighting of Work Places - Part 1: Indoor Work Places).

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REFERENCES

Çelik, K. (2018). Eğitim yapılarında sürdürülebilir aydınlatma tasarımı için bütüncül bir yaklaşım [Doctoral

Thesis]. Yıldız Technical University, Istanbul.

Dağdeviren, M., Akay, D., & Kurt, M. (2004). İş değerlendirme sürecinde analitik hiyerarşi prosesi ve uygulaması. Gazi Üniv Müh Mim Fak Derg, 19(2), 131‒138.

Gaisma. (2023). Sunrise, sunset, dawn and dusk times around the world! Adana, Türkiye. https://www.gaisma.com/en/location/adana.html.

Gaisma. (2023). Sunrise, sunset, dawn and dusk times around the world! İstanbul, Türkiye. https://www.gaisma.com/en/location/istanbul.html.

Güvenkaya, R. (2008). İlköğretim dersliklerinde aydınlatma enerjisi yönetimi açısından yönlere göre uygun cephe seçeneklerinin belirlenmesi üzerine bir yaklaşım [Doctoral Thesis]. İstanbul Technical University, İstanbul.

Çevre, Şehircilik ve İklim Değişikliği Bakanlığı. (2022). Planlı alanlar imar yönetmeliği. https://www.mevzuat.gov.tr/File/GeneratePdf?mevzuatNo=23722&mevzuatTur=KurumVeKurulusYonetmeligi&mevzuatTertip=5

Öztürk, L. (2018). Pencere tasarımını etkileyen önemli bir parametre: Günışığına yönelik yeni Avrupa standardı. İstanbul 1. Konut Kurultayı (pp.556-571). İstanbul, Türkiye

Saaty, T. (1994). Fundamentals of decision making and priority theory with the analytic hierarchy process. RWS Publications.

Sakınç, E. (2006). Sürdürülebilirlik bağlamında mimaride güneş enerjili etken sistemlerin tasarım öğesi olarak değerlendirilmesine yönelik bir yaklaşım [Doctoral Thesis]. Yıldız Technical University.

Şener, F., & Yener, A. (2012). Sky model determination based on meteorological data for daylight calculations in architecture – An application for Istanbul. Balkan Light 2012, 3-6 Ekim 2012, Belgrad, Serbia (pp. 331‒339). Belgrad, Serbia.

TS EN 12464-1:2021, T. E. (2021). Işık ve aydınlatma: çalışma yerlerinin aydınlatılması - bölüm 1: Kapalı çalışma alanları.

TS EN 17037+A1:2021. Binalarda günışığı standardı. https://pldturkiye.com/ts-en-17037-binalarda-gunisigi-standardi-ve-uygulamasi/

Uyan, F. (2010). Binalarda aydınlatma sistemlerinin sürdürülebilirliklerini değerlendirme ilkeleri [Master's Thesis]. İstanbul Technical University.

Yılmaz, F. (2019). Binalarda günışığı performans ölçütlerine güncel bir bakış: EN 17037 Standardı ve uygulaması. https://www.emo.org.tr/ekler/fbc100939031373_ek.pdf

Yücel, Ş. (2019). Açık planlı ofislerde aydınlatma tasarımının irdelenmesi [Master's Thesis]. Yıldız Technical University.