Daylighting Analysis In Selected Shopping Center Examples and A Horizontal Opening Proposal


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Abstract: *Designs that can make maximum use of daylight in shopping areas, provide visual comfort conditions for users, increase the work performance and provide economic benefits in addition to healthy and relaxing spaces. In this context, as a method, illuminance level measurements were made at the determined points in the circulation areas of selected shopping centres; Galleria, Flyinn, Profilo and Cevahir AVM, and in line with the results obtained, the shopping center with the lowest illuminance level is chosed and a system design is proposed. In order to examine the relationship between the illuminance levels under different lighting conditions, the natural lighting simulation model of the shopping mall was composed and measurements were carried out for the characteristic dates of the year which are 21 March, 21 June, 21 September and 21 December. The aim of the study is to provide maximum natural lighting efficiency in the space; to provide economic benefits, to increase the workforce in the shopping mall, and thus to increase the satisfaction rate of the users, to ensure the sustainability of the use of the shopping mall. As a result of the study, evaluations were made by comparing the current measurements and a proposal of natural lighting system performance.*

Keywords: *Visual comfort, shopping spaces, skylight*

Seçili Alışveriş Merkezi Örneklerinde Günışığı Analizi ve Yatay Açıklık Önerisi

Özet: Alışveriş mekânlarında günışığından maksimum oranda fayda sağlayabilecek tasarımlar ile, kullanıcıların görsel konfor koşullarını sağlayan sağlıklı ve rahatlatıcı mekânların iş görmeye bağlı performansı arttırdığı ve ekonomik bakımdan fayda sağladığı bilinmektedir. Bu bağlamda çalışmada yöntem olarak, seçili alışveriş merkezleri olan Galleria, Flyinn, Profilo ve Cevahir AVM'de ortak kullanım alanları olan giriş kat sirkülasyon alanlarında belirlenen noktalarda aydınlık düzeyi ölçümleri yapılmış ve elde edilen sonuçlar doğrultusunda aydınlık düzeyi en düşük olan AVM için bir doğal aydınlatma sistem tasarımı önerilmiştir. Farklı aydınlatma koşulları altında aydınlık düzeyleri arasındaki ilişkiyi incelemek için, doğal aydınlatma performansı en düşük olan AVM'nin doğal aydınlatma simülasyon modeli oluşturularak, yılın karakteristik tarihleri olan 21 Mart, 21 Haziran, 21 Eylül ve 21 Aralık'ta sabah-öğlen-akşam saatlerinde aydınlık düzeyleri ölçülmüştür. AVM içi sirkülasyon alanlarında kullanıcıların maksimum oranda doğal aydınlatmadan faydalanabilmeleri için çatı ışıklığı sistem tasarımı önerisinde bulunulmuştur. Çalışmanın amacı, yeni önerilen doğal aydınlatma sistem tasarımından sağlanan maksimum oranda hacim içi doğal aydınlatma verimi ile; ekonomik açıdan fayda sağlanması, AVM içi iş gücünün arttırılması ve dolayısıyla kullanıcıların memnuniyet oranının da artması ile AVM kullanımının sürdürülebilirliğinin sağlanmasıdır. Çalışmanın sonucunda, mevcut ölçümler ile doğal aydınlatma sistem önerisi karşılaştırılarak değerlendirmeler yapılmıştır.

Anahtar Kelimeler: *Görsel konfor, alışveriş mekânları, çatı ışıklığı*

1. INTRODUCTION

The lighting methods applied in shopping centre common areas and store interiors are the most important architectural components that provide the visual perception of users. Due to the inward-oriented architecture of many shopping centres designed today, it is seen that daylight cannot be used sufficiently in the interior spaces and the use of artificial lighting has gained vital importance due to the fact that these spaces serve until late at night. Since the sun is the most important inexhaustible renewable energy source, various methods have been developed to make the most efficient use of solar energy in buildings. An example of these methods is the effective use of daylight consisting of sunlight and skylight in shopping mall buildings with the skylight system, which is one of the contemporary lighting strategies.

The correctly applied design of natural lighting systems applied in shopping spaces, which are common use areas, is the one that provides international lighting values and ensures the visual comfort of business users and most importantly, reduces the use of artificial lighting. According to the researches, it has been revealed that natural lighting applications have visual and perceptual effects on users as well as their positive or negative effects on the business depending on efficient energy use and energy use amounts. Depending on these factors, users work performance and satisfaction are also affected [1]. Since the natural lighting selected as the subject of the research depends on many different external variables, the effects of natural lighting were tried to be determined.

2. NATURAL LIGHTING IN SHOPPING CENTERS

Comfortable interiors created by improving the quality of the natural lighting system and lighting increase the productivity and performance of the user [2]. Shopping malls do not have the potential to use high natural lighting because they are multi-storey buildings due to their structure and there are no openings on the exterior facades in order to increase the display areas of the stores. In this context, the majority of stores do not utilize natural lighting and do not use a natural lighting design combined with artificial lighting [3]. With the emergence of the psychological and physiological effects of natural lighting on people with the studies conducted in the past, the potential users of shopping spaces increase sales with a pleasant in-space experience, strengthen the in-space atmosphere and achieve a good color rendering in the space by bringing daylight into the space from the atrium area [3].

2.1 Natural Lighting Elements in Shopping Spaces

Throughout history, the most basic form of lighting has been the illumination of the environment by taking daylight into the space. Natural light has been transferred into the space by architects and designers using windows, roof skylights and lanterns and lighting plans have been created accordingly [4].

Natural lighting systems should be designed with the aim of receiving sunlight into the interior space in the most efficient way. The most basic natural lighting element is the system where light is received through the openings created on the facades, that is, through the windows of the building. Roof lighting is the method of transferring light from the roof area of the building to the environment and distributing it into the space. The most basic example used in the method of natural lighting from the roof is roof skylights [5].

In terms of providing visual comfort in natural lighting applications, the amount of light received into the interior space is as important as the amount of light received in a controlled manner. This is because uncontrolled natural light can cause visual discomfort by causing glare and glare formation in the space and can cause thermal discomfort due to the heating effect of the sun in the space [6]. For these reasons, shading elements are frequently used in natural lighting systems against negative situations that may occur. In order to ensure maximum energy saving in buildings, control systems

should be established to ensure the integrated operation of the elements used in natural lighting and artificial lighting systems [7].

2.1.1 Facade Openings

It is known that traditionally designed and implemented façade openings create environments with excessive illumination in the front parts of the windows and little light if the depth of the space is high [8]. Since the facades of the stores inside the shopping centres are considered as display areas, the natural lighting system is generally provided by roof skylights.

2.1.2 Skylights

With the use of rooflights in shopping spaces, the lighting character of the building can be completely changed and it is seen that by positioning the rooflights in a section of 3/5 of the roof area, significant amounts of annual energy savings are achieved in the buildings by using the artificial lighting system very little during daylight hours [9].

Due to the fact that the stores in the shopping areas use the exterior areas of the stores as display areas, the traditional window system cannot be applied, and daylight is transferred into the space with the roof skylight applications created in the roof areas of the natural lighting system.

2.1.3 Shading Elements

As a result of intense and direct sunlight, which is one of the components of daylight, glare, high illuminance, and shaded areas can occur together. Shading elements help to create visual and thermal comfort by providing the opportunity to control direct and intense sunlight. With the help of these elements, heat gain can be controlled, and proper distribution of daylight indoors can be provided [10].

3. LIGHTING CRITERIA FOR SHOPPING CENTERS

In line with the researches conducted, lighting is the most fundamental element of the formation of the space atmosphere of shopping spaces. Since it is known that lighting conditions have psychological and physiological effects on users, it should be aimed to provide visual comfort by determining the lighting criteria suitable for the function during the design phase of the building.

The main criteria in shopping centers are to provide good visual conditions for the users, to reduce energy consumption to a great extent with the use of natural lighting, to create a place where they are in contact with the outdoor environment, to increase the preferability of the place and to increase the sales of the store. In this section, illuminance level, light color (color rendering, color temperature) and glare are examined as criteria to be considered in the examination of natural lighting applications in shopping centers.

3.1 TS EN 12464-1 Standard

According to this standard, the illuminance level of the stores in the shopping areas should be 300 lx, the color rendering index (Ra) of the artificial lighting elements should be minimum 80, the uniformity value (Uo) should be 0.4 and the glare index UGR value should be lower than 22. While evaluating the illuminance measurements of the common areas of the four shopping centers to be evaluated within the scope of the study, the 100 lux value recommended by the aforementioned standard and the International Commission on Illumination (CIE) for recreation areas was taken as the limit value [11].

3.2 EN 17037 Standard Assessment of Daylight In Interior Spaces, Daylight Provision;

3.2.1 General

Daylight can contribute significantly to the lighting needs of any type of building. This means that daylight openings should have appropriate areas to provide sufficient daylight throughout the year. Thus, the evaluation of daylight provision should make account of the availability of daylight at the site in the addition to accounting for the properties of the space (e.g. external obstruction, glazing transmittance, thickness of walls and roofs, internal partition and surface reflectance, furnitures).

3.2.2 Criteria for daylight provision

A space is considered to provide adequate daylight if a target illuminance level is achieved across a fraction of the reference plane within a space for at least half of the daylight hours [12].

In addition, for spaces with vertical or inclined daylight openings, a minimum target illuminance level is also to be achieved across the reference plane. The reference plane of the space is located 0,85 m above the floor, unless otherwise specified. A small fraction of the reference plane may be disregarded to account for singularities.

Values for target illuminances, minimum target illuminances and fractions of reference plane are given in Table 1.

Table 1. Recommendations of daylight provision by daylight openings in a horizontal surface

Level of recommendation for horizontal daylight opening	**Target illuminance** E_T lx	**Fraction of space for target level** $F_{plane,\%}$	**Fraction of daylight hours** $F_{time,\%}$
Minimum	300	95 %	50 %
Medium	500	95 %	50 %
High	750	95 %	50 %

4. ANALYSIS OF NATURAL LIGHTING SYSTEM DESIGN OF SELECTED SHOPPING MALL EXAMPLES WITHIN THE SCOPE OF FIELD STUDY

The relationship between different lighting conditions consisting of natural and artificial lighting conditions and the general illuminance level in the shopping centre interiors was examined with the illuminance level measurements made in Galleria Shopping Mall, Profilo Shopping Mall, Flyinn Shopping Mall and Cevahir Shopping Mall, which were selected as sample areas. Different functional areas in the sample shopping malls were determined and measurement points representing each area were selected. BENETECH GM1010 Digital Luxmeter was used as the measuring device and the illuminance level measurements at the selected measurement points were made on March 21, June 21, September 23 and December 21, which are the characteristic dates of the year.

After the measurements made in the field, a simulation model was created and a new natural lighting system proposal simulation was put forward in line with the findings obtained.

To create the simulation model;

1- All necessary measurements were taken with a laser meter and plans of four selected shopping malls were obtained from the shopping mall managements. (To create a base for three-dimensional modeling and lighting analysis programs.)

2- Through the Rhino program, a new 3D roof light model was prepared by creating 2 different types. It can be modeled in its own structure and has the ability to import drawings in different formats from other programs.

3- Climate Studio (Solemma) is a program that can import 3D models from the Rhino program. Through this program, natural lighting data can be obtained in detail by entering the necessary information of simulation models.

In the study, a new 3D rooflight model with 2 different layers designed in Rhino program was imported into Climate Studio program and natural lighting data were examined.

The light reflection, transmission and absorption properties of the materials used in the area were entered into the program as data, and natural lighting results were obtained using the real sun and sky model. The calculation results obtained are very close to reality.

- The results obtained from all necessary measurement points in all shopping mall samples were compared with each other. After the most inefficient use of the integration of artificial and natural lighting systems was determined, the new natural lighting system proposal that will provide maximum efficiency was put forward through the simulation program Climate Studio.
- In line with the illuminance level data obtained, the current situation and the second model of the skylight with low U-value, increased transmittance and double-layer were composed through the simulation program.

4.1 Natural Lighting Measurement Values of Selected Shopping Mall Samples

Galleria Shopping Center, Bakırköy (Figure 1): Galleria Shopping Center, designed and executed by Hayati Tabanlıoğlu, was opened in 1988 in Bakırköy as Turkey's first shopping center. The mall consists of six sections with a three-storey atrium and two five-storey parking lots, and has a total area of 130.000 m² on a 40.000 m² plot, with a shopping area of 62.000 m² with 143 stores and a parking lot of 67.000 m² [13].

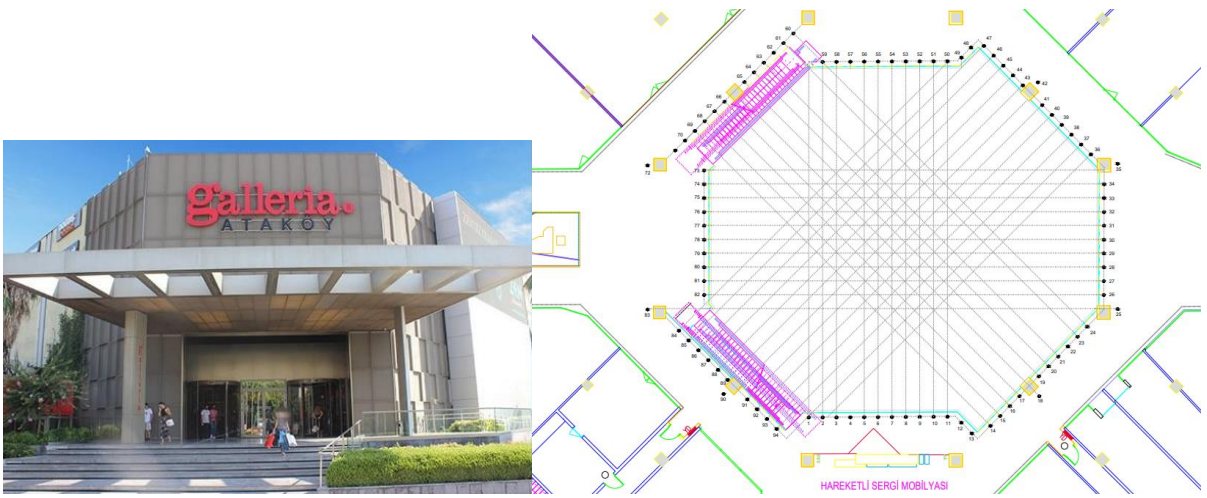


Figure 1. Galleri Shopping Mall Front Facade View and Ground Floor Common Circulation Area Measurement Points

The circulation area in Galleria Shopping Mall where natural lighting measurements were made is 735 m² in total and is located on the ground floor of the mall. Natural lighting measurements were made at 1 meter intervals from a height of 90 cm following the railings of the atrium area, and the illuminance levels taken on the days and hours of measurement are written separately in Table 2.

Table 2. Galleria Shopping Mall Natural Lighting Measurements

AVM	NATURAL LIGHTING MEASUREMENT						NATURAL LIGHTING MEASUREMENT					
GALLERİA AVM	21.03.2022			21.06.2022			21.09.2022			21.12.2022		
	10.00	13.00	15.00	10.00	13.00	15.00	10.00	13.00	15.00	10.00	13.00	15.00
1	33,1	36,7	50,2	38,5	**114,5**	96,3	23,9	81,6	91,1	90,5	66,1	48,8
2	40,2	39,1	52,9	42,3	**117,3**	96,6	21,5	**145,5**	78,3	84,7	60,3	36,3
3	42,1	43,5	53,1	39,5	**108,4**	95,7	22,5	**175,1**	65,2	87,7	60,7	103,4
4	48,2	54,9	53,9	42,5	**104,6**	98,2	**215,6**	**166,4**	60,7	92,7	59,9	47,4
5	39,1	50,2	52,2	38,4	**102,7**	95,7	**197,8**	**146,3**	58,1	82,9	58,1	55,2
6	43,2	53,4	50,4	39,9	**103,8**	94,3	**179,6**	**139,2**	56,1	75,5	55,4	60,4
7	38,7	50,7	51,9	36,7	**116,3**	96,6	**170,1**	**135,3**	57,4	69,1	52,6	68,1
8	37,7	39,2	40,9	39,3	**109,5**	89,6	**162,2**	**131,1**	62,8	67,1	51,5	92,5
9	40,8	46,2	40,3	42,2	**117,8**	74,9	**160,1**	**122,7**	76,9	66,6	50,5	76,3
10	43,9	38,4	38,9	48,6	78,9	78,6	**126,7**	**114,7**	84,6	70,2	50,1	54,2
11	29,4	43,5	37,1	45,3	52,9	99,8	**105,1**	97,6	77,1	69,5	51,6	99,9
12	44,6	37,5	40,2	49,5	74,6	47,9	70,9	66,5	62,9	61,5	52,5	87,4
13	54,8	57,2	43,9	**109,9**	62,4	62,9	42,3	34,6	57,9	56,7	50,8	100,2
14	45,6	51,8	42,9	93,2	74,4	76,2	29,2	23,5	58,1	51,8	47,2	95,6
15	55,6	50,2	44,8	83	62,5	88,9	**119,9**	**106,1**	60,4	48,8	45,5	101,3
16	49,4	53,6	39,3	84,1	60,2	96,5	**108,3**	96,1	41,9	38,2	39,8	**107,8**
17	56,8	59,2	33,9	**104,5**	78,3	84,9	**129,7**	**108,4**	28,1	25,8	32,6	**109,7**
18	**145,2**	**188,4**	**219,5**	**159,6**	**204,8**	**210,8**	**102,2**	**121,6**	**179,7**	**152,2**	23,4	**111,1**
19	46,2	52,8	37,2	56,4	69,8	58,8	24,9	**197,3**	80,2	101,1	142,3	**115,4**
20	48,7	53,1	46,4	54,8	79,2	57,7	29,7	42,2	62,2	65,9	96,7	**113,7**
21	34,2	47,8	39,9	55,9	75,9	81,8	40,2	63,9	50,2	62,2	67,5	**111,1**
22	37,1	43,2	40,5	62,7	89,7	78,5	38,2	59,5	81,1	56,7	61,1	**112,3**
23	50,2	52,5	32,8	69,6	98,7	82,3	36,1	60,1	90,5	86,1	68,7	**114,4**
24	51,4	55,2	40,3	78,9	89,6	87,9	40,7	68,9	56,6	26,8	93,9	**110,8**
25	**138,2**	**175,4**	**198,2**	**157,8**	**170,5**	**187,6**	43,4	75,9	33,1	87,1	58,7	**109,1**
26	54,6	57,3	45,3	78,2	87,6	91,4	45,1	78,9	48,1	26,5	23,5	**102,9**
27	49,3	53,2	42,6	82,3	98,6	100,1	47,4	82,6	52,4	31,6	28,7	98,9
28	52,8	66,8	43	78,2	98,5	102,6	46,6	84,9	49,6	30,9	28,4	91,7
29	45,2	59,3	40,2	71,5	87,1	98,4	47,9	85,3	44,1	29,9	27,5	86,3
30	48,5	55,3	38,2	64,8	86,2	90,2	47,5	87,1	57,3	28,8	27,1	80,6
31	54,7	62,1	30,3	72,6	98,4	76,9	45,8	86,5	66,9	30,6	29,8	75,2
32	39,4	55,2	29,2	77,9	85,2	79,2	45,1	82,4	65,6	32,2	30,9	69,2
33	33,5	49,5	28,4	61,2	98,7	74,8	43,4	81,9	68,9	33,6	31,1	62,5
34	37,4	54,5	33,6	68,3	83,9	82,8	43,7	77,9	69,6	34,1	32,8	62,7
35	**169,2**	**178,3**	**201,2**	**189,9**	**202,8**	**213,9**	51,5	78,7	72,1	33,6	33,1	57,6

36	58,5	60,4	43,2	61,1	98,4	74,2	39,9	67,8	80,4	33,8	33,4	38,8
37	55,9	59,2	40,3	58,2	68,9	76,8	36,4	58,5	100,3	33,2	34,1	45,7
38	41,7	54,3	38,4	51,7	59,8	62,5	33,1	51,1	94,2	34,4	34,3	**202,7**
39	50,2	47,9	35,7	100,6	**109,6**	75,2	**110,8**	40,3	95,5	33,1	34,8	67,1
40	33,1	46,1	44,1	35,6	62,1	73,1	33,8	152,3	97,4	33,4	35,3	46,2
41	30,2	45,2	42,9	34,8	67,4	74,7	34,8	128,4	95,3	32,2	34,8	44,7
42	98,3	**149,2**	**163,2**	101,4	**138,7**	**148,2**	33,2	39,4	106,6	31,1	35,3	56,2
43	32,5	42,3	35,8	27,6	46,6	78,3	31,5	40,3	107,8	28,9	33,9	**215,3**
44	37,8	48,5	38,9	54,1	58,9	79,4	**105,7**	38,5	106,1	28,3	34,3	27,5
46	43,8	53,6	36,1	56,2	69,8	78,9	**157,8**	37,6	**128,2**	26,2	33,5	39,6
47	49,7	59,3	40,7	53,3	57,3	68,4	40,9	39,4	**147,7**	33,2	34,5	46,2
48	48,1	56,3	43,4	54,6	66,8	66,2	41,5	37,8	**169,2**	25,8	40,1	45,6
49	45,9	54,2	40,3	54,8	55,2	72,2	43,1	36,5	**158,1**	**160,3**	22,8	47,6
50	40,3	57,2	39,3	55,7	61,2	61,8	43,9	**115,6**	**134,2**	**124,2**	**178,6**	46,4
51	42,8	48,9	38,1	58,8	64,1	62,9	49,4	**128,3**	**214,7**	90,2	83,9	46,7
52	47,1	51,8	37,9	57,9	62,1	63,1	50,4	59,5	**187,4**	**107,2**	**188,3**	45,7
53	38,7	53,8	35,7	44,6	68,2	58,7	49,7	65,4	**209,2**	**150,1**	**206,5**	44,5
54	39,5	59,3	32,1	55,6	69,2	73,2	49,4	68,2	21,4	**144,5**	**201,4**	42,7
55	35,1	49,5	31,3	53,5	71,9	71,6	57,8	70,8	23,5	**145,7**	**191,1**	41,4
56	38,4	46,1	32,8	42,7	52,8	72,4	56,2	74,1	25,8	**143,4**	**189,2**	39,6
57	37,8	45,2	32,2	45,8	55,2	74,8	68,6	76,8	28,3	**143,7**	**179,1**	40,7
58	42,9	43,8	48,1	38,7	48,6	75,1	**158,1**	80,2	28,7	**138,1**	**184,5**	41,1
59	43,6	52,4	46,4	47,9	54,9	75,4	86,2	80,9	179,6	73,4	72,9	41,6
60	88,5	92,4	**109,3**	93,5	98,7	**145,3**	100,6	81,8	**143,8**	78,4	55,5	40,7
61	80,2	98,3	**112,1**	88,2	**112,3**	**148,9**	**105,6**	52,2	**26,9**	**115,7**	31,4	35,6
62	83,2	87,4	**113,9**	89,5	97,2	**152,6**	**117,3**	**165,5**	**24,5**	**207,5**	34,2	31,6
63	86,3	90,4	119,3	92,7	98,4	**155,8**	**135,9**	84,1	**24,7**	**212,1**	37,1	**170,1**
64	84,2	89,3	**125,8**	86,5	97,5	**156,9**	**127,6**	91,8	23,7	23,1	38,2	**120,2**
65	90,2	94,2	**127,5**	93,9	96,3	**149,7**	63,3	99,6	22,9	29,7	40,2	98,1
66	92,4	94,9	**132,9**	**109,1**	98,1	**147,1**	**162,2**	**113,2**	22,5	23,8	40,5	65,1
67	91,1	95,7	**128,4**	**108,8**	100,2	**138,9**	**150,7**	**126,1**	21,8	25,1	40,3	55,4
68	93,1	104,2	**145,6**	96,2	96,3	**138,1**	**162,2**	**158,3**	20,5	25,7	41,8	55,7
69	94,2	100,6	**107,4**	**105,3**	**107,4**	**118,5**	**186,8**	**147,2**	**202,4**	26,9	43,6	91,1
70	98,2	**106,6**	**115,3**	**106,9**	**109,5**	**121,8**	22,1	36,9	192,4	25,5	43,9	**157,8**
71	89,3	96,3	**108,3**	96,3	98,2	**116,9**	24,3	46,7	**171,6**	26,3	45,7	**202,3**
72	**135,4**	**158,2**	**159,4**	**159,1**	**169,5**	**112,8**	30,7	51,5	**163,6**	22,8	41,1	25,9
73	34,6	74,3	48,2	51,1	**112,4**	33,3	35,5	55,8	**152,6**	95,4	100,8	24,9
74	31,1	56,5	33,1	41,6	54,3	43,5	41,1	58,4	**123,3**	**130,3**	**148,9**	23,1
75	33,2	58,2	29,3	42,4	52,9	33,6	46,3	57,9	**119,9**	23,8	31,1	25,7

The values above 100 lx were coloured in Table 4.1. The existing roof skylight designed for Galleria Shopping Mall is located at a total height of 23 meters from the ground floor, and metal and semi-transparent glass materials are preferred as construction. During the measurements, it is thought that

the natural lighting received from the roof skylight into the interior space does not provide maximum efficiency during the periods when natural lighting measurements were made at selected times.

Flyinn Shopping Center, Florya (Figure 2 and 3): Flyinn Shopping Center opened its doors to visitors in Florya on December 21, 2003 as the first shopping center with panoramic view in Turkey. Designed by Murat Tabanlıoğlu. Flyinn Shopping Mall is built on a total land area of 5.500 m² and a construction area of 38.500 m² with 78 stores, 6 cinemas, a fast food court, an entertainment center for children and circulation areas [14].

Figure 2. Flyinn Shopping Center Front Facade View [14].

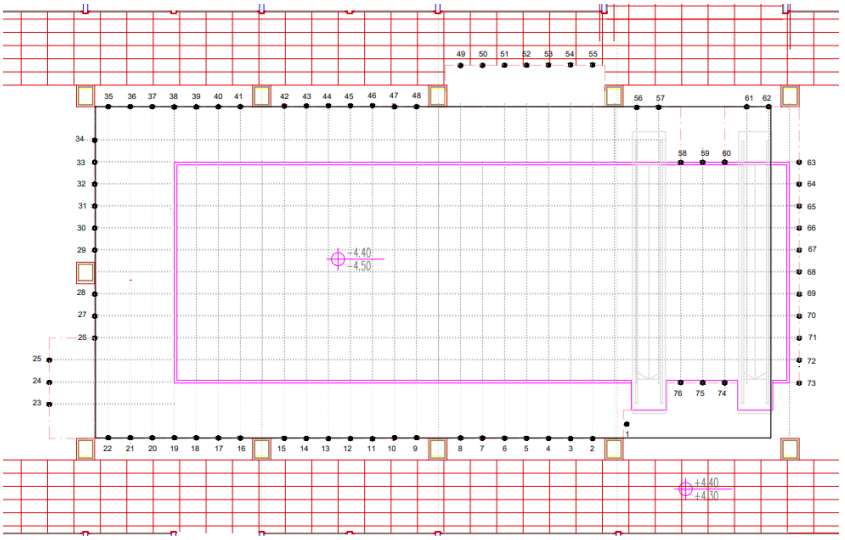


Figure 3. Flyinn Shopping Mall Ground Floor Common Circulation Area with Natural Lighting Measurement Points

The most important feature that distinguishes Flyinn Shopping Mall from other shopping centres is the design of a large opening on the facade facing Atatürk Airport, which provides both a panoramic view of the mall and natural lighting into the interior space from this facade. In addition, in order to ensure the sustainability of the building, eating-drinking, resting and terrace areas were designed for the users of the shopping centre on this façade, and areas where the psychological and physiological comfort of the users were given importance were created. The existing roof skylight in the building is preferred as a metal construction and transparent glass material in order to benefit from maximum natural lighting

in the interior, and metal lamellas that can rotate manually and according to the position of the sun are used as shading elements.

The circulation area where natural lighting measurements were made in Flyinn Shopping Center is 475 m² in total and is located on the ground floor of the shopping center. In Table 3, the illuminance measurements taken on the days and hours of measurement are written separately and values above 100 lx are coloured.

Table 3. Flyinn Shopping Mall Natural Lighting Measurements

AVM	NATURAL LIGHTING MEASUREMENT						NATURAL LIGHTING MEASUREMENT					
FLYINN AVM	21.03.2022			21.06.2022			21.09.2022			21.12.2022		
	10.00	13.00	15.00	10.00	13.00	15.00	10.00	13.00	15.00	10.00	13.00	15.00
1	60,9	68,3	79,9	42,4	87,1	**116,4**	28,1	25,7	38,4	38,2	40,2	51,2
2	34,5	38,9	43,4	31,7	43,4	23,9	22,2	**192,1**	40,8	23,7	42,2	55,2
3	33,2	41,6	44,6	29,5	32,3	49,2	21,5	**159,2**	**156,4**	**195,3**	29,3	38,7
4	35,6	43,8	44,7	32,9	41,7	48,3	21,3	**115,6**	**137,7**	**178,3**	21,5	26,8
5	32,1	38,9	45,7	45,2	40,6	44,3	**170,3**	**121,9**	**141,1**	**169,3**	**171,1**	**213,6**
6	35,8	42,7	43,6	33,8	48,8	53,4	**150,1**	**147,1**	**159,2**	**174,1**	**173,2**	**181,5**
7	30,5	38,6	42,8	35,7	42,8	45,5	**169,3**	**110,3**	**126,3**	**165,2**	**182,1**	**140,6**
8	32,6	33,8	40,3	23,7	40,8	48,5	**148,6**	**117,3**	**121,8**	**188,5**	**181,4**	**194,6**
9	28,5	37,9	42,4	40	37,9	42,8	**123,8**	**115,8**	**118,5**	**134,1**	**177,9**	**200,8**
10	27,6	35,9	39,4	21,8	33,6	40,9	25,4	**115,1**	**114,8**	**151,5**	**169,8**	**199,1**
11	25,5	34,6	37,5	31,1	41,5	48,5	25,6	**114,1**	**108,4**	**116,1**	**183,7**	**193,4**
12	29,5	37,6	43,5	35,9	40,8	46,9	26,9	**117,7**	29,1	**153,1**	**189,3**	**202,5**
13	32,6	39,6	42,6	40,5	44,6	46,3	27,7	**115,2**	74,4	29,8	201,1	192,9
14	35,8	43,7	45,7	38,5	40,3	44,9	26,2	52,8	76,4	66,9	23,7	197,1
15	37,8	47,6	43,5	40,3	29,6	46,8	21,4	37,1	37,2	81,2	21,9	56,9
16	29,5	34,8	40,4	32,3	37,6	43,2	**155,2**	**208,4**	30,8	96,8	152,1	**193,9**
17	27,5	36,8	39,5	34,5	30,7	46,8	**161,2**	23,9	23,6	**113,2**	**186,6**	**216,7**
18	24,6	34,6	40,4	36,9	38,4	43,9	**166,4**	**127,7**	**122,6**	**115,4**	**174,6**	**200,8**
19	26,8	32,8	35,9	32,4	36,8	41,8	**166,8**	**126,4**	**114,8**	**112,2**	**140,1**	**162,5**
20	32,6	31,5	36,6	33,5	33,5	39,6	**159,2**	**134,9**	**118,3**	**111,3**	**129,8**	**144,6**
21	30,7	34,7	36,3	37,4	32,6	42,8	**164,7**	**127,7**	**120,9**	101,2	**148,6**	**160,5**
22	29,7	33,4	37,1	36,8	37,5	45,2	**170,1**	**143,1**	**117,2**	91,8	28,5	**105,1**
23	**136,8**	**123,6**	**139,4**	**170,5**	**176,9**	**165,4**	**192,7**	**113,8**	**113,2**	78,4	66,2	**213,1**
24	**143,5**	**146,9**	**149,9**	**180,8**	**199,3**	**178,6**	**177,7**	**104,8**	**109,4**	73,8	92,1	24,4
25	**167,4**	**154,3**	**161,6**	**209,6**	**218,9**	**169,6**	**166,1**	96,2	81,3	51,4	**104,3**	**184,2**
26	32,5	34,6	42,4	38,6	41,8	45,6	**168,7**	82,1	55,5	52,2	**112,8**	**180,1**
27	29,2	36,6	41,8	33,5	37,9	43,8	**162,4**	81,9	32,7	30,9	**111,9**	**142,1**
28	31,5	38,9	43,1	32,6	43,8	48,6	**159,5**	**116,7**	24,1	26,2	**108,1**	**150,4**
29	33,6	39,2	42,5	35,5	41,8	46,2	**169,9**	**196,8**	**131,1**	**182,4**	**103,2**	**162,1**

30	25,8	34,4	36,3	28,5	36,8	49,7	**172,8**	53,7	152,6	**177,7**	86,6	**151,3**
31	35,6	39,5	39,1	37,9	40,7	44,3	**175,4**	62,4	164,1	24,1	**155,7**	**171,3**
32	32,1	40,3	41,2	32,4	44,6	49,2	**182,9**	63,8	23,8	27,4	64,9	**161,2**
33	28,5	36,4	38,5	34,7	38,5	43,4	**165,9**	73,2	24,9	26,9	47,3	**165,3**
34	29,4	35,4	33,5	30,5	37,1	44,6	**197,3**	74,6	25,7	28,7	75,1	**157,8**
35	30,6	37,5	39,5	36,7	39,2	47,6	**219,9**	76,1	26,5	25,9	29,4	**155,1**
36	32,5	39,5	43,5	42,6	45,9	56,8	38,2	74,9	**181,1**	**168,5**	36,2	**158,8**
37	28,6	36,9	41,5	46,8	52,7	58,9	39,2	75,5	**185,4**	**212,7**	90,3	**141,8**
38	27,6	33,6	44,6	44,9	54,6	62,8	41,3	73,6	**189,8**	**210,9**	73,8	**152,1**
39	32,2	35,4	43,6	37,9	55,9	66,3	40,3	63,6	**162,4**	22,3	42,8	**162,8**
40	33,4	39,4	42,8	45,8	49,5	69,7	41,3	51,8	**190,3**	23,6	**162,6**	**205,8**
41	31	35,7	46,7	48,6	56,7	57,3	36,2	42,8	**194,3**	25,3	**187,2**	40,5
42	34,9	41,5	45,6	47,2	60,9	61,5	35,1	**191,4**	**189,4**	**192,1**	23,3	41,6
43	34,2	42,9	48,4	49,4	57,9	64,9	33,5	29,8	**179,8**	22,7	70,8	43,7
44	31,5	36,4	43,5	39,7	56,3	61,6	31,9	**125,6**	184,8	**173,5**	**154,4**	40,2
46	28,6	33,6	46,1	37,4	43,6	47,7	27,8	26,8	**189,6**	23,6	28,4	39,2
47	36,4	38,1	42,7	47,9	54,8	58,7	23,9	24,5	**160,4**	**198,8**	25,3	35,3
48	34,9	45,6	48,9	45,6	65,8	67,9	24,1	26,9	**179,1**	**195,9**	44,7	32,6
49	**112,5**	**128,5**	**139,6**	**144,6**	**150,3**	**165,4**	29,7	24,9	23,6	**137,9**	44,2	31,1
50	**132,6**	**143,4**	**141,4**	**159,7**	**167,3**	**159**	36,1	27,7	31,1	**191,6**	41,5	39,2
51	**137,6**	**156,7**	**153,5**	**164,6**	**178,3**	**188,2**	37,2	24,1	76,2	201,1	40,2	51,8
52	**141,6**	**169,6**	**167,3**	**170,6**	**189,3**	**198,7**	35,5	**189,7**	59,3	36,5	38,1	59,3
53	**148,5**	**152,5**	**163,6**	**173,6**	**192,3**	**208,3**	32,2	**197,5**	**123,1**	38,2	37,4	67,4
54	**134,6**	**143,8**	**172,4**	**179,5**	**188,4**	**178,4**	29,5	**176,8**	56,1	36,9	30,4	71,9
55	**124,7**	**134,5**	**143,6**	**168,6**	**190,4**	**167,7**	27,9	23,1	86,4	33,2	33,5	66,8
56	66,8	79,8	75,4	84,6	98,4	87,3	27,7	28,3	52,4	24,1	49,9	54,1
57	68,3	82,4	67,4	99,7	**109,4**	90,2	25,6	34,6	69,1	29,6	51,8	47,1
58	57,8	68,5	62,4	45,9	48,3	65,3	23,5	36,9	40,7	27,1	46,8	40,5
59	48,5	52,4	48,4	53,9	49,5	56,7	**209,2**	34,2	47,9	**200,5**	40,2	38,9
60	46,3	49,5	54,5	50,4	39,3	65,7	**213,1**	31,1	55,5	29,2	34,4	36,1
61	67,8	73,5	68,9	75,3	89,4	67,5	**193,6**	**263,3**	54,6	36,5	23,7	22,3
62	69,4	76,4	79,4	87,5	92,4	95,3	**174,4**	**210,2**	44,5	37,7	28,1	31,2
63	63,1	68,4	72,7	78,4	87,3	98,4	**147,3**	**179,2**	37,1	22,4	25,4	28,9
64	54,8	58,4	68,9	65,3	78,1	82,4	**134,2**	**164,8**	31,5	23,6	23,1	25,9
65	46,9	53,5	59	67,1	74,4	88,5	**113,2**	**157,8**	29,1	**200,9**	**179,4**	23,2
66	52,8	63,7	66,8	65,3	85,3	94,6	**143,1**	**136,6**	26,7	22,3	**150,4**	25,4
67	45,4	49,4	56,9	76,9	84,3	87,5	**163,4**	**111,2**	24,8	**184,6**	**180,6**	24,1
68	59,5	63,2	61,5	81,9	98,4	**108,5**	**170,8**	**148,5**	203,7	**173,6**	**183,7**	34,7
69	68,9	74,3	78,4	84,2	**106,4**	**113,3**	26,3	**131,3**	**163,2**	**153,2**	27,8	46,4
70	62,7	58,9	62,7	88,9	89,9	95,3	29,5	26,4	**185,5**	**134,2**	35,5	55,6
71	67,3	62,3	69,2	95,2	98,4	**109,4**	31,4	29,2	**200,4**	**212,5**	39,6	58,4

Cevahir Shopping Mall, Şişli (Figure 4): Cevahir Shopping Mall, designed by American architect Minoru Yamasaki, was constructed by Cevahirler Project Design Center and opened in Şişli in 2005. It is thought to be the second largest shopping center in the world and the largest shopping center in Turkey, with a total land area of 62,475 m², six floors and 324 stores, 348,299 m² shopping area, 71,016 m² parking area for 2500 vehicles and 420,000 m² building area.

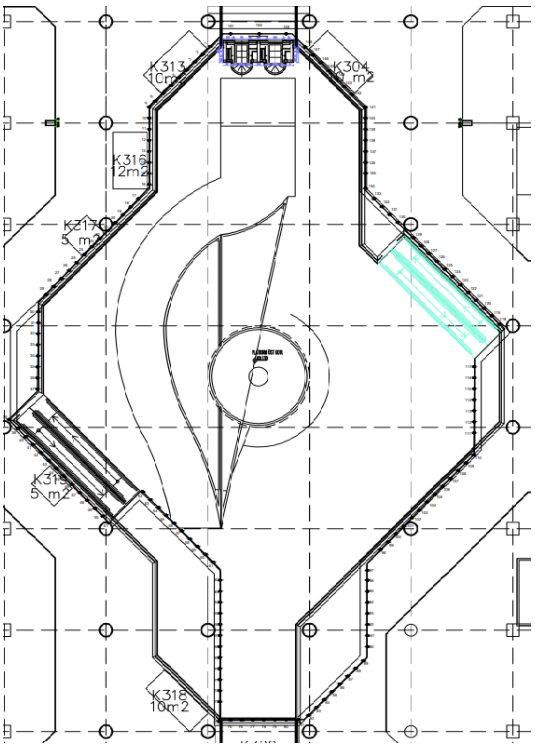


Figure 4. Cevahir Shopping Mall Front Facade View and Plan Area with Natural Lighting Measurement Points

The existing roof skylight in the shopping center is made of glass pyramids, metal construction and transparent glass material were preferred in order to benefit from maximum natural lighting in the interior space, and when examined, no shading elements were seen on it. Due to the fact that the glass material used in the roof skylight is completely transparent glass, air conditioning devices are in constant operation in order to keep the heat that may occur in the volume at the desired level.

The circulation area in Cevahir Shopping Center where natural lighting measurements were made is 1140 m² in total and is located on the ground floor of the shopping center and is named as the 4th floor in the shopping center. In Table 4 below, the illuminance level measurements taken on the days and hours of measurement are written separately.

Table 4. Cevahir Shopping Mall Natural Lighting Measurements

AVM	NATURAL LIGHTING MEASUREMENT						NATURAL LIGHTING MEASUREMENT					
	21.03.2022			21.06.2022			21.09.2022			21.12.2022		
CEVAHİR AVM	10.00	13.00	15.00	10.00	13.00	15.00	10.00	13.00	15.00	10.00	13.00	15.00
1	143,2	113,6	104,3	117,1	163,6	98,8	64	66,1	48,2	49,9	51,8	41,4
2	189,3	128,3	154,2	192,3	24,7	143,3	91,5	90,2	72,4	85,6	74,1	67,4
3	210,4	106,4	169,4	202,9	24,9	159	121,8	95,5	100,5	94,3	75,4	71,1
4	219,2	98,4	172,4	207,9	27,4	166,6	118,1	89,3	107,5	31,6	76,9	70,3
5	209,3	86,3	176	196,8	26,8	158,1	105,2	83,3	73,5	100,9	80,9	78,7
6	209	78,5	182,1	204,1	40,8	154,8	130,8	109,4	138,5	94,7	78,4	73,6
7	198,3	26,4	178,3	183,4	38,9	165,7	95,4	101,9	135,9	91,1	81,3	66,5
8	215,2	24,6	168,3	202,4	34,8	153,9	119,7	110,8	126,5	102,8	184,9	180,7
9	188,5	27,8	172,4	179,4	35,6	160,4	119,9	112,1	90,5	96,1	90,1	73,6
10	22,5	24,5	154,3	29,5	46,9	148,7	99,7	147,7	148,6	94,7	91,5	67,2
11	23,5	27,7	176,4	28,7	51,7	164,8	146	158,1	154,9	86,8	72,2	63,1
12	24,2	30,5	194,3	36,5	56,8	183,9	143,2	95,3	163,1	98,4	95,4	74,6
13	34,7	129,4	188,4	38,5	102,6	178,5	169,5	202,6	177,9	82,7	117,9	72,4
14	48,9	119,8	216,3	38,1	108,6	204,1	178,8	22,5	194,8	96,7	108,9	83,6
15	38,5	25,3	154,2	36,7	43,3	125,9	21	22,1	20,3	106,7	125,9	85,9
16	27,4	202,4	21,5	36,8	196,6	32,6	21,7	23,5	20,9	119,1	131,3	101,1
17	27,5	132,4	22,3	38,1	111,6	26,5	22,2	26,3	195,7	119,8	137,5	105,9
18	24,5	32,4	20,3	36	41,1	26,3	21,3	28,3	23,7	32,1	42,3	48,7
19	90,5	166,4	24,5	36,2	155,8	36,2	208,9	30,8	23,2	138,6	133,8	143,5
20	92,6	78,4	23,4	37,2	48,9	28,4	203	35,8	26,9	143,4	127,3	112,8
21	109,6	76,4	21,4	30,5	98,9	26,3	204,1	49,4	129,1	145,6	136,6	124,9
22	98,5	87,5	22,3	22,8	43,8	27,1	196	104,8	44,6	46,2	43,2	77,3
23	87,4	95,6	21,3	30,4	90,9	26,1	198,4	110,2	94,2	83,2	62,8	96,3
24	90,3	98,3	26,2	37,1	75,2	35,9	188,2	180,7	69,5	147,1	128,9	125,9
25	80,2	115,3	78,4	36,4	74,3	25,2	201	103,6	48,7	138,8	125,8	120,8
26	23,4	117	65,3	35,6	71,4	23,5	21,3	44,2	44,2	106,2	116,6	139,4
27	21,1	125,5	26,4	38,2	63,7	34	204,8	45,4	72,1	137,1	95,7	131,3
28	28,3	34	30,4	34,6	45,7	37,4	207,3	52,3	156,2	146,1	156,8	126,8
29	178,4	36,6	32,5	168,8	43,8	38,8	206,1	166,5	86,8	160,3	138,9	122,2
30	169,3	28,3	23,7	168,2	33,9	28,1	166,7	176,1	144,4	134,9	129,6	123,1
31	187,9	20,4	68,4	164,7	28,3	77,2	133,1	95,3	166,5	135,9	124,2	121,1
32	179,4	24,5	78,3	163,4	30,5	87,1	119,4	197,7	85,6	76,4	80,6	93,6
33	178	22,1	56,4	150,7	37,3	46,9	102,3	118,5	72,1	106,1	95,6	122,8
34	187,4	21	38,4	153,6	28,7	35,8	101,4	63,4	171,6	126,5	79,1	103,7
35	205,2	26,4	29,4	162,5	35,5	38,9	104,2	148,1	90,5	121,6	80,6	117,3

36	**208,1**	28,4	24,6	**168,4**	43,5	31,9	99,1	82,9	**131,7**	**112,1**	97,6	**122,4**
37	**202,3**	**217,4**	25,3	**159,3**	**195,5**	32,6	98,2	68,3	**200,2**	**103,5**	96,5	**111,4**
38	**156,3**	**209,3**	**167,3**	**117,8**	**199,1**	**155,9**	97,9	**113,7**	36,6	66,8	92,1	**131,1**
39	**143,5**	**218,9**	**173,5**	**121**	**196,3**	**149,7**	93,8	37,9	**159,3**	87,8	91,5	**119,1**
40	**128,2**	**216,3**	**177,1**	**118,3**	**207,7**	**156,3**	82,7	66,2	40,3	86,9	91,6	101,6
41	**134,3**	**210**	**183,2**	**105,8**	**202,9**	**152,3**	74,1	25,5	**147,7**	85,9	**105,2**	93,1
42	**134**	**218,4**	**145,3**	**105**	**204,1**	**131,2**	**111,9**	**121,8**	**183,1**	**182,7**	**198,5**	**194,1**
43	**143,5**	**222,5**	**125,2**	98,6	**206,2**	**115**	94,4	**172,4**	**162,7**	86,8	96,6	81,2
44	**142,5**	**207,4**	**118,4**	86,6	**188,5**	**106,7**	89,4	**144,7**	**141,7**	95,6	**116,8**	90,5
46	**68,4**	**205**	**104,3**	27,1	**178,6**	83,7	**108,1**	**127,6**	**128,4**	95,2	39,9	89,8
47	**105,2**	**198,3**	78,4	36,5	**169,2**	69,1	**105,4**	61,9	100,9	31,1	**103,9**	**195,1**
48	**165,3**	**178,1**	128,9	42,3	**156,3**	**116,7**	65,5	92,3	94,6	**162,8**	**192,2**	**194,3**
49	**161,3**	**165,3**	94,2	48,3	**125,6**	89,4	62,4	**109,6**	**131,2**	90,5	74,2	92,6
50	**158,3**	90,4	87,4	47,1	80,1	76,5	80,1	29,7	74,5	93,5	51,6	90,5
51	**164,3**	**139,5**	78,3	54,1	**143,8**	60,3	**134,9**	67,2	95,7	98,2	58,6	88,1
52	27,4	**134,5**	89,4	56,2	**121,9**	65,3	23,2	**201,2**	**139,7**	**184,5**	84,2	**176,4**
53	23,9	21,3	92,5	53,2	26,6	55,8	28,1	30,5	82,2	66,1	87,9	71,1
54	29,5	89,3	93,7	51,1	**190**	54,5	**122,9**	100,8	85,5	50,3	83,3	72,3
55	24,6	98,4	**104,3**	48,6	28,7	57,8	**126,3**	35,9	96,2	111,2	**193,4**	65,6
56	26,3	**139,4**	76,3	47,3	**124,4**	53,8	**107,1**	36,2	**203,5**	**128,7**	20,9	57,3
57	27,5	**143,2**	78,1	48,9	**127,4**	65,7	27,3	24,2	36,5	22,1	38,9	42,9
58	33,5	**189,5**	86,4	45,6	**172**	62,8	22,8	28,5	62,5	26,9	30,4	36,6
59	31,3	78,4	88	44,7	21,3	64	**121,1**	32,2	48,3	29,4	29,8	31,3
60	38,6	75,4	92,3	42,8	**122**	58,3	**177,2**	**165,4**	38,2	37,5	32,3	**132,9**
61	37	68,4	78,4	40,7	28	43,6	30,4	**116,2**	30,7	43,7	33,3	33,9
62	54,9	21	**108,3**	45,9	27,8	38,7	26,7	23,4	24,7	95,7	31,8	34,5
63	51,9	23,4	64,1	44,9	34,3	48,7	27,7	23,6	22,3	34,5	33,1	48,7

Profilo Shopping Center, Mecidiyeköy, (Figure 5): The former Profilo Factory was redesigned by Utarit İzgi and opened as Profilo Shopping Mall in Mecidiyeköy in 1998. The shopping center has a total construction area of 110.000 m² on a 20.000 m² land area with 5 floors and 201 stores, 100.000 m² shopping area and 10.000 m² parking lot area for 1500 vehicles [15].

Natural lighting is provided up to the ground floor with a roof skylight using matte glass that continues along the gallery spaces, and the heat of the sunlight is tried to be prevented with the use of this material. In addition to the roof skylight, mirrored glass used on the entrance façade is also used to benefit from natural lighting. The ceilings are made of plasterboard and metal suspended ceilings, and the corridors with very low ceilings are covered with mirrors to make them feel higher. Matte gray granite was used for flooring, and square patterns were designed using pink, gray and white granite in the areas where the squares are located.

Figure 5. Profilo Shopping Mall Front Facade View and Plan Area with Natural Lighting Measurement Points

When all the measurements are evaluated for the 4 shopping center buildings, according to the results of the illumination level measurements; Profilo Shopping Center needed more artificial lighting support than the other buildings, and it is thought that the existing roof skylight cannot provide enough natural lighting support for the interior space. Table 5 shows the natural lighting measurements of Profilo Shopping Center and values above 100 lx are coloured.

Table 5. Profilo Shopping Mall Natural Lighting Measurements

AVM	**NATURAL LIGHTING MEASUREMENT**						**NATURAL LIGHTING MEASUREMENT**					
PROFİLO AVM	**21.03.2022**			**21.06.2022**			**21.09.2022**			**21.12.2022**		
	10.00	**13.00**	**15.00**	**10.00**	**13.00**	**15.00**	**10.00**	**13.00**	**15.00**	**10.00**	**13.00**	**15.00**
1	**103,9**	41,7	46,3	35,9	58,9	49,3	46,8	35,4	28,1	28,1	67,3	94,3
2	100	**106,5**	**123,4**	**111,3**	24,3	**126,7**	**139,3**	87,5	63,9	57,3	63,9	60,9
3	82,6	94,6	**134,3**	**130,9**	35,8	**143,6**	23,8	**168,2**	**102,5**	75,7	84,1	79,9
4	**131,8**	94,3	95,1	**126,5**	36,4	**117,5**	25,6	**185,7**	**118,1**	83,6	97,2	90,1
5	26,5	88,2	**127,7**	**128,2**	23,8	**113,3**	26,5	**190,7**	**126,9**	90,6	**106,4**	**104,1**
6	29,6	**106,2**	**145,7**	**122,3**	33,4	**126,1**	23,6	**181,7**	**110,2**	97,1	**102,5**	**105,8**
7	31	**107,2**	**117,2**	**108,8**	22	**117,7**	21,6	**153,8**	**112,5**	84,2	**108,1**	99,9
8	38,8	78	**118,1**	**142,4**	28,6	**115,4**	21,1	**147,5**	**102,6**	72,5	95,7	84,2
9	34,3	56,6	**107,3**	**131,6**	35,5	**133,4**	22,6	**156,5**	98,4	71,7	100,8	75,7
10	70,2	88,2	**106,4**	**126,6**	35,6	**141,4**	25,7	**173,1**	**103,4**	70,2	**105,7**	72,8
11	26,5	76,5	**110,3**	**123,7**	25	**115,7**	25,4	**165,2**	99,1	66,9	**111,4**	66,1
12	64,1	86,2	69,6	66,9	**113,5**	83	23,1	**187,5**	75,5	66,7	97,3	51,6
13	40,8	98,6	67,5	80,2	**191,8**	50,8	21,4	**198,4**	58,1	62,9	82,9	74,3

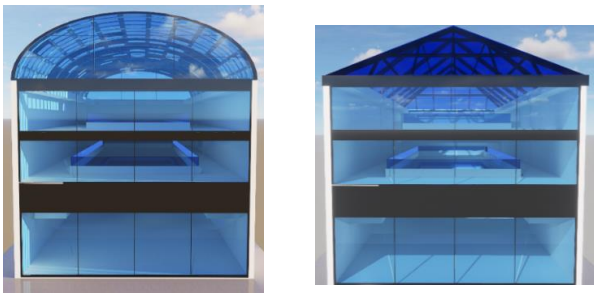
14	66,7	93,4	59,6	**109**	27,6	85,1	23,8	**203,2**	**167,7**	**175,2**	**172,5**	**182,1**
15	**105,2**	100,5	80,2	**110,1**	21,9	**113,9**	26,5	**170,3**	65,9	**185,8**	**164,2**	**187,2**
16	41,1	68,9	101,3	**115**	23,4	97,3	28,1	**121,2**	70,5	85,9	71,1	77,5
17	**106,1**	**117,8**	85,2	**145,3**	35,4	95	27,3	97,4	**186,1**	73,5	**173,4**	**180,4**
18	**122,9**	65,7	78,4	**157,9**	36,1	**117,3**	27,4	95,5	92,1	66,2	72,7	70,7
19	41,6	37	84,3	**160,8**	35,4	**127,7**	23,1	**129,9**	95,9	56,2	75,6	59,7
20	126	63,2	65,7	**164,4**	34,4	**138,2**	**163,6**	**149,7**	**102,2**	56,1	84,4	47,6
21	**110,4**	57,8	71,8	**135,3**	30,3	**125,4**	**113,3**	**163,1**	**112,3**	**124,4**	**119,8**	**160,7**
22	**149,5**	54,6	84,9	**147,8**	31,6	**126,1**	**103,1**	**158,1**	**120,1**	**120,4**	**156,3**	**175,3**
23	**178,4**	53,2	78,5	**170.6**	37,5	**108,6**	**154,2**	**161,2**	**114,2**	**134,8**	**140,9**	**155,4**
24	**168,5**	67,9	82	**181,7**	45,2	**112,1**	**190,6**	**176,5**	**112,1**	59,5	85,5	74,2
25	**183,1**	87,3	87,4	**172,9**	46,4	**121,2**	**203,7**	**189,9**	**134,3**	61,8	80,6	69,3
26	**148,4**	78,9	90,3	**177,3**	48,2	**143,8**	23,1	**195,5**	**140,5**	**121,4**	**164,1**	**178,5**
27	**118,5**	65,3	47,8	**145**	40,5	**130,8**	23,4	**202,3**	**143,2**	**105,5**	**164,3**	**177,4**
28	97,5	59,2	55,3	**119,2**	33,5	**140,3**	23,8	**205,8**	**148,6**	**138,5**	**158,4**	**183,1**
29	**114,6**	72,5	59,5	**145,5**	29,2	**123,3**	22,5	**178,6**	**153,5**	77,6	38,9	82,3
30	**166,7**	76,3	65,4	**149,4**	31,9	97,8	28,3	21,3	**144,7**	79,8	26,9	84,2
31	**158,9**	65,6	59,3	**148,3**	32,4	**121,3**	29,2	23,5	**142,5**	**129,9**	**133,5**	**181,8**
32	**145,8**	56,2	54,2	**138,8**	28,1	**138,1**	29,3	25,6	**158,5**	79,8	55,4	82,9
33	**135,7**	69,3	64,6	**154,9**	21,5	**146,1**	28,8	25,8	83,1	85,6	**166,8**	**189,4**
34	**178,5**	56,4	54,7	**189,1**	27,4	**131,6**	29,5	29,4	59,7	93,4	**182,4**	**184,6**
35	**176,3**	77,8	69,4	199	34,3	**116,8**	29,1	25,4	99,7	**102,8**	80,3	100,4
36	**142,7**	67,9	90,4	**164,5**	31,1	**156,7**	24,1	27,6	**109,2**	**107,1**	89,9	87,8
37	95,7	35,7	132,5	89,5	22,5	**170,3**	26,5	23,2	**189,3**	89,5	86,5	91,1
38	68,8	93,5	48,7	60,7	113	**150,3**	27,7	21,1	**211,7**	**145,5**	**134,9**	**194,8**
39	78,9	**105,5**	56,4	**162.1**	**131,8**	**104**	28,4	25,9	22,4	94,8	74,5	102,8
40	54,8	87,4	27	21,7	28,9	54,7	27,2	**196,1**	23,2	97,9	75,6	**96,6**
41	69,6	65,2	49,4	22,6	33,7	93	24,1	**152,6**	24,1	87,7	73,1	100,6
42	**149,3**	71,4	71,5	**156,3**	33,5	**155,6**	22,2	**145,2**	24,5	62,8	81,4	**106,3**
43	**119,5**	69,4	65,3	**103,5**	21,1	**168,5**	21,2	**188,4**	25,4	60,4	88,9	99,8
44	**109,6**	80,4	101,4	**133,8**	23,9	**175,2**	**199,1**	65,9	93,5	**166,2**	**160,1**	**184,7**
46	**125,8**	77,3	81,2	**127,9**	27,9	**134,7**	**168,8**	68,1	23,1	73,7	**183,6**	**174,3**

5. EVALUATION OF THE MEASUREMENTS OF SELECTED SHOPPING MALLS AND PROPOSING A NEW HORIZONTAL OPENING

After comparing the results obtained from all the necessary measurement points in all shopping mall samples, it was seen that Profilo Shopping Mall needs more daylight, so a new natural lighting system proposal that will provide maximum efficiency was put forward through the simulation program Climate Studio Program.

In line with the illuminance level data obtained through measurements, the current situation was modelled first. Then, a new proposal with triangular form was proposed. Two different types of glazing layers are used for both the current and proposed form. These different types of glazing are one-layer glazing and double-layer glazing with low U-value. By these different trials, an efficient skylight system was tried to be revealed. For the method, 3D models of Profilo Shopping Mall were

created in Rhino program and natural lighting simulation data were obtained using Climate Studio Program (Figure 6).

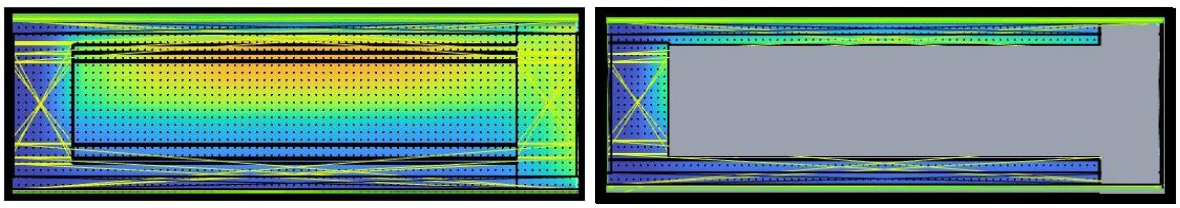


A **B**

Figure 6. The current (A) and proposed (B) skylight systems

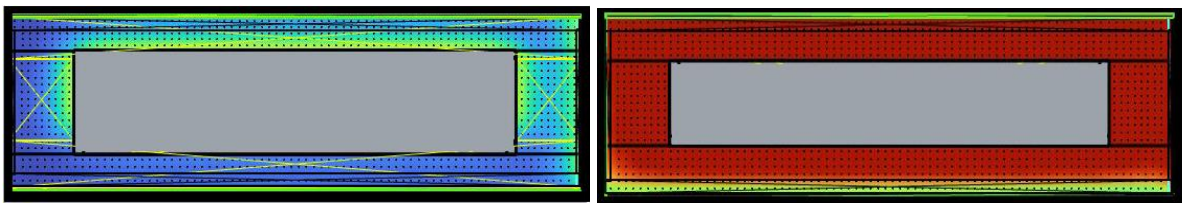
5.1 Simulation of Existing Design (A)

Natural lighting simulation data were obtained for the current situation using the Climate Studio Program (Figure 7, 8 and 9).



a **b**

Figure 7. Profilo Shopping Mall Current Status Ground Floor (a) and First Floor Simulation Data (b)



a **b**

Figure 8. Profilo Shopping Mall Current Status Second Floor (a) and Third Floor Simulation Data (b)

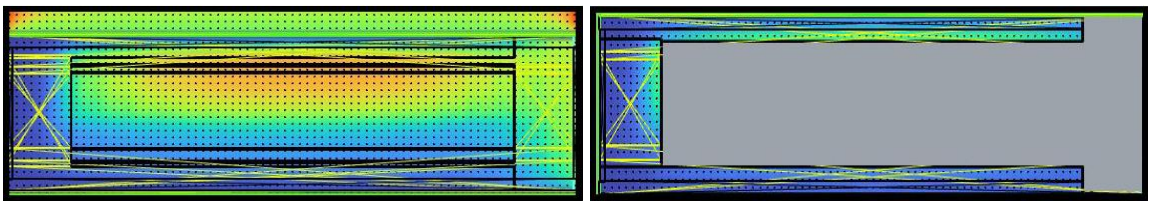
	Fail	Minimum	Medium	High
Target Level	%0,0	%2,0	%1,6	%96,4
Minimum Level	%0,0	%10,0	%5,0	%85,0

Figure 9. Profilo Shopping Center Current Status Analysis for All Floors

As evaluation of Figure 9, for all floors the target illuminance level for high performance is provided but minimum illuminance level cannot be provided. To provide the required levels both for the target and minimum illuminance, values should ensure to be higher than %95 (Table 1).

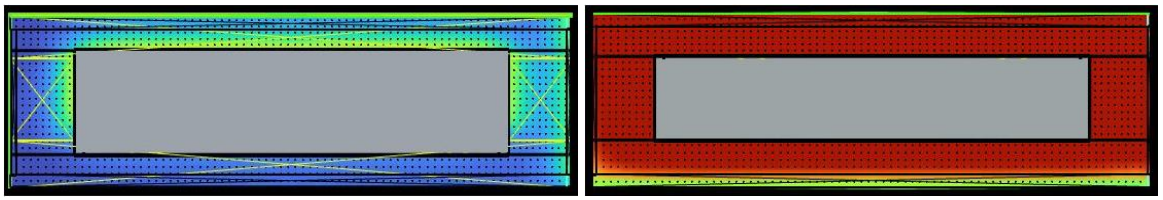
Double Layer Glazing Analysis of Existing Design (A)

Using the Climate Studio Program, natural lighting simulation data were obtained with low U-value, double-layered glass (Figure 10, 11 and 12).



a **b**

Figure 10. Profilo Shopping Mall Current Status Ground Floor (a) and First Floor Simulation Data (b)



a **b**

Figure 11. Profilo Shopping Mall Current Status Second Floor (a) and Third Floor Simulation Data (b)

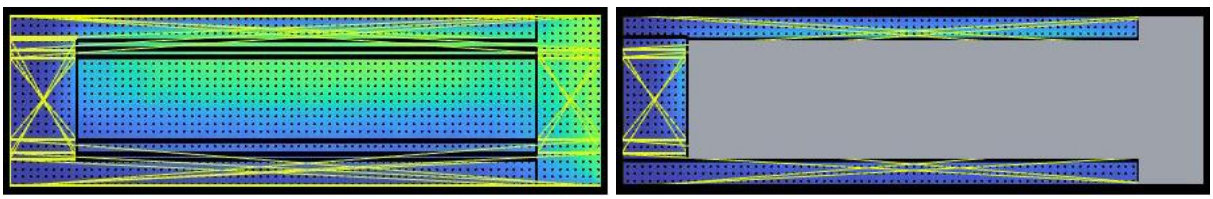
	Fail	Minimum	Medium	High
Target Level	%0,0	%2,0	%1,6	%96,4
Minimum Level	%0,0	%8,3	%6,6	%85,0

Figure 12. Profilo Shopping Center Current Form with Double Layer Analysis for all Floors

As evaluation of Figure 12, for all floors the target illuminance level for high performance is provided but minimum illuminance level cannot be provided. To provide the required levels both for the target and minimum illuminance, values should ensure to be higher than %95 (Table 1).

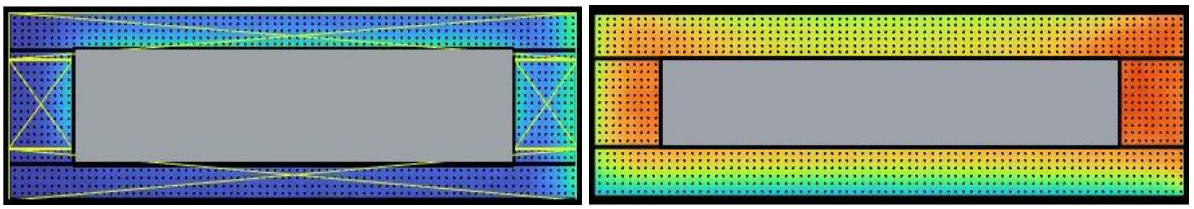
5.2 New Triangular Type Skylight System Proposal (B)

Through the Climate Studio Program, natural lighting simulation data of new triangular shaped skylight was obtained, and it was aimed to acquire high daylighting values (Figure 13, 14). Firstly, double-layer glazing with low U value is simulated and checked. But, it is seen that required illuminance levels referred by EN 17037 (Tablo 1) is not obtained. In the line of this study the one-layer glazing is calculated, and the values are obtained as seen in Figure 15.



a **b**

Figure 13. Triangular Skylight Form Ground Floor (a) and First Floor Simulation Data (b)



a **b**

Figure 14. Triangular Skylight Form Second Floor (a) and Third Floor Simulation Data (b)

Building Compliance [% of rooms, area-weighted]

	Fail	Minimum	Medium	High
Target Level	%0,0	%0,0	%0,0	%100,0
Minimum Level	%0,0	%0,0	%0,0	%100,0

Figure 15. Profilo Shopping Center Proposed Form Analysis for all Floors

As evaluation of Figure 15, for all floors the target and minimum illuminance levels for high performance is provided (higher than %95) (Table 1).

6. CONCLUSION

Daylight environment is an important factor for healthy spaces as well as providing good vision conditions by composing visual comfort. Besides, effective utilization of daylight not only improves visual comfort but also helps save energy. Especially for shopping spaces, providing good visual conditions while saving energy is an important management strategy. As the scope of this study, the natural lighting data of four shopping mall buildings are obtained by measurements. Then the shopping mall with lower values were considered and simulations were conducted via Rhino and Climate Studio (Solemma) Programmes. The current skylight and proposals were revealed by simulations.

Two different types of glazing layers which are one-layer and double-layer glazing with low U-value are used for both the current and proposed triangular form. By this method, an efficient skylight system was tried to be revealed. As a result of these trials the triangular shaped skylight with one-layer glazing gave the required values (Figure 13, 14, 15). But when the triangular shaped form was considered with double-layer glazing, the required values cannot be obtained. This double-layer material with low U value will be effective in terms of providing thermal comfort in the interior space, while requiring minimum heating-cooling load in summer and winter.

In line with the results obtained in the study, it is aimed to create psychological and physiological comfort conditions by ensuring that the active users and visitors of the shopping mall make maximum use of natural lighting with the newly proposed roof light system, and to provide economic benefit and sustainability by minimizing the use of artificial lighting and heating-cooling load inside the shopping mall.

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