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Thinking Daylight in Interiors: An Effective Way to Use Interior Shading Elements

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Abstract

The use of daylight in interiors should provide maximum efficiency by ensuring energy-efficient daylight utilization while offering benefits to designers in meeting the cognitive and physiological needs of users. Design decisions for the use of daylight in interiors are determined by factors such as interior shading elements, model, fabric type, fabric thickness, direction of movement, and light transmittance properties. The aim of this study is to reveal the daylight distribution and parameters of indoor shading elements in residential living spaces. In this context, a simulation model was created using REVIT and ECOTECT programs by applying the scanning model technique with the data obtained from semi-structured interviews and daylight analysis was performed on the model. As a result of the study, it was determined that rustic, balloon and roman blinds do not prevent glare, while double-breasted, rustic, balloon and roman blinds do not transmit light deep into the space.

Keywords: *Daylight, living areas, shading systems, glare, illuminance level.*

İç Mekanlarda Gün Işığını Düşünmek: İç Mekan Gölgeleme Elemanlarını Kullanmanın Etkili Bir Yolu

Öz

İç mekanlarda gün ışığı kullanımı, enerji verimliliği sağlayarak maksimum verimlilik sunarken, kullanıcıların bilişsel ve fizyolojik ihtiyaçlarını karşılamada tasarımcılara fayda sağlamalıdır. İç mekanlarda gün ışığı kullanımı için alınacak tasarım kararları, iç mekan gölgelendirme elemanları, model, kumaş türü, kumaş kalınlığı, hareket yönü ve ışık geçirgenlik özellikleri gibi faktörler tarafından belirlenir. Bu çalışmanın amacı, konut yaşam alanlarında iç mekan gölgelendirme elemanlarının gün ışığı dağılımını ve parametrelerini ortaya koymaktır. Bu bağlamda, yarı yapılandırılmış görüşmelerden elde edilen verilerle tarama model tekniği uygulanarak bir simülasyon modeli oluşturulmuş ve model üzerinde gün ışığı analizi yapılmıştır. Çalışmanın sonucunda, rustik, balon ve stor perdelerin parlamayı önlemediği, çift katlı, rustik, balon ve stor perdelerin ise ışığı mekânın derinliklerine iletmediği belirlenmiştir.

Anahtar kelimeler: *Gün ışığı, yaşam alanları, gölgeleme sistemleri, kamaşma, aydınlık düzeyi.*

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1. Introduction

Depending on the aims of the study, the answer to the following question was sought: As the design parameters (model, direction of movement, fabric thickness, light transmittance) of the indoor shading element used in residential living spaces change, what kind of effects do they have on preventing daylight-related problems and homogeneous distribution of daylight in the interior?

Daylight is the primary element in creating spaces (Arpacıoğlu, 2010). Light not only enables the eye to perform its vision function, but also makes the equipment that makes up the space visible. The roughness or flatness of a surface, the light or dark color, the beginning and end of a space, the gloomy or lively nature of a space, in short, the whole of spatial fiction comes to life thanks to light. When we look at the relationship between daylight and space, there is a need for sufficient daylight to facilitate all the actions performed in the space (Rossi, 2019; Grondzik et al., 2010). These actions can be difficult and light-oriented actions performed in an operating room, or they can be simple actions such as reading a book or resting. For this reason, the required light level for spaces differs (Philips, 2000).

Daylight has factors such as glare, illuminance level, luminance distribution, and smoothness that affect human vision and movement (Leslie et al., 2012). Glare is the result of unwanted luminance in the field of view. The most common and most important factor in the relationship between daylight and user comfort is glare. Because not only the actions are difficult to perform, but also negatively affect human health. The illuminance level is defined as the level of lightbeams incident on a surface (Bellia et al., 2008; Pierson et al., 2017). Illumination of a space adequately or excessively is related to the level of illumination (Grondzik et al., 2010). The level of smoothness arises from the difference in illuminance between the viewing surface and the surfaces behind. An example of an inappropriate level of smoothness is a study area only the table is illuminated. If the book is read in a dark place where only the table is illuminated, after a while, there will be a problem of focusing (Grondzik et al., 2010).

In the study, a literature search was conducted on daylight shading elements and their use in houses, and the theses and other documents written on the subject were examined. Studies in the literature on shading elements take place in architecture and many engineering fields. For this reason, mostly studies in the field of architecture are discussed. Erel (2004) includes information about outdoor shading elements in his thesis. Okutan (2008) examined the structure, movement and angle of incidence of daylight in his study and conducted studies to ensure effective use of daylight in buildings. Köse (2019) examined prismatic panels, one of the advanced daylight systems, in order to increase daylight performance in interiors facing south. Duraler (2017) conducted a study on the effective use of daylight in primary school classrooms. Kılıç (2018), in his thesis, examined the parameters related to the window through the façade openings and mentioned the shading elements used in the exterior and interior environments. Şahinoğlu (2012) examined the effect of shade elements on the heating/cooling energy and visual comfort performance of the window. Sönmez (2019), on the other hand, revealed the daylight distribution to the interior space through different window types based on BREEAM standards in educational buildings. To summarize; Studies have examined daylight shading systems specifically for facades and windows. No study has been found that examines daylight shading elements in interior spaces. Similarly, it has been seen in the literature that studies have been carried out on office, hospital and school buildings, but they have not been examined in terms of housing. The study will contribute to the literature by focusing on residential living spaces and indoor daylight shading systems.

Most of the daylight researches in the literature focus on office buildings. In the keyword search made from academic search engines, it was seen that 65% of 6865 publications focused on office buildings and 35% focused on residential architecture (Doğan & Park, 2017). However, as a result of the pandemic period, people have started to spend more time in residences. For this reason, the importance of daylight parameters increases in residences, which are the areas where various actions are carried out. Housing living spaces have been an important part of the houses from past to present. Today, many different actions such as eating, resting, reading, working are carried out in residential living spaces. Daylight factors such as illuminance and glare should be kept at certain levels in order to carry out all these actions in comfort and health conditions with the highest efficiency. The primary openings in the residential living areas, through which daylight is brought into the space, are windows. Window size, type, joinery features, number of sash, sash width and type of glass used, parameters of daylight related to window; space dimensions, orientation and form parameters are the space-related parameters of daylight (CIBSE, 1999; IESNA, 2011).

The only obstacle between the windows and the light rays that enter the space, reflect from the surfaces and are in a continuous circulation in the space, are the interior shading elements (Kittler et al., 2012; Olbina & Beliveau, 2010). For this reason, choosing the right interior shading element during the space design and application stages will prevent glare, luminance distribution and negative situations arising from the level of illumination (Olbina & Beliveau, 2010; Scuito, 1998). As a result of the studies, it has been seen that the most preferred curtain models in residential living areas are roller blind, rustic, pleated, roman, balloon and double-breasted. The fact that these curtain models move vertically or horizontally, the weaving frequency of the fabric used, the type of fabric, the light transmittance parameters of the fabric are the most effective parameters in terms of taking the daylight into the space.

1.1. Interior Space and Daylight

Daylight is defined as the direct rays of light emitted from the sun (Kelley et al., 2006). The angle of the sun with the earth varies between +23° and -23°. The date when the sun's rays reach the earth at an angle of +23° is June 21, and the date when they reach the earth at an angle of -23° is December 21 (Lechner, 2015) . The reaching of the sunbeams to the earth varies according to the climate, weather conditions and the latitude of the building. In daylight calculations, it is necessary to know the daylight factor, illuminance level, light intensity and luminance distribution quantities (Tregenza et al., 1994). The daylight factor is a ratio that represents the illuminance measured outdoors and the illuminance measured indoors under cloudy sky conditions. Daylight factor is the most common measurement tool used in simulation-based studies (Arpacıoğlu et al., 2020).

In order to measure daylight parameters in the space, first of all, the orientation of the window must be known. North-facing windows will receive more daylight than south-facing windows. But here, it is necessary to determine the expectations from the space at the design stage. If it is aimed to spend the summer season cool, the window should be directed to the north. For users who expect the winter season to be warm, the south oriented window arrangement is more logical (CIBSE, 1999). When we consider the city of Trabzon, the living areas of the houses are oriented to the north in order to take in the view. This causes insufficient daylight in residential living areas, especially in winter.

Daylight has an undeniable value in various aspects of architectural design, from energy efficiency to user comfort, to the perception of architectural space (Koster, 2004). Daylight affects the mood, alertness and stress level of the users of the space. Sufficient daylight in working environments increases the efficiency of working. Lighting enables users to perceive objects in an environment and perform an activity or task. It is impossible to see and visually perceive any element in an environment without light (Yılmaz et al., 2005; Reinhart et al., 2006). Adequate lighting allows users to see better and feel visually comfortable. However, insufficient lighting can cause various problems regarding both the physiology and psychology of the users. These problems can be eyestrain, stress, headache, sleep in daily hours, fatigue, loss of concentration, poor performance in daily work/activities, negative mood, visual discomfort and dissatisfaction (Çiftçi & Arpacıoğlu, 2021).

Trabzon is a city where the Black Sea climate is experienced and heavy rainfall is seen throughout the year. As a result, there are generally cloudy sky conditions in the city of Trabzon, and only diffuse lights reach the city. According to the analyzes made by determining the measurement periods of 1927-2021; The time period when the sunshine duration of Trabzon city is the most is June and July. It receives 6.4 hours of sun per day in June and 5.7 hours per day in July. The months with the lowest sunshine duration for Trabzon are December and January. It receives 2.1 hours of sunshine a day in December and 2.3 hours a day in January (MGM, 2022).

1.2. Interior Shading Elements

Openings on a residential building, in other words, windows, act as a bridge between daylight and interior space (Lee et al., 1998). For this reason, the design of the windows is the first design parameter to both ensure the most efficient use of the daylight taken into the interior and prevent the problems caused by daylight. However, windows that not designed well during the building design phase and cannot keep up with the seasonal changes of daylight require a secondary design element. These design elements can be advanced shading systems applied to the building facade, as well as interior shading elements applied to the interior (Lee et al., 1998; CIBSE, 1999).

According to Türk Dil Kurumu (2005), indoor shading elements (curtains) are defined as a cover stretched over a window or in front of an opening to block the view, light, and hide something. Indoor shading elements are basically divided into two categories. While the soft category includes curtains applied with various fabrics, the alternative category includes colored glasses and blinds-like applications (Nielson & Taylor, 2011). Systems applied in residential living areas are mostly shading elements (curtains) in the soft category. Curtains are examined in 3 groups according to their movement properties, light transmission properties and model and form properties. According to their movement characteristics, curtains are of three types: horizontally moving, vertically moving and fixed curtains. Curtains that move in the horizontal direction are called double-panel, single-panel, multi-group, fringe, slip, stretched and vertical curtains (Neubauer, 2011; Clifton-Mogg & Merrell, 2005; Cargill, 2002; Clifton-Mogg & Paine, 1992) (Figure 1).

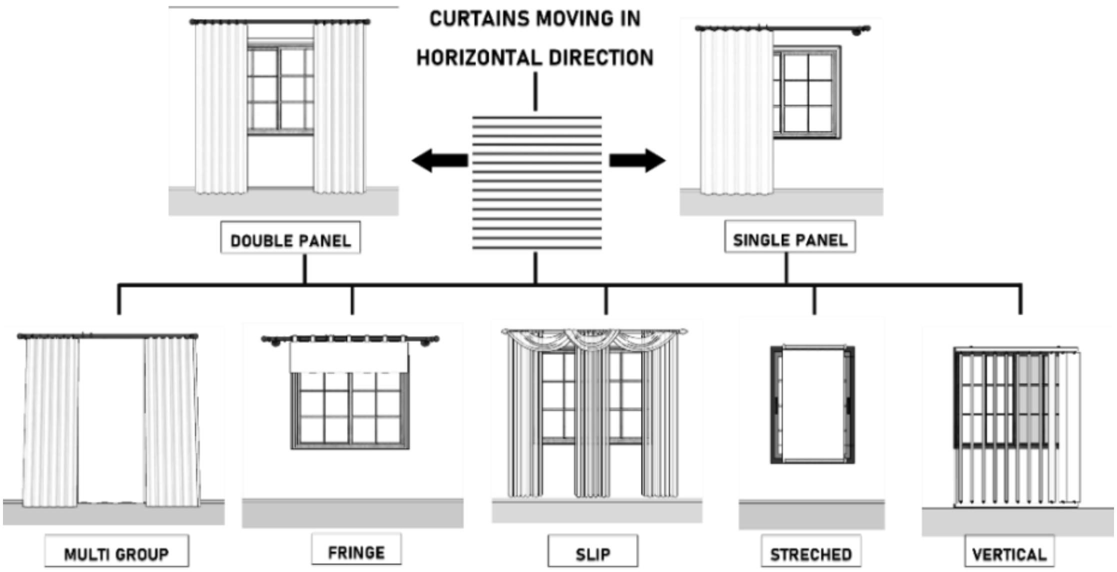


Figure 1. Horizontal moving curtains (Bektaş, 2022)

Curtains moving in the vertical direction, are examined in two groups according to the way they are folded (with or without a mechanism) and according to their form. According to the way of folding, waterfall, roman and balloon curtain models are in the group with mechanism, and the throw curtain model is in the group without mechanism. According to the form of curtains moving in the vertical direction, they are called silhouette, pleated, plisse, duet and roller blinds (Nielson & Taylor, 2011; Clifton-Mogg & Merrell, 2005; Randall & Howard, 2002) (Figure 2).

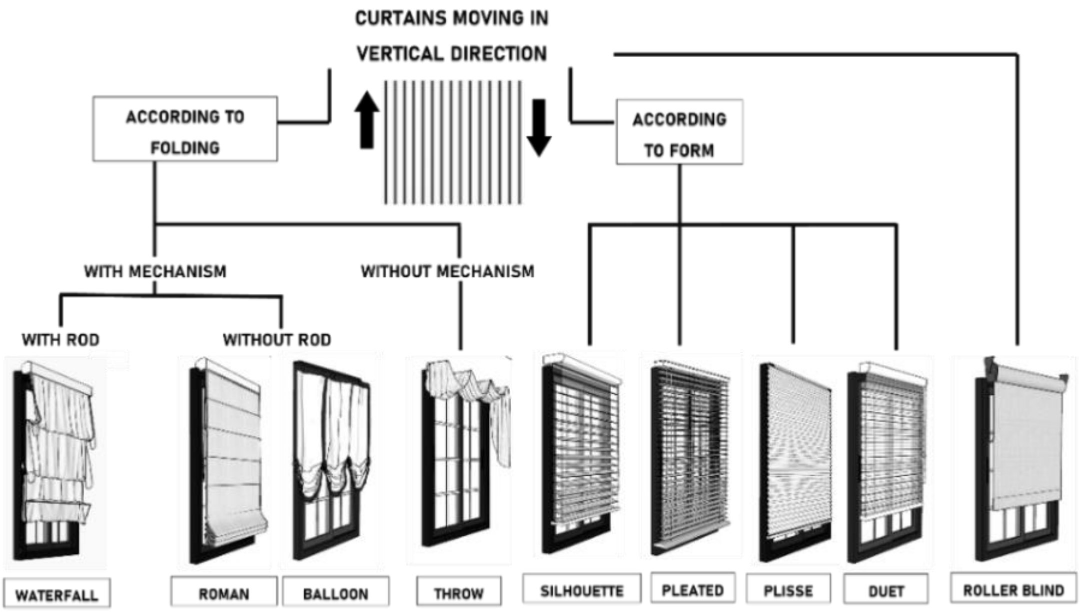


Figure 2. Vertical moving curtains (Bektaş, 2022)

According to their light transmission properties, curtains are of 3 types: transparent, translucent and blackout curtains (Figure 3). Transparent curtains are the type of curtains with the highest light transmittance, while blackout curtains have the lowest light transmittance. The most widely used of transparent curtains are tulle curtains. Tulle curtains can be used indoors alone or together with blackout curtains. Translucent curtains, on the other hand, are a type of curtain that transmits less light than transparent curtains and more than blackout curtains. Translucent curtains block the view while allowing the passage of light.

Name	**Transparent**	**Translucent**	**Blackout**
Light Transmittence	%60-80	%20-60	%0-20

Figure 3. Examples of transparent, translucent and blackout curtains (Bektaş, 2022)

Curtains cannot adapt to every model and shape according to their fabric types, weaving density, light transmittance, colors and similar features (Szmyt & Mikolajczyk, 2010; Schuman et al., 1992). Especially the use of heavy fabrics in mechanism curtain models and the use of light fabrics in vertically moving curtain models are not appropriate.

Similarly, curtains should be positioned at certain points of the window according to their light transmittance (Clifton-Mogg & Merrell, 2005; Randall & Howard, 2002). In addition to these features, due to cultural factors, application systems that are changing and developing day by day, and period trends, curtain models and shape features are changing. As a result of semi-structured interviews with companies that make indoor shading element applications in the city of Trabzon, it has been determined that the curtain models frequently applied in residential living areas are double-breasted, pleated, rustic, Japanese, rochelia and balloon models.

2. Material and Method

The primary purpose of the study, which deals with the daylight factor and distribution in residential living areas; To reveal the effect of indoor shading systems applied in residential living areas in preventing daylight-related problems and using daylight. The following data were obtained as a result of the studies carried out depending on this purpose.

- Daylight factor distribution depending on curtain models
- Monthly average illuminance levels of spaces depending on curtain models
- Daylight factor of the models according to the hours on 21 June and 21 December in residential areas.
- Daylight factor and distribution on 21 June and 21 December in residential areas

In the first part, which is shaped within the framework of daylight distribution of indoor shading elements, semi-structured interviews were conducted as a qualitative data collection method. Interviews with construction, architecture and interior shading companies were conducted to determine the housing design approaches of the city of Trabzon. As a result of the semi-structured interviews, it was concluded that the length of the living space was 6.8 meters; the width was 5.5 meters; the height was 3 meters; and the orientation was north. The window height and width were 310 cm - 210 cm and the sash width was 84 cm; the joinery type was PVC and the glass type was double glazed (4+12+4). As a result of semi-structured interviews, the window/curtain ratio of the models was determined as follows: 2 for model 1; 1.4 for model 2; 3 for model 3; 1 for model 4; and 1.9 for models 5 and 6.

In the second part; The data obtained from the semi-structured interview technique and simulation program are presented. In this context, the effects of indoor shading element transparency, permeability, weaving density, application style parameters on the daylight distribution in the interior are revealed. In addition, the findings of the scenarios prepared in the simulation environment were examined. Inferences were made regarding the application method, model, fabric properties and weaving properties of the interior shading elements (Figure 4).

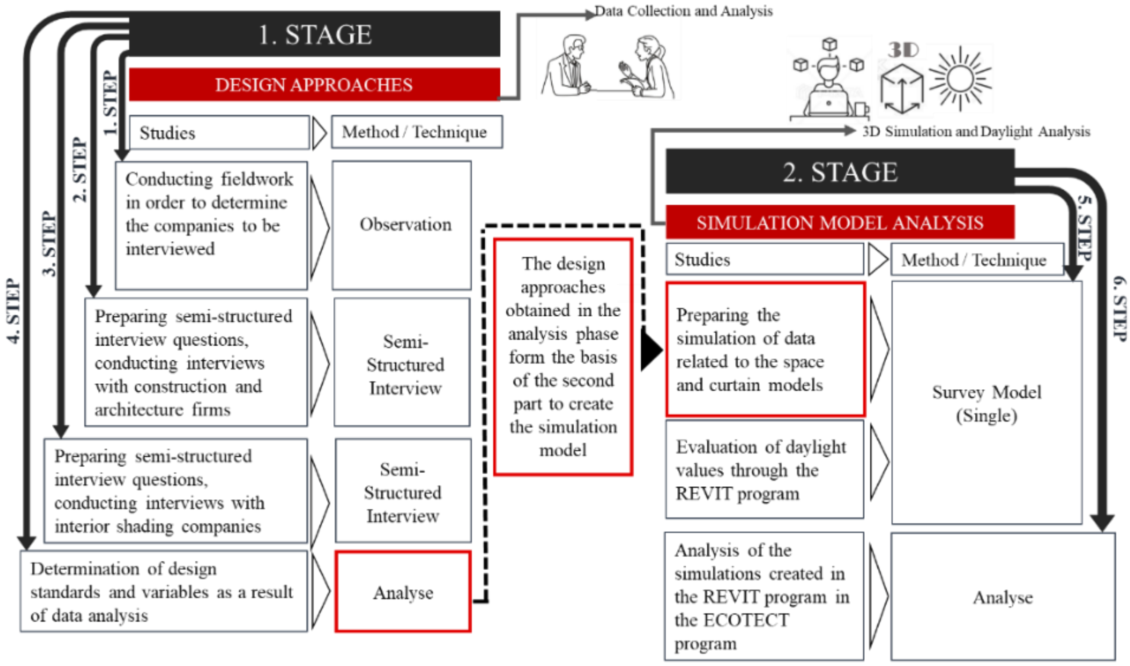


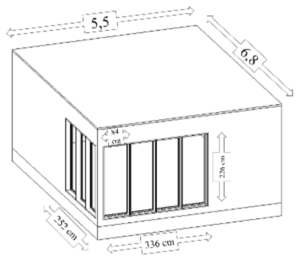
Figure 4. Stages of work (Bektaş, 2022)

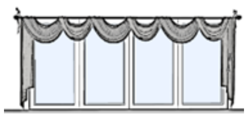
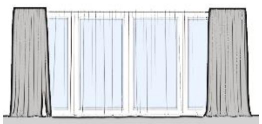
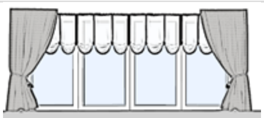
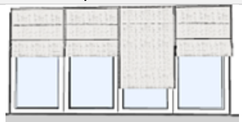
In the first stage of transferring the data to the simulation, a living space simulation was created through the REVIT program with the design standards determined for the residential living spaces of the city of Trabzon. Orientation, window type, size, and space dimensions data related to the living space were entered in the simulation. In the second stage, the shading elements obtained from the interview with the interior shading equipment companies were modeled on the program together with their technical specifications. Finally, daylight factor analysis and daylight-related values were analyzed for each of the indoor shading elements via the ECOTECT program. ECOTECT is a simulation and analysis software used to evaluate the energy efficiency and environmental performance of buildings. It supports sustainable design by providing detailed analysis in areas such as lighting, sunlight, thermal comfort and energy consumption.

3. Findings and Discussion

Firms say that the relationship between curtain fabrics and light transmittance stems from the weaving type and frequency of the fabrics. For example, because blackout curtain fabrics are densely woven and generally have dark color values, their light transmittance is between 1-4%. The light transmittance can go up to 80-85% for tulle, which is a transparent curtain fabric. As a result of the interviews with the firms, the relationship between the curtain models and the properties of the fabrics and their light transmittance is as in Table 1.

Table 1. Curtain models and fabric features (Bektaş, 2022)

LIVING SPACE			
GENERAL INFORMATION	IMAGE		
	Parameters	Form	Rectangle
		Area	37,4 m^2
		Width	5,5 m
		Length	6,8 m
		Height	2,7 m
		Orientation	North
WINDOW	Parameters	Floor Dist.	0,2 m
		Ceiling Dist.	0,25 m
		Light Orien.	Northeast
		Joinery	PVC
		Window Type	Double Glazing (4+12+4)
	Dimensions	Width	310 cm
		Height	226 cm
		Sash Width	84 cm
		Number of Sash	4+3

MODELS		FABRIC	MAIN	SECONDARY
1 / ROLLER BLIND		Name	Polyester	Polyester
		Motion	Vertical	Horizontal
		Light Trans.	Translucent	Blackout
		Permeability	%55	%5
2 / DOUBLE-BREASTED		Name	Voile	Polyester
		Motion	Horizontal	Horizontal
		Light Trans.	Transparent	Blackout
		Permeability	%75	%5
3 / RUSTIC		Name	Satin	-
		Motion	Horizontal	-
		Light Trans.	Blackout	-
		Permeability	%15	-
4 / PLEATED		Name	Silk	Polyester
		Motion	Horizontal	Horizontal
		Light Trans.	Transparent	Blackout
		Permeability	%80	%5
5 / BALLOON		Name	Organza	Polyester
		Motion	Vertical	Horizontal
		Light Trans.	Translucent	Blackout
		Permeability	%50	%5
6 / ROMAN		Name	Linen	-
		Motion	Vertical	-
		Light Trans.	Translucent	-
		Permeability	%70	-

FABRIC PARAMETERS					
Fabric	Thickness (Mm)	Light Transmit.	Fabric	Thickness (Mm)	Light Transmit.
Cotton	0,4-0,6	%0-75	Polyamide	0,4-0,5	%0-70
Linen	0,5-0,6	%70-75	Polyacryl	0,4-0,6	%0-55
Silk	0,4-0,5	%75-80	Polyester	0,4-0,5	%60-75
Wool	0,7-0,8	%40-50	Siphon	0,45-0,5	%70-75
Acetate	0,4-0,5	%60-80	Satin	0,6-0,7	%0,55
Viscose	0,4-0,5	%75-80	Voile	0,5-0,6	%70-75

Daylight analyzes made on roller blind, double-breasted, rustic, pleated, balloon and roman curtain models were examined under three headings: 21 June, 21 December, and monthly average illuminance levels.

3.1. Findings of June 21

According to the data of the models for the date of June 21, model 0 (no curtain), model 1 (roller blind) and model 4 (pleated) transmit light into the depths of the space; It has been revealed that models 2 (double-breasted), 3 (rustic), 5 (balloon) and 6 (roman) cannot transmit the light deep into the space. The reason for this situation is that the models cover the upper part of the window, so the light reflected from the ceiling cannot reach the depths of the space. On June 21, models 0 (no curtain), 3 (rustic), 5 (balloons) and 6 (roman) caused glare in front of the window. Among the models, after model 0 (no curtain), model 3 (rustic) causes the most glare (Figure 5).

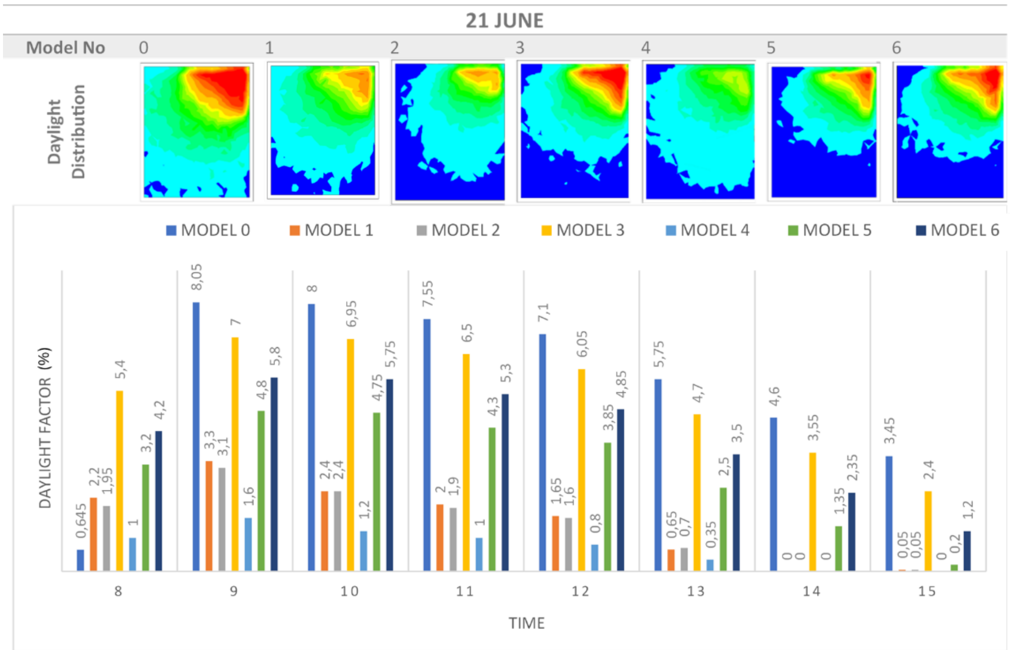


Figure 5. Daylight analyzes of models for 21 June (Bektaş, 2022)

In order to prevent glare caused by daylight, excess light from one direction should be avoided. For this reason, models 3 (rustic), 5 (balloon) and 6 (roman), which define rustic, balloon and roman curtain types, cannot prevent glare caused by daylight. It was observed that models 1 (roller blind), 2 (double-breasted) and 4 (pleated), which define the blind, double-breasted and pleated models, prevent glare caused by direct sunlight (Table 2).

Table 2. Daylight analyzes of models for 21 June (Bektaş, 2022)

21 JUNE							
Model No	0	1	2	3	4	5	6
Name	No Curtain	Roller Blind	Double Breasted	Rustic	Pleated	Balloon	Roman
Time	DAYLIGHT FACTOR						
08.00	0,645	2,2	1,95	5,4	1	3,2	4,2
09.00	8,05	3,3	3,1	7	1,6	4,8	5,8
10.00	8	2,4	2,4	6,95	1,2	4,75	5,75
11.00	7,55	2	1,9	6,5	1	4,3	5,3
12.00	7,1	1,65	1,6	6,05	0,8	3,85	4,85
13.00	5,75	0,65	0,7	4,7	0,35	2,5	3,5
14.00	4,6	0	0	3,55	0	1,35	2,35
15.00	3,45	0,05	0,05	2,4	0	0,2	1,2

According to Table 2, while the rustic, balloon and roman curtain model created glare on 21 June; roller, double-breasted and pleated curtain models do not create glare. While roller blind, double-breasted and pleated curtain models can transmit the light deep into the space, the rustic and balloon curtain models could not. On June 21, double-breasted and pleated curtain models provided the appropriate daylight factor value in residential living spaces, while roller blind, double-breasted, rustic, balloon and Roman curtain models exceeded this value.

When the daylight factor of the models was examined on June 21, it was observed that the daylight factor of model 4 (pleated) was 0 at 06.00, 16.00 and 17.00. It was determined that model 4 had the lowest daylight factor in every time period, while model o (no curtain) and 3 (rustic) had the highest daylight factor.

The time period of models with the highest daylight factor is at 10.00-11.00 am. The daylight factor value of model 0 (no curtains) at 10.00 is 4.5; model 3 (rustic) is in the range of 4, model 6 (roman) and 5 (balloon) in the 3-4 range, model 1 (roller blind) is 3.5. The daylight factor value of model 2 (double-breasted) at 10.00 is in the range of 1-2 and 1-2 of model 4 (pleated). The value of the daylight factor, which is considered appropriate in residential living areas, should be in the range of 1-2. In this case, on June 21, at 06.00, 16.00 and 17.00, model 1 (roller blind), 2 (double-breasted), 5 (balloon) and 6 (roman) provide this situation. Between 07.00-09.00 and 13.00-15.00, the model provides the appropriate daylight factor value is 4 (pleated) in residential living spaces.

3.2. Findings of December 21

Considering the daylight factor distributions of the models for December 21, it was observed that models 0 (no curtain), 1 (blind) and 4 (pleated) transmit light into the depths of the space. Similar to June 21, on December 21, it was determined that models 2 (double-breasted), 3 (rustic), 5 (balloon) and 6 (roman) could not transmit the light deep into the space. On December 21, it was observed that models 0 (no curtains), 3 (rustic), 5 (balloons) and 6 (roman) created glare in the space, while other models prevented glare.

Although the daylight factor distribution of the models observed on 21 June and 21 December is very close to each other, there are slight differences between them. One of these differences was observed in model 2 (double-breasted). On June 21, model 2 (double-breasted) and model 4 (pleated) were more successful in transmitting the light deep into the space, while on December 21, there was a decrease in transmitting the light deep into the space. For model 1 (roller blind), the daylight factor values near the window on June 21 are higher than on December 21. Although there was no glare in model 1 (roller blind) on both dates, it was observed that there were differences in the value of the daylight factor. Among the models, model 0 (no curtain) has the best ability to transmit light to the depth of the space. This is because model 0 does not have any shading elements. As a result of this, it was observed that model 0 was the model with the most glare (Figure 6).

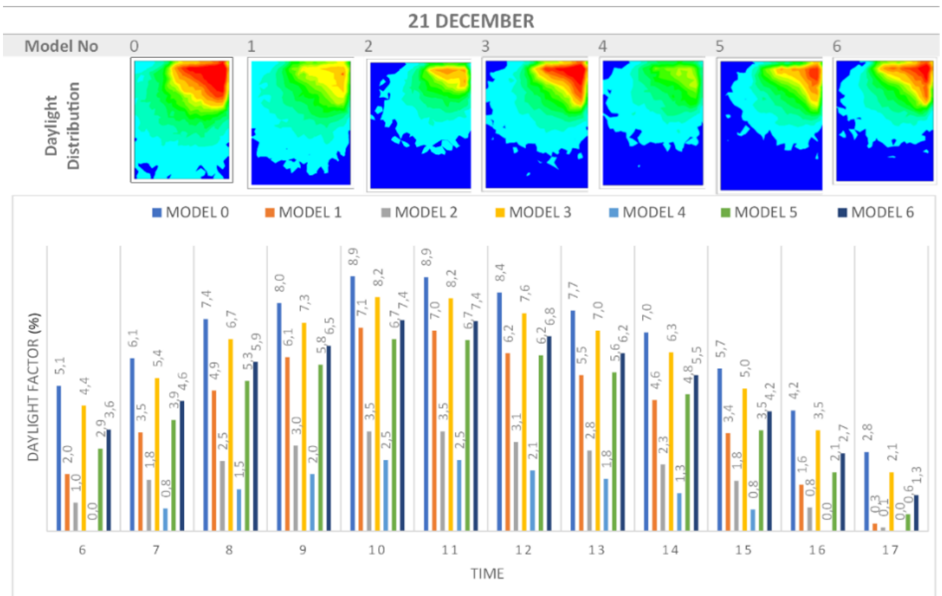


Figure 6. Daylight analyzes of models for 21 December (Bektaş, 2022)

According to Table 3, while rustic, balloon and roman curtain models created glare on 21 December; Roller blind, double-breasted and pleated curtain models prevent glare. Among the curtain models, only the roller blind model could transmit the daylight deep into the space, while the double-breasted, rustic, pleated, balloon and Roman curtain models could not transmit the daylight into the depths of the space. On December 21, while the roller blind and double-breasted curtain models provided the appropriate daylight factor value in residential living spaces, the pleated curtain model remained below this value. Rustic, balloon and Roman curtain models, on the other hand, have a value above the value of daylight factor, which is considered appropriate in residential living spaces.

Table 3. Daylight analyzes of models for 21 December (Bektaş, 2022)

21 DECEMBER							
Model No	0	1	2	3	4	5	6
Name	No Curtain	Roller Blind	Double Breasted	Rustic	Pleated	Balloon	Roman
Time	DAYLIGHT FACTOR						
06.00	5,1	2,0	1,0	4,4	0,0	2,9	3,6
07.00	6,1	3,5	1,8	5,4	0,8	3,9	4,6
08.00	7,4	4,9	2,5	6,7	1,5	5,3	5,9
09.00	8,0	6,1	3,0	7,3	2,0	5,8	6,5
10.00	8,9	7,1	3,5	8,2	2,5	6,7	7,4
11.00	8,9	7,0	3,5	8,2	2,5	6,7	7,4
12.00	8,4	6,2	3,1	7,6	2,1	6,2	6,8
13.00	7,7	5,5	2,8	7,0	1,8	5,6	6,2
14.00	7,0	4,6	2,3	6,3	1,3	4,8	5,5
15.00	5,7	3,4	1,8	5,0	0,8	3,5	4,2
16.00	4,2	1,6	0,8	3,5	0,0	2,1	2,7
17.00	2,8	0,3	0,1	2,1	0,0	0,6	1,3

When the daylight factor of the models was examined on December 21, it was observed that models 1 (no curtain), 2 (double-breasted) and 4 (pleated) were almost 0 at 14.00-15.00 time period. In the same time period, it was determined that model 0 (no curtain) had a daylight factor in the range of 2-3, model 3 (rustic) in the range of 1-2 and model 6 (roman) had a daylight factor in the range of 0-1. The time period with the highest daylight factor of the models is 10.00-11.00. At 10.00, the daylight factor of model 0 (no curtain) is 4, model 3 (rustic) is in the 3-4 range, models 6 (roman) and 5 (balloon) are in the range of 2-3, model 1 (roller blind) and 2 (double-breasted) is in the range of 1-2 and model 4 (pleated) is in the range of 0-1.

The value of the daylight factor, which is considered appropriate in residential living areas, should be in the range of 1-2. In this case, models 1, 2 and 4 provide this condition at 11.00, 12.00 and 13.00 on 21 December. Model 4 also reaches the appropriate daylight factor value in residential living areas between 08.00-10.00.

3.3. Monthly Average Illuminance Levels

When the monthly average illuminance level of the models is examined, It has been found the maximum and minimum illuminance levels are respectively 0 (no curtain), 3 (rustic), 6 (roman), 5 (balloon), 1 (blind), 4 (pleated) and 2 (double-breasted). The highest illuminance level of model 0 (no curtain) is between 18.00-19.00 in August. Model 1 (blind) and model 4 (pleated) have similar illuminance levels, but the highest illuminance is between 18.00-19.00 in June, July and August.

Although the monthly average illuminance levels of models 5 (balloon) and 6 (roman) are close to each other, in June and July, when the illuminance level is highest, model 5 is at the highest illuminance level between 18.00-19.00 and model 6 is between 19.00-20.00. The highest illuminance level of model 2 (double-breasted) is between 18.00-19.00 in June and July. It was observed that model 2 reflects daylight to the space only between 11.00 and 16.00 in January, February and December. When the monthly average illuminance levels of the models were compared, it was observed that the models 0 (no curtain) and 3 (rustic) had the highest illuminance levels. In June, July and August, it was determined that models 0 and 3 had an illuminance in the range of 300-400 lux.

In June, the illuminance level of models 1 (roller blind), 4 (pleated), 5 (balloon) and 6 (roman) exceeded 300 lux and model 2 (double-breasted) had an illuminance level between 200-300 lux. The lowest illuminance levels are in December and January. In December, models 0 (no curtain), 3 (rustic), 5 (balloon) and 6 (roman) have an illuminance of 100-200 lux, while models 1 (rolled blind), 2 (double-breasted) and 4 (pleated) have an illuminance of 0-100 lux. It was determined that the model with the lowest illuminance level among the models was model 2, which is the double-breasted model. As a result of the studies, it was observed that there was a sudden increase in the illuminance levels of the models as they passed from March to April (Table 4).

Table 4. Illuminance level of indoor shading elements depending on the months (Bektaş, 2022)

<table>
<tr><th rowspan="2">Model</th><th>No</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
<tr><th>Name</th><th>No Curtain</th><th>Roller Blind</th><th>Double-breasted</th><th>Rustic</th><th>Pleated</th><th>Balloon</th><th>Roman</th></tr>
<tr><td rowspan="12">Months</td><td>January</td><td rowspan="2">100-200 lx</td><td>0-100 lx</td><td>0-100 lx</td><td rowspan="3">100-200 lx</td><td>0-100 lx</td><td>0-100 lx</td><td rowspan="3">100-200 lx</td></tr>
<tr><td>February</td><td rowspan="2">100-200 lx</td><td rowspan="2">100-200 lx</td><td rowspan="2">100-200 lx</td><td rowspan="2">100-200 lx</td></tr>
<tr><td>March</td><td>200-300 lx</td></tr>
<tr><td>April</td><td rowspan="6">300-400 lx</td><td rowspan="2">200-300 lx</td><td rowspan="6">200-300 lx</td><td rowspan="2">200-300 lx</td><td rowspan="2">200-300 lx</td><td rowspan="2">200-300 lx</td><td rowspan="2">200-300 lx</td></tr>
<tr><td>May</td></tr>
<tr><td>June</td><td rowspan="2">300-400 lx</td><td rowspan="3">300-400 lx</td><td>300-400 lx</td><td rowspan="2">300-400 lx</td><td rowspan="3">300-400 lx</td></tr>
<tr><td>July</td><td rowspan="3">200-300 lx</td></tr>
<tr><td>August</td><td rowspan="2">200-300 lx</td><td rowspan="2">200-300 lx</td></tr>
<tr><td>September</td><td>200-300 lx</td><td>200-300 lx</td></tr>
<tr><td>October</td><td>200-300 lx</td><td rowspan="2">100-200 lx</td><td rowspan="2">100-200 lx</td><td rowspan="3">100-200 lx</td><td rowspan="2">100-200 lx</td><td rowspan="3">100-200 lx</td><td rowspan="3">100-200 lx</td></tr>
<tr><td>November</td><td rowspan="2">100-200 lx</td></tr>
<tr><td>December</td><td>0-100 lx</td><td>0-100 lx</td><td>0-100 lx</td></tr>
<tr><td colspan="3">Low daylight level</td><td colspan="3">Sufficient daylight level</td><td colspan="3">High daylight level</td></tr>
</table>

When the monthly average illuminance levels of the models and the data for 21 June and 21 December are examined, the curtain with the least glare level is model 4 (pleated). Model 4 (pleated) is also the model with the lowest illuminance. For each model, there was no intense change in the distribution of daylight to the space on 21 June and 21 December.

4. Conclusion and Suggestions

Curtains are the most frequently used element as a daylight shading element in residential buildings. Curtains have an important place in interior design as an aesthetic and functional element for centuries. The increase in window sizes of residential buildings over time has brought the functionality of curtains to the fore in interior design. As the daylight taken into the space increases, the need for shading elements also increases. In this study, which was carried out with curtain models, which are frequently applied in the city of Trabzon, the results of daylight analyzes are discussed in two parts: the dates of 21 June and 21 December and the monthly average illuminance levels.

Since the light rays reflect from the ceiling surface of the space and reach deep, the curtains, which move vertically and have the feature of translucent and darkening, could not transmit the light to the depths of the space. Because the sky conditions were clearer on June 21 than on December 21 and the light rays came at an angle of +23° on June 21, the models were more successful in transmitting light deep into space on June 21.

The fact that the rustic and roman models both create glare and cannot transmit the light deep into the space shows that they are not suitable for use in large and tall windows. Although the balloon curtain model cannot transmit the light deep into the space, it prevents glare to a certain extent. For this reason, although it is not the first-choice curtain model for wide and tall windows, it is suitable to use. Pleated and double-breasted curtain models spread the daylight homogeneously and prevent situations such as glare and luminance distribution caused by daylight. For this reason, among the curtain models, the most suitable curtain models for wide, long and corner windows are pleated and double-breasted curtain models.

On June 21, only double-breasted and pleated curtain models meet the appropriate daylight factor value in residential living spaces. On December 21, while the roller blind and double-breasted curtain models have the appropriate daylight factor in residential living areas, the daylight factor value of the pleated curtain model is insufficient (Table 5).

Table 5. Outputs of the models for June 21 and December 21 (Bektaş, 2022)

Model No		0	1	2	3	4	5	6
Model Name		No Curtain	Roller Blind	Double Breasted	Rustic	Pleated	Balloon	Roman
21 JUNE								
Average DF		6,68	4,35	2,18	5,97	1,27	4,50	5,16
Daylight Level	Low							
	Enough			■		■		
	High	■	■		■		■	■
There is glare	Yes	■			■		■	■
	No		■	■		■		
Daylight is transmitted deep into space	Yes	■	■	■		■		
	No				■		■	■
21 DECEMBER								
Average DF		5,64	1,53	1,46	4,31	0,74	3,11	4,11
Daylight Level	Low					■		
	Enough		■	■				
	High	■			■		■	■
There is glare	Yes	■			■		■	■
	No		■	■		■		
Daylight is transmitted deep into space	Yes	■	■					
	No			■	■	■	■	■
Daylight factor value in residential living spaces: 0 – 1 = Low 1 – 2 = Enough 2 – 10 = High								

The fact that the curtain model has the highest illuminance levels does not mean that it is suitable for indoor use. As a result of the study, it was seen that the models with the highest illuminance level were rustic, roman and balloon models. These models are also the models with the most glare. Models get the most sunlight in June, July and August. The months when the models are least exposed to daylight are January, February, November and December. The illuminance level, which is considered suitable for residential living areas, is around 100 lux, according to the action. Accordingly, in January and February, the roller blind, pleated and balloon curtain models provide the appropriate lighting level in residential living spaces.

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All authors contributed equally to the article. There is no conflict of interest.

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