THE EFFECTS OF DAYLIGHT DESIGN FEATURES ON THE VISITOR SATISFACTION OF ART MUSEUMS

A MASTER'S THESIS

BY

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DEPARTMENT OF

INTERIOR ARCHITECTURE AND ENVIRONMENTAL DESIGN

İHSAN DOĞRAMACI BİLKENT UNIVERSITY

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GRADUATE SCHOOL OF ECONOMICS AND SOCIAL SCIENCES OF

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BY

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JULY 2015

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts in Interior Architecture and Environmental Design.

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ABSTRACT

THE EFFECTS OF DAYLIGHT DESIGN FEATURES ON THE VISITOR SATISFACTION OF ART MUSEUMS

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M.F.A. in Department of Interior Architecture and Environmental Design

Supervisor: Asst. Prof. Dr. Yasemin Afacan

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Daylight is an important element of lighting design strategies. Daylight allows visual comfort and enhances visual environmental quality within architectural spaces. Daylight usage also allows sustainability by allowing energy conservation. In this manner, proper daylight design issues and control strategies have significant role. However, in art museums, daylight is a very difficult element to deal with. The difficulty is caused because of the damage that can be caused by daylight exposure on different objects with different sensitivity levels in art museums. This study aims to search the effects of daylight design features on the visual environmental quality of art museums and visual comfort of the visitors. A case study was conducted in İstanbul Modern Art Museum, Istanbul. The thesis is based on the user data obtained through a survey questionnaire and daylight simulation data obtained by Autodesk 3D's Max 2014. A three part questionnaire was conducted with 100 participants for both overcast sky and clear sky condition to rate visitor satisfaction with the museum

and importance levels of daylight design issues by considering all art museums in general. The daylight illuminance data of the museum was measured in a scaled model by a computer simulation program. According to the statistical analyses and simulation renderings, daylight design is a multi-parameter task. There are many significant correlations between visual comfort and satisfaction. The study concludes with a number of daylight design guidelines.

Keywords: Daylight Design, Daylight Control Strategies, Visual Comfort, Sustainability

ÖZET

GÜNIŞIĞI TASARIM ÖZELLİKLERİNİN MÜZE ZİYARETÇİLERİNİN MEMNUNİYETİNE ETKİSİ

Şevkiye Merve Kaya

İç Mimarlık ve Çevre Tasarımı Yüksek Lisans Programı

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Günışığı, ışıklandırma tasarımının önemli bir elemanıdır. Günışığı sadece görsel konfora katkıda bulunmaz aynı zamanda mimari mekânların görsel çevre kalitelerinde gelişme sağlar. Aynı zamanda günışığı kullanımı enerji tasarrufu sağlayarak sürdürülebilir bir çevre yapısına katkıda bulunur. Bu kapsamda etkili bir günışığı tasarımı ve kontrol stratejileri çok önemli bir role sahiptir. Ancak sanat müzelerinde günışığı tasarımı kolay değildir. Sanat müzelerinin bünyesinde barındırdığı farklı hassasiyet yapısındaki farklı sanat objeleri, günışığı tasarımını sanat müzeleri için zorlaştırır. Bu farklı hassasiyet yapısındaki sanat objelerinin fazla ve filtresiz gelen günışığına maruz kalarak bozulması, müze kavramına ters düşer. Bu çalışma günışığı tasarım özelliklerinin sanat müzelerinin görsel çevre kalitesine ve ziyaretçilerinin görsel konforuna etkileri üzerinedir. Bu çalışmaya yönelik İstanbul Modern Sanat Müzesinde saha çalışması yapılmıştır. Çalışma anket analizleri ve Autodesk 3D's Max 2014 ile yapılan simülasyondan oluşmaktadır. Anket üç bölümden oluşmaktadır. İlk bölümde demografik bilgi edinilirken, ikinci bölümde belirlenen müze kullanıcılarının memnuniyet dereceleri belirlenmektedir. Anketin son bölümü ise listelenen günışığı faktörlerinin önem dereceleri üzerinedir ve bu bölüm genel olarak sanat müzelerini kapsar. Anket hem açık hava şartı hem de bulutlu hava şartı için aynı 100 kişiye uygulanmıştır. İstanbul Modern Sanat Müzesinin aydınlanma değerleri simülasyon programı ile elde edilmiştir. İstatistiksel analizlere ve simülasyon analizlerine göre günışığı kullanımı çok parametreli bir işlemdir. Günışığının, görsel konfor ile birçok korelasyonu tespit edilmiştir. Çalışma sonucunda günışığı tasarımına yönelik önerilerde bulunulmuştur.

Anahtar Kelimeler: Günışığı Tasarımı, Günışığı Kontrol Stratejileri, Sürdürülebilirlik, Görsel Konfor

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CHAPTER I

INTRODUCTION

Museums are the places, where art and science related works are presented, preserved and protected. Museums are significant for their cultural values and they are able to create cultural interactions (Şener & Yener, 2008). Daylight is considered as one of the most important natural source of energy. Daylight usage with control strategies allow energy conservation and thus, sustainability (Entwistle, 1999). It is clear to see an inextricable link of daylight and building throughout the history as well. Historically, daylight was considered as one of the primary sources of illumination and the building designers were aware of how to bring daylight into spaces at the appropriate time. Some of the examples of ancient times planned and controlled use of daylight are; The Great Temple of Ammon in ancient Egypt and the Pantheon in ancient Rome (Bougdah & Sharples, 2010).

Even if it is very difficult to design daylight because of its dynamic character, it is very beneficial both for enhancing visual qualities and developing visual environmental qualities of interior spaces. On the other hand, daylight contributes to energy conservation, which allows sustainable environment. As a result, daylight integration to buildings is beneficial in terms of sustainable future. However, it is very fundamental issue in the aspect of art museums since deterioration of the display object should be prevented. Since art museums contain “protection” function within its functional definition (Melendez, Mecklenburg, & Domenechcarbo, 2010).

Thus, this study is based on questioning the effects of daylight design features on the visual environmental quality of art museums and visual comfort of the visitors.

1.1. The Aim of the Study

The main purpose of this study is to understand the effects of daylight design features of art museum buildings on the visual environmental quality and on its visitor visual comfort.

Daylight design strategies are very crucial for art museum buildings. To be able to examine art museums and daylight design, these two subjects are examined in detail within the scope of this study. The relationship between two subjects was considered as well. The impact of daylight integration with artificial light usage in art museum environment is examined. The examination of the daylight is done in two groups depending on the two different weather conditions, which are clear sky condition and overcast sky condition. The findings of the study are based on these two different daylight conditions.

Additionally, this study is also concerned with sustainability issues. In order to obtain sustainable building, energy conservation is a key point. Since effective daylight design allows energy conservation, it is considered within the study as well. Because of this reasons, how energy conservation of the art museums are enhanced by daylight design strategies are discussed.

1.2. Structure of the Thesis

This study focuses on the effects of daylight design features on the visual environmental quality of art museums and visual comfort of the visitors. The first chapter is the introduction part.

The second chapter examines daylight design in art museums. Architectural structure and functions of art museums, daylight design and daylight design strategies, daylight control strategies and sustainable design features of daylight usage are examined in this chapter.

The third chapter is related with visitors of art museums. This chapter has a purpose to examine the daylights effects on art museum visitors. The effects that are examined in this chapter are related with issues of visual comfort, health and wellbeing of art museums visitors as well as perception and museum experiences.

The fourth chapter describes the research of this study. Computer simulation is presented. 3-D renderings of the simulations are presented and discussed within the daylight design features. Objectives of the field survey are illustrates with variables, research questions and hypotheses. Sample group and techniques and procedure of this study are also explained in this chapter. After these sections, study results and discussions of the findings are stated.

Lastly, in the chapter five, conclusion is given. In this part, limitations of the study are mentioned. There are not only suggestions in this last chapter, but there is also some suggestions and guidelines for designing daylight in art museums with control strategies. Guidelines are expected to be beneficial to the design field for future studies by helping sustainable design and providing enhanced visual environments and better visual comfort for art museum visitors.

CHAPTER II

DAYLIGHT DESIGN IN ART MUSEUMS

2.1. Architectural Structure and Functions of Art Museums

Museums are the places, where art and science related works are presented, preserved and protected. According to Greek mythology “muse” means temple. Fist museum was built in 300 B.C in first Ptolemaios times, in İskenderiye. This museum was built to be able to run various activities for scholars. Throughout the history museums are generally built to exhibit objects and for some social activities. Museums are significant for their cultural values and they are able to create cultural interactions. In eighteenth century, first modern museums were built for art exhibitions. They are rectangular shaped and designed with skylights for daylight intake, also walls are used as exhibition spaces. In the nineteenth century transparent and flexible museum buildings were started to be built by the influence of Joseph Paxton, who is the designer of Crystal Palace in London, used as an exhibition area (Şener & Yener, 2008). After Joseph Paxton’s implications in this area, museums started to have geometric shapes and they are designed according to concepts of transparency and flexibility. In the twentieth century, museums started to have research and education functions as well (Şener & Yener, 2008). Finally, in our last few decades, museum buildings have an iconic attitude. Iconic attitude means that museum building structures of modern world, acts like museum objects by themselves (Şener & Yener, 2008). So, as well as exhibited objects, museum buildings themselves became attractive and interesting as well. They have also become center of attention by visitors in our recent world (Şener & Yener, 2008).

Museums include; representations of natural occurrences and human efforts. Museums use these sources for human beings knowledge enhancements and for preservation of the cultural heritage. To allow display objects of museums to reach people effectively and efficiently, objects should be protected deliberately. Protection and display are two major functions that cannot be eliminated. However, there can be some other minor functions added to museums such as researching, arranging educational programs and cultural events. Therefore, enabling visitors to benefit from visual environment qualitatively and perceive efficiently are very significant design issues. There are also other minor functions added to museums such as researching, arranging educational programs and cultural events. Also to manipulate, to provide interactions between occupants and display objects and to attract people are the main functions that make museum experiences enhanced for the visitors (Kim & Chung, 2010).

Museums have three different types according to the classification of the objects that they display and preserve within their architectural shelves. These types are historical, science and art according to their display objects. Historical museums display objects about history, science museums display scientific objects and art museums display art objects (Kurtay, *et al*., 2003). Objects that are displayed in museums have a crucial role in all types of museums since they aim to obtain and conserve tools that have cultural, historical, artistically or scientific significance. Museums aim to use these tools for researches, display purposes and educational and teaching purposes. These different purposes affect the structures of museums as well. Architectural structures are designed according to these different types and the functions that they require (Jacobsson & Davidsson, 2012).

Daylight is a significant source of energy and has important role on visual environment which will be discussed. The importance of daylight should be analyzed according to structure and function of museums (Kim & Chung, 2010). In this study art museums will be considered and analyzed according to their daylight design issues and its contribution on visitor's visual comfort and sustainability and energy conservation.

Art museums have objects mostly related with visual arts. So art museums appeal mostly to the sense of sight. Because of this reason; an art museum aims to create a space that enhances human perception and museums visual environmental qualities (Anthierens, *et al*., 2008). Therefore, lighting design within art museums is a very important issue that should be handled with care for the sake of the 'display' and 'protection' functions of it.

2.2. Daylight and Daylight Design Strategies

2.2.1. Daylight Features

Daylight is considered as one of the most important natural source of energy. The primary source of natural light is sun; it provides light directly during the day and indirectly by the help of moon at night, and stars also contribute to reflecting suns light at night. Even the intensity of the sun, efficiency and color changes according to weather conditions, sun plays a huge role on daylight and its effects (Entwistle, 1999).

There are two types of daylight, one of them is warm daylight, and the second type is cool daylight. Warm daylight is used in hot climates and also considered for energy conservation issues. Control of warm daylight is also significant to regulate the thermal comfort of an interior space such as interior terrace doors as a buffer zone, aluminized louvers to reflect the daylight are some of the ways daylight is used without damaging the thermal comfort of an interior space. Cool daylight is a type that is used in cold weathers. Sloped double glazing, vertical louvers are some of the solutions to have efficient cool daylight without disturbing the thermal comfort level of the space. As a result, even if daylight provides energy consumption by allowing natural light, it should also not disturb the optimal thermal comfort levels. Otherwise, there will be loss of energy to provide optimal thermal comfort levels that have been lost because of daylight design (Johnson, 1994).

There are two kinds of daylight radiations. First one is the direct radiation and the second is diffuse radiation. Direct radiation is directional depending on the solar azimuth unlike diffuse radiation. Diffuse radiation is non directional. Also, diffuse radiation is the product of scattering of solar radiation in the atmosphere. Direct radiation is dependent on the degree of cloudiness and is subject to strong variation depending on weather conditions.

Daylight enters to interiors from different types of glazing configurations, which are either vertical or horizontal and from side or from the top. A daylight system is defined by as; “ a device located near or in the openings of building envelope, whose primary function is to redirect a significant part of the incoming natural light flux to improve interior lighting conditions” (Alrubaih, *et al*., 2013, p. 496).

There are two main daylight systems. These are side lighting and top lighting. Side lighting is more commonly observed simply as windows. Top lighting is an opening in ceiling or roof element of the building. The most common way of use of the top lighting are skylight, saw tooth and roof monitors (Alrubaih, *et al*., 2013).

Daylight, daylight sources and daylight availability are the other daylight design features that should be considered carefully. According to the Illuminating Engineering Society of North America (IESNA) Lighting Handbook (2000), the sun is the source of natural light energy. The path of the sun determines the available sunlight at a particular building location. There are three types of weather conditions which are; overcast, clear and partly cloudy skies. Daylight design should be considered in these three types of weather conditions. In the overcast condition, the sky is generally the brightest element in an outdoor scene and the light reflected off of other surfaces has much lower luminance levels. The second sky condition is; partly cloudy sky. In this type, there is a constant change between direct sunlight and hazy daylight and fluctuations in intensity, distribution and color temperature. The last type is; clear sky condition. In this condition, the sun is the brightest source of light and is practically a point source (Alrubaih, *et al*., 2013).

Daylight availability refers to the amount of daylight available from the sun and the sky at a specific location, time, date, and sky condition. So the sun, sky, buildings and ground are the main sources of luminance distribution. In addition to the above explained daylight design features, the latitude, climate and building orientation should be also considered (Alrubaih, *et al*., 2013).

2.2.2. Advantages and Disadvantages of Daylight in Art Museums

Architecture and light are inevitably linked together to museums. The form of a museum building is first perceived by the light penetrating from the sun and the sky that is reflected from the building‘s external surfaces. The aesthetic appearance and emotional sensation of an internal space are influenced by the interplay of light, color and texture. They are interpreted with these factors as well. According to Le Corbusier architecture is the masterly, correct and magnificent play of masses brought together in light (Bougdah & Sharples, 2010).

Many great architects, such as Louis Kahn; architect of Design Museum in London and Tadao Ando architect of Naoshima Contemporary Art Museum, Nariwa Museum etc. have used daylight as a fundamental design element in the museum buildings that they designed.

Architectural lighting can be defined as both an art and a science, requiring an understanding of not only the physical properties of natural and artificial light sources, but also the visual effects that create when introduced into a space (Bougdah & Sharples, 2010).

It is clear to see an inextricable link of daylight and building throughout the history as well. Historically, daylight was considered as one of the primary sources of illumination. The Great Temple of Ammon in ancient Egypt and the Pantheon in ancient Rome are some of the examples of the planned and controlled use of daylight. The development of artificial lighting in the twentieth century meant that designing with daylight became a lost art. However, the environmental and financial costs associated with artificial lighting have led to a renewed interest in the use of daylight in sustainable buildings (Bougdah & Sharples, 2010).

In addition to the aesthetic appearance and illustration qualities, daylight design is inevitable because of its energy conservation benefits and the opportunities for various light qualities and color rendering impacts. Daylight with these impacts helps spaces to provide efficient visual comfort for people. Thus, occupants also prefer daylight as well as architects. They expect to have adequate quality and quantity of daylight penetrating to an interior space that they spend time. The quality and the quantity are different for different spaces and depend on ideal values depending on functions of a space. As highlighted in the previous sections, one of the important spaces that daylight is significant and should be handled with so much care is art museums to increase the visual environmental qualities of art museums and visual comfort for occupants for it (Kim & Chung, 2010).

Even if there are many benefits of daylight usage in art museums as mentioned in detail above, there are also disadvantages such as deterioration of the collections and the discomfort factors affecting visitors like glare, uncomfortable backlighting, irregular and unbalanced light etc. (Anthierens, *et al*., 2008). A major design problem with using daylight is the rapid decrease in daylight levels with distance from a window, leading to the parts of the room not close to the window appearing gloomy. To try to overcome this problem control strategies needs to be applied. These innovative techniques, explained in detail in 'shading system' section, include the light directing louvers, light shelf, movable shading systems, mirrored systems, prismatic glazing and light pipes (Bougdah & Sharples, 2010).

Deterioration is one of the most important disadvantages of daylight usage in art museums. Deterioration of the display object is related with the 'protection' function of the art museums. Deteriorations need to be eliminated for the sake of the display objects and should be analyzed according to the sensitivity levels of the display objects. Since the daylight includes short wavelength radiations such as ultra violet and infra-red radiations, which cause deterioration. It should be used carefully and controllably. Direct sunlight penetration should be eliminated with control strategies.

Moreover, light should be distributed homogeneously for all types of display objects in art museums (Melendez, Mecklenburg, & Domenechcarbo, 2010). When vision is considered, visible spectrum should be analyzed and vision should be understood starting from eye to brain. Visible light has wavelengths range between 100 to 400nm. Visible light is the light that can be detected by the human eye. However, human eye cannot see the whole spectrum of light. Ultra violet and infra-red radiations are some of these invisible radiations. However, we can see the effects of them. For example, ultra violet radiation can make damages in our skin or it can deteriorate organic materials. We can experience infra-red radiation as heat within the environment. Daylight consists of these short wavelengths. Since daylight is rich in these kinds of harmful short wavelengths, in art museums it is significant to preserve art collections from these radiations with control strategies. Otherwise, exposure to these radiations can damage art museums displayed objects. This damage on art objects can create a conflict with the design aim of light on art museums with the efficient use of daylight since the protection function of museums would not be achieved (Bougdah & Sharples, 2010).

In art museums, display objects illumination standards are decided according to the levels that they get affected from it and deteriorate. This is related with their light sensitivity (Şener & Yener, 2008). There are three types of levels according to the sensitivity of art museums display objects. First level is high sensitive objects and they are mostly the organic based art works such as; cloths, carpets, leathers, watercolors, drawings etc. Since this group is the most sensitive, protection should be done with a special care. Otherwise, there can be deteriorations, which might cause an object to be lost. Maximum level of light should be 50 lux and the maximum color temperature should be 2900 Kelvin. Second level is medium sensitive objects. These are; oil paints, polished materials, enamels etc. For this group of objects, maximum light level should be 150 lux and the maximum color temperature should be 4000 Kelvin. The third level is low sensitive objects. These are stone, glass, sculpture, jewelry etc. The maximum light level should be 300 lux and the maximum color temperature should be 6500 Kelvin. These maximum levels are according to “CIBS, Lighting Guide Museums and Art Galleries”. To be able to eliminate deteriorations, there are some design strategies different than control issues. An art museum should be able to free of any kind of light when the museum is closed. The daily hours and the working days should be considered according to these issues of lighting. Some sensitive display objects should be displayed during certain times of a day, but not at all the times so that they are exposed to maturation (Kurtay, *et al.*, 2003).

Second significant disadvantage of daylight usage in art museum is related with discomfort factors affecting the museums occupants such as; glare, uncomfortable backlighting, irregular and unbalanced light etc. These kinds of issues require control strategies within art museums interiors for qualitative lighting design and satisfied art museum visitors.

2.3. Daylight Control Strategies

2.3.1. Significance of Daylight Control Strategies

Lighting control strategies are strategies that provide efficient luminous environment that are suitable and comfortable to the building visitors and users as well as sustainability issues. In public buildings, large amount of energy can be saved by using appropriately designed lighting control systems that can take advantage of the daylight available (Galasiu & Veitch, 2006). Control strategies for daylight design in art museums are significant to achieve important objectives of art museums daylight design. These essential objectives are as follows; (i) there should not be glare on any kind of art objects or display windows or shiny objects should not act like mirror; (ii) vertical and horizontal illumination should be appropriate and balance there should not be any kind of light patches or dark spots; (iii) daylight intake should be purified on infrared and ultra violet radiation's which can be harmful to allowable standards; (iv) daylight spectrum should be efficient enough for effective color rendering qualities and effective perception and visual comfort; (v) lights spectrum should not be different in vertical and horizontal illumination levels; (vi) according to the level of intensity of objects there should not be any over illuminations within the interior; (vii) display surface should be light grey and it should be matte color; (viii) there should not be adaptation problem because of different light levels within the art museum. By control strategies these objectives can be achieved successfully within art museum, which will create qualitative visual environment for art museums (Sirel, 1990).

Designing a museum building that derives benefit from daylight in a controlled, energy efficient and aesthetically satisfying manner is not a simply question of using large areas of glazing. This kind of an approach will only create a new set of problems. Instead, daylight design has to be an integral part of the overall design process. A design strategy to ensure good daylight conditions in art museums should consider the following features; daylight availability and sky conditions, the site and any obstructions, the form and function of the building, interior planning and design, protection issues, window and façade design, innovative daylight techniques, testing of the design strategy (Bougdah & Sharples, 2010). Figure 2.1 illustrates an exemplary critical obstruction angle for specific latitudes in obstructed sites in order to take effective daylight. To be able to check if good daylight on an obstructed site is possible, a simple method can be applied. This method is based on a section drawing of the new building and an existing obstruction (Bougdah & Sharples, 2010). Draw a line from a point two meters above ground level on the new building to the top of the obstruction. After this step, measure the angle between the line and the horizontal, as shown in Figure 2.1. If this angle is less than the critical obstruction angle h for various latitudes then there is potential for adequate daylight of the new building. For up to 40 degrees latitude, critical obstruction angle should be less than 40 degrees. If the latitude is between 40 degrees to 45 degrees, critical obstruction angle should be less than 35 degrees. For latitudes between 45 degrees to 50 degrees than critical obstruction angle should be less than 30 degrees. For latitudes between 50 degrees to 55 degrees critical obstruction angle should be less than 25 degrees and for latitudes between 55 to 60 degrees critical obstruction angle should be less than 22 degrees. Lastly for latitudes more than 60 degrees the critical obstruction angle should be less than 20 degrees.

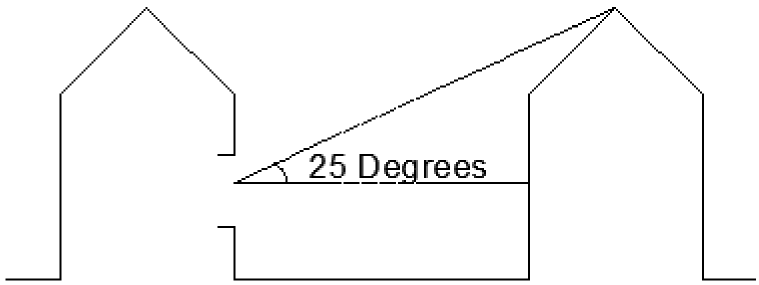

Figure 2.1: An exemplary diagram showing critical obstruction angle for specific latitudes for obstructed sites effective daylight availability. (Drawn by author, adapted from Boughdah & Sharples, 2010)

Because of dynamic, variable and intense characteristics of the control strategies in art museums, daylight should be applied deliberately and efficiently in order to fulfill architectural satisfaction, protect the objects and display units and achieve visual comfort. Design based control strategies are related with tasks, light level preferences, glare mitigations and sensitivity levels of display artifacts. On the other hand, user based control strategies are related with personal necessities, health, privacy and perceptional issues (Fadzil & Sia, 2003).

There are three primary reasons for control of daylight. First reason is that because of nature of daylight which is intense, dynamic and variable it can be harmful for the humans and the interiors and objects within. The second reason is that modification of the daylight source is necessary to support critical visual tasks performed within interior spaces; light level, preferences, glare etc. The third reason is because of the personal needs of users and visitors, such as view out, privacy and health etc. (Day, Theodorson, & Wymelenberg, 2012).

To be able to understand the significance of daylight control strategies in interior spaces, the characteristics of daylight should be fully understood, that is why it is mentioned in detail in previous parts of this study. Also since the study's focus is on art museums and art museum visitor's visual comfort, vision should be also considered in detail. Since art is highly related with visual aspects and visual environmental qualities visible spectrum and perceptional qualities of humans should be expressed.

2.3.2. Methods of Daylight Control Strategies

To prevent discomfort factors and allow satisfactory visual environmental quality within sustainable levels by preventing deteriorations, there should be qualitative daylight design strategies in art museums. These strategies are as follows; (i) provision of effective light design (both daylight and artificial light) that is used with controlled strategies; (ii) provision of good visual comfort for enhanced vision; (iii) perception of the occupants and (iv) protection of display objects from harmful radiations, which are mainly short wavelength radiations such as ultra violet, infrared etc. Furthermore, integration of daylight and artificial light to provide adequate illumination is significant. Allowing display elements enhancements of visional qualities such as color rendering effects, shapes etc. is another aspect that should be considered in daylight design of art museums (Kurtay, *et al*., 2003).

2.3.2.1. Windows

Windows are mostly used as architectural elements that allow daylight intake. However, every kind of window is not effective and efficient for a place; especially in art museums. The arrangement, size and division of windows play an important role in daylight to penetrate deeper into the space. Because of this reason, floor to ceiling windows are more advantageous for daylight intake. There is a standard about efficient window size; the room depths must not exceed two and a half times the window heights. This standard leads efficient window size for effective daylight intake. So taller the windows, better the daylight utilization. Also views from the windows and obstructions on daylight intake should be considered for effective visual comfort and museum experience (Müller & Schuster, 2012).

Thus, in art museums it is significant to handle the shape, size and location of windows carefully in this manner. Windows are not only elements to take daylight, but they are also for allowing a view of the exterior. Moreover, when they are used efficiently and in a correct way windows help energy savings (Bean, 2004).

Adequate daylight penetration for typical ceiling heights will only be approximately equal to one and a half times the distance from the floor to the top of the window for north facing glazing or overcast skies. But different scenarios should be kept also in mind. If the window is south facing and if sunlight exists, or contains a reflective element such as a light shelf the daylight penetration may increase by up to 2.5 times the window head height. To give an example, if there is a depth of 7.5m for a 3m window head height. Another issue that should be kept in mind is that a window area should be around 20 percent of room floor area to avoid excessive overheating in summer and excessive overcooling in winter (Bougdah & Sharples, 2010).

Window position and shape of openings in a building envelope are important. Windows should be placed high on a wall and, if feasible, ceiling heights should be raised for better illumination (Bougdah & Sharples, 2010).

Double glazing, tinted or coated glazing, sensors tracking daylight and adopting window systems are some examples of window technologies to enhance daylight while eliminating distractions in thermal comfort (Barker, 1994). Shading projections can have a negative effect since they do not only reduce direct radiation, but they also reduce percentage of diffuse light under an overcast sky (Müller & Schuster, 2012).

2.3.2.2. Skylights

Skylights are significant design elements of museums in case of daylight, since openings in roofs are more efficient than lighting from the sides like windows. Skylights are more advantageous, because they prevent direct daylight penetration on the objects. Since the direct penetration might be harmful on museum elements it is very safe to use skylights, where walls reflect daylight and there is a direct penetration. Furthermore, because of the geological reasons, skylights can intake daylight with better illuminance qualities (Müller & Schuster, 2012). A second reason, why windows are less effective compared to skylights, is the distribution of brightness under an overcast sky, which diminishes by approximately one third from the zenith to horizon.

However, because of solar heat gains caused by skylights there are also some control issues about energy gain from skylights. These kind of passive solar heat gains are desirable for heating applications but they are not advantageous for cooling applications (Müller & Schuster, 2012).

2.3.2.3. Shading Systems

Shading systems are significant in daylight control strategies. An effective shading system prevents overheating in a building’s interior. They help adaptation to different weather and daylight conditions. The shading system automation is a sustainable solution that is enhanced by complementing automatic controls with manual options. This flexible way it enables the users to adjust lighting condition on an individual standard of comfort and needs (Müller & Schuster, 2012).

A major design problem with using daylight is the rapid decrease in daylight levels with a distance from a window, leading to the parts of the room not close to the window appearing gloomy. To try to overcome this problem, control strategies need to be applied as well. Since there are many innovative daylight strategies, it is possible to achieve satisfactory visual qualities. These innovative techniques include the light directing louvers, light shelf, movable shading systems, mirrored systems, prismatic glazing and light pipes (Bougdah & Sharples, 2010).

Daylight integration to lighting design of public buildings is an effective approach in creating a pleasant visual environment as mentioned. Daylight is considered as the best source of light to create good color rendering and its quality is the one of the light sources that most closely matches human visual response (Tsang & Li, 2007). The amount of daylight entering a building interior through window openings, does not only take light for indoor environment to allow more attractive, comfortable and pleasing environment, but it also allows people to maintain visual contact with the outside surrounding environment. As a result, people are in need for good daylight in their interior environment. Therefore, outdoor environment, building area and orientation are important factors considering daylight design issues to allow sufficient daylight intake within interiors and make users and visitors comfortable, satisfied and attracted (Tsang & Li, 2007).

External obstructions might influence the daylight performance in two ways. First way is the amount of the sky being obstructed or unobstructed. The second way is the color of the external surface finish that can be effective as the reflected luminance from the obstructing buildings. Furthermore, the dimensions of buildings in the neighborhood are key points in this manner; i.e. when buildings are located close to each other, blockage of daylight can occur, particularly for the lower floors. The colors of the external surface finish can be grouped into light and medium as the best solutions. Light surface finishes might not be causing drastic glare problems. However, high reflectance depending on the color from nearby obstructions may cause glare problems, which will affect the visual comfort of the interior space. Because of these reasons, it is very important to locate buildings in proper areas, where there are not buildings causing daylight blockage or causing glare problems because of their finish materials. As mentioned before, these kinds of obstructions will prevent view that makes users and visitors pleasant and it might disturb the feeling of exploring the outside world through window openings (Tsang & Li, 2007).

For all sky types it is desirable to make most use of the south and north facing glazing for daylight. South facing glazing is relatively easy to shade using horizontal devices that will not interfere with the view out, and north facing glazing will require no shading (in the northern hemisphere) and admit skylight. East and west facing glazing are the most difficult to shade because the lower sun means vertical shading devices must be used, which have a very negative impact on the view through a window (Bougdah & Sharples, 2010).

Even if there is a change in the intensity and efficiency of daylight according to time, daylight is a key factor in the aspect of visual comfort as well as sustainability, and visual environmental qualities of buildings. Daylight is an effective approach in creating a pleasant visual environment. It helps to prevent discomfort factors. Moreover, daylight quality closely matches to human visual response in the highest level (Tsang, 2007).

The shading systems are mainly; light pipes, atriums, remote source lighting systems, light directing systems, light shelves, filters, shading systems, mirror systems and reflected light techniques (Xue, Mak, & Cheung, 2014).

Light shelf is a light colored horizontal partition that is located inside and/or outside a window and reflects light via the ceiling to the back of a room. It can also act like a solar control device since it affects thermal comfort as well. Important point is that light shelves should be carefully positioned and sized and should not act as obstructions to light. They need to be placed above eye-level, both to preserve the view and to prevent reflected glare. For their effective usage, a room height must be greater than 3m (Bougdah & Sharples, 2010). Figure 2.2 shows an exemplary light shelve.

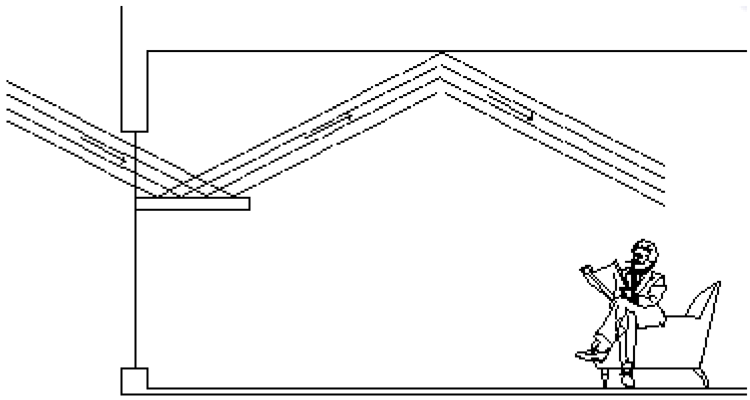

Figure 2.2: An exemplary light shelve diagram (Drawn by author, adapted from Boughdah & Sharples, 2010)

Mirror systems are generally acts a series of mirrored louvers positioned above a window or placed within a double glazed unit. They are generally placed in the upper sections of windows to avoid glare and by this way it does not cause obstruction problems. Mirror systems can be effective for reflecting the daylight from a low altitude sun into rooms through ceiling reflection. It is also beneficial as a solar control by reflecting solar gain from a high summer sun away from a room. These systems have maintenance problems and they may act as obstructions on cloudy days (Bougdah & Sharples, 2010).

Prismatic glazing systems use optical principles to redirect light either into a room (low sun) or away from a room (high sun). They use reflection techniques. The prismatic elements are applied to the upper part of a window either as part of the glazing or as a film that is attached to the glass surface. They can act as obstructions and distort views, however their maintenance is easier compared to mirrored systems. They can also be used as glare control technique (Bougdah & Sharples, 2010).

A light pipe can redirect light deep into a building or even underground. It consists of three parts; a light collection element, the light pipe itself and a diffusing cover to emit the light. The pipe can be either a shiny metal tube that reflects light directly or solid components, such as acrylic and fiber optic bundles, which use total internal reflection to guide the light into a space. There are two kinds of this system; active and passive system. In an active light pipe system, a mirror to track the sun and directs the sunlight down the pipe and through an emitter. This kind of a system is highly dependent on the sun. This is also expensive and its maintenance is not easy. In a passive system, skylight and sunlight are collected by a transparent dome and reflected downwards via a metal tube into a room (Bougdah & Sharples, 2010). Figure 2.3 shows an exemplary light pipe system for effective daylight intake.

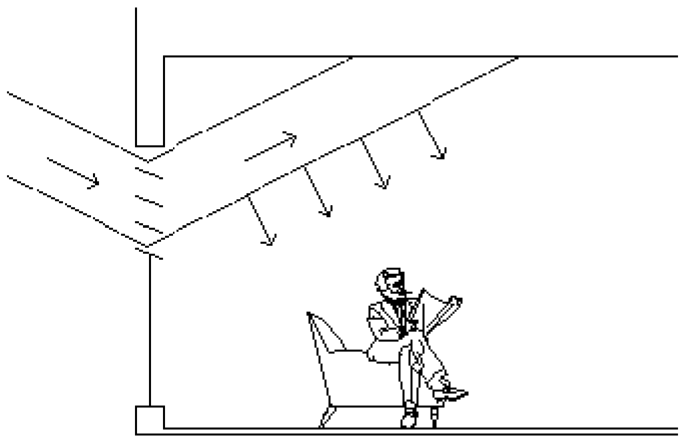

Figure 2.3: Light pipe system for effective daylight intake (Drawn by author, adapted from Boughdah & Sharples, 2010)

There are three types of daylight factors that should be handled with care. The first factor is the amount of daylight and its intensity. Operable louvers and UV filtered glazing systems are appropriate solutions to overcome uncontrolled daylight within art museums. However even if the excessive amount should be controlled there should be enough daylight for to allow visual quality when there is a performance, when there are sensitive materials and there should be appropriate amount in working spaces like laboratories etc.

Sensitive materials should be displayed with luminance level of 50 lux approximately. Work areas should have maximum 100 lux of luminance. The second factor is duration and exposure of the daylight. When this factor is analyzed the important point should be that short duration of intense light affects art work as much as low intensity level exposed over an extended period of time. Because of this some art work that are displayed should be moved to different spaces regularly. Also art museum objects should be in dark when the art museum is closed. Automatic shade systems can be advantageous to overcome this exposure in critical day times when sun light comes directly. The third one is spectral characteristics of the daylight. Glazing and shading systems are also suitable to have good spectral characteristics of the daylight (Navvab, 2013).

There are also some specific innovative techniques for controlling daylight within art museums. Daylight optimization for general illumination and exhibit display is one of the specific innovative techniques for controlling daylight (Zannis, *et al*., 2006). There should be a system to protect the sensitive exhibits from solar radiations and fulfill the requirements that concern their exposure to daylight. Automation systems also provide sufficient illuminations within the interior. Another innovative technique is innovative glazing components like super insulating and diffusing glass. Innovative diffusing glass has a role on increasing the visual comfort of the visitors while providing reduction of heat flow through the glazing of windows of the art museums (Zannis, *et al*., 2006). Another technique is light redirection ceiling geometry for the best daylight distribution. This technique aims to increase the 'penetration depth' of the daylight within interior space by redirecting the on the ceiling of the space. By this way, this techniques aims to enhance the daylight distribution by letting the distribution of daylight to reach spaces far away from the opening areas. Also this system aims to protect art objects by preventing direct exposure of daylight by reflecting daylight. Another technique is special window panels. These systems aim to control daylight and acoustics by providing sound absorptions (Zannis, *et. al*., 2006).

In addition to architectural daylight design control strategies, there can be strategies about the art museum management and rules. Appropriate art museums rules can enhance protection of objects and prevent deteriorations. First important issue in this aspect is the exhibition hours (Kurtay, *et al.*, 2003). Exhibition hours should be well decided. When there is not any visitors and when the art museum is not working, art objects should not be exposed to any kind of light. They should be in dark (Kurtay, *et al.*, 2003). According to different levels of sensitivities, there can be some certain time limitations on exhibitions of objects. Highly sensitive objects exhibition hours should be limited. There can be also different sensitive objects that are exhibited every period of times allowing sensitive objects to have decreased time of getting light exposure (Kurtay, *et al.*, 2003).

2.4. Sustainable Design Features of Daylight Usage

Until the invention of electrical light, daylights effects and characteristics were well known and fully considered because there were no other medium that could support adequate illumination to interior spaces. However, after the invention of electrical light, concern on daylight has been decreased. Artificial light is an indisputable process since it has the capacity to illuminate even rooms without windows. It is a source without any weather and climate dependencies unlike daylight (Müller & Schuster, 2012). However in the recent times, there is a growing interest in daylight. Growing interest on daylight is not only because of effective visual comfort benefits that it provides but also for its energy conservation and economic benefits (Müller & Schuster, 2012).

If the daylight design strategies are implied in innovative new buildings. They will be considered as effective and successful prototypes for future buildings. Their sustainable design will lead to sustainable future as well. To design sustainable buildings and conducting studies on them are key elements of our future architectural lives. These building studies allow to compare performance in use to design and make assumptions for the better use of the building. To see 'what is working' and 'what is not' regarding the specific daylight design strategies technologies should be implemented (Konis, 2012)**.** The second issue is to improve the design guidance and assumptions for comfort and satisfaction used in the design of future projects (Konis, 2012).

2.4.1. Energy Benefits and Conservation

Globally, electricity consumes approximately 20 percent of the world's generated electricity (Bougdah & Sharples, 2010). Electricity usage for lighting is a very inefficient and energy consuming process. Since people in many developed countries use electricity, it has a large impact on energy consumption. For example, in United Kingdom the total annual electricity consumption for lighting is around 230,500 GWh, producing around 9 percent of the United Kingdom's total carbon dioxide emissions (Bougdah & Sharples, 2010). As a result of this, there are many good reasons for trying to develop a lighting design in building interiors that is effective, efficient and environmentally friendly without harming the environment (Bougdah & Sharples, 2010).

Reviewing the literature showed that art museums that are optimized for daylight, can drastically lower the operational costs without any obvious increase in constructional costs (Müller & Schuster, 2012).Energy conservation through daylight integration to interior spaces is inevitable. It is also a complex issue because the environmental requirements for the preservation of the materials impose very strict rules to avoid the deterioration of exhibits (Müller & Schuster, 2012). However, it is possible to have qualitative daylight design with efficient visual comfort and save energy efficiently without harming the display objects within art museums. Therefore, art museums should be qualified with bioclimatic, environmental friendly and energy conscious design (Zannis, *et. al*., 2006).

An efficient and sustainable museum building design can fully meet the architectural, functional, comfort, control and safety requirements, by also providing radical amounts of energy savings and providing reduction of carbon dioxide emissions (Sala & Gallo, 2007).

2.4.2. Environmental Benefits

Buildings use energy to heat, cool, light, ventilate and service usages in internal spaces. In most industrialized countries the energy used by buildings generally represent around 50 per cent of total energy consumption (Bougdah & Sharples, 2010).

Most this energy comes from the burning of fossil fuels. Buildings are also responsible for approximately 50 per cent of CO_2 emissions into the atmosphere. In addition, because of these burnings there is also 10 per cent of methane emissions, 25 per cent of NO_x emissions and 25 per cent of SO_x emissions (Bougdah & Sharples, 2010).

Therefore, buildings are a major impact of global warming, climate change, air pollution and acid rains (Bougdah & Sharples, 2010).

Aside from the qualitative significance of daylight for humans and architecture, ecological points of daylight integration are also very crucial for sustainable lighting design. Daylight without pollutant usage supplied through its design is readily available and is environmentally friendly also cost free (Müller & Schuster, 2012). Each year eight million of fluorescent lamps are disposed in many landfill sites these disposals cause a lot of hazardous materials such as mercury (Bougdah & Sharples, 2010). According to the studies on the impact of daylight in Hospitals 60% of patients in rooms with high indoor daylight intake were hosted for less time amounts of recovery compared to rooms with lower levels of daylight (Hourani & Rizeq, 2012). A two years study in United States elementary schools showed that more attendance of students was ensured in sufficient daylight existing classrooms than students in other classes where there are lower amount of daylight (Hourani & Rizeq, 2012).

It is clear that when there is daylight usage there is a less pollution and less damage on environment. Hence, daylight usage is also beneficial for our environment. Within the art museums, this is also very beneficial because this means quality of life will be increased in places where museums are located and this will lead to reduction of air pollution of the art museum buildings and improvement of the indoor environment (Zannis, *et. al*., 2006).

CHAPTER III

3. DAYLIGHT DESIGN EFFECTS ON ART MUSEUM VISITORS

3.1. Visual Comfort

“Vision is when a view is captured by the eye as light enters through the pupil, is focused by a lens onto a surface at the back of the eye called retina, which converts the light into signals that are transmitted to and interpreted by the brain… The retina consists of light receptors called cones and rods. There are approximately six million cone receptors in the retina and they are clustered around the center of the retina and operate during good lighting conditions (pho-topic vision), such as in the day” (Bougdah & Sharples, 2010, p. 142). The cones are color sensitive, and they are responding to yellow-green wavelengths of light (the most copious in the solar spectrum). Rod receptors process during low light conditions (sco-topic vision), such as at night. There are approximately 100 million rods that are sited around the circle of the retina (Bougdah & Sharples, 2010).

When the eye views a scene it may see a large variety of luminance or brightness, for example a bright window, in a dark colored wall (Hebert, Arsenault and Dubois, 2012). The eye can deal with a certain range of brightness. However, if the contrast between the bright and dark areas is too large then the sensation of glare will occur which is disadvantageous because it prevents visual comfort disturbing the eye. There are many quantitative factors of daylight affecting visual comfort such as; intensity, daylight temperature conditions, glare, shadow, angle, spectrum, transmittance and distribution (Hebert, Arsenault and Dubois, 2012). There are two types of glare; disability glare and discomfort glare (Bougdah & Sharples, 2010). Disability glare affects the ability to see objects in detail. It generally arises from reflections off surfaces. Common examples of disability glare include reflections from glass cabinets housing exhibits in museums and images of surroundings reflected off a computer screens. Discomfort glare causes visual discomfort and may be the result of a very bright object in the field of view of a person (Bougdah & Sharples, 2010). Minor levels of glare can be irritating but can be neglected however at high levels glare can interrupt performance or even cause risk to get injured for people as they move around unfamiliar spaces (Bougdah & Sharples, 2010). Therefore, one very important aim in a lighting design is to try and control the range of brightness likely to be experienced by a building user (Bougdah & Sharples, 2010). A design that tries to provide sufficient amount of daylight within interior spaces may incorporate large glazing areas, which can cause the problem of excessive glare. "Sizing the windows to provide view, daylight and some solar gain; using controllable and moveable shading devices, such as Venetian blinds; reducing the contrast between the window and its wall by using light walls; positioning computer work spaces perpendicular to windows; partitioning large, open plan spaces; orientating the building" (Boughdah & Sharples, 2010, p. 151).

Another visual comfort feature is eye adaptation (Bougdah & Sharples, 2010). Adaptation is a process, which the eye adjusts to varying lighting levels as a person moves around a space where there are varying brightness levels within the interior space. When there is bright light in the environment the eye's pupil will contract because of the need for reducing the amount of light entering the eye (a minor adaptation mechanism) and receptors that are on the retina chemically deplete their sensitivity (the major adaptation mechanism). Conversely, when there is dark lighting conditions the pupil gets expand and the retina's receptors will change to become more sensitive because of the dark environment. This adaptation processes take a very limited and finite time amount. When a light is switched off in a room than room gets dark. It will take a few minutes before rod vision is invigorated and shapes of the environment can be perceived. However, when a light is switched on in a dark room then cone vision gets activated rapidly, in standard conditions it takes a few seconds, and good vision is obtained accordingly (Bougdah & Sharples, 2010). However during both dark and light adaptation the eye's ability to see is vitiated, and this causes a potential danger for a building user or visitor and for their experiences. Consequently, lighting design aims is to provide space and time for people to adapt to changing lighting levels. A human eye can adapt to high levels of brightness easily, however it cannot easily adapt to low levels after high levels. So, in art museums lighting levels should gradually decrease between external entrances and the viewing spaces accompanied, preferably, by ramped rather than stepped walkways (Bougdah & Sharples, 2010). Moreover, backlighting of objects should be designed according to control glare and to provide visual comfort. Backgrounds should not be bright because, if the background is relatively bright some details will be lost (Bougdah & Sharples, 2010).

Visual comfort should be considered carefully for a success of a space. However visual comfort level varies according to the task performed. Human beings adjust to behavior to course of a daily biological rhythm; it occurs that human beings comfort perception evolves during the day. "In an attempt to meet visual comfort criteria, we shall take into account the environment (material and people) and the task at the hand in order to specify the notion of visual atmosphere" (Anthierens, *et al*., 2008, p. 415). According to Anthierens *et al*., 2008, if there is visual discomfort, then there is imbalanced light, uncomfortable backlighting, local glare, high contrast zones and inadequate lighting intensity and causes problems like loss of productivity, increase in level of stress, early tiredness and adaptation problems.

When daylight design is considered there are two issues first one is quantity of light and the second one is quality of light (Bougdah & Sharples, 2010). The quantity of light required to perform task is relatively easy to calculate, however the visual quality of a space is much more difficult to predict. Because of this reasons lighting design is often described as both an art and a science. There are some visual objectives for daylight an interior space. These objectives are mainly; space function, use and style; building materials and finishes; age of occupants; tasks to be done in space; times of occupancy; visual appearance, impact and mood for example; prestigious, vibrant, relaxing, clean etc.; priorities and restraints such as financial, energy and environmental strategies (Bougdah & Sharples, 2010).

3.2. Health and Wellbeing of Occupants

There are also non-visual effects of daylight received by eye. These are physiological and psychological effects (Müller & Schuster, 2012). Even if physiological and psychological effects are dependent on people and even if they are subjective, psychological studies shows that daylight design has measurable neuroendocrine and neurobehavioral effects on the human body, in particular with respect to ensuring a healthy sleeping and waking up cycle and maintaining the energy and alertness. Thus, there is a relationship of quality and nature of the internal daylight environment and human health according to these studies. So there is a subjective link between daylight exposure and health and productivity (Andersen, Mardaljevic & Lockley, 2012). Human beings need daylight because of the two main reasons. First reason is that illumination of the room is needed for visual performances. Second reason is about biological stimulation of the psychological and physical sense of wellbeing (Müller & Schuster, 2012). There are evidences that degree of exposure to daylight has a role to determine how pleasant the atmosphere is for living and spending time through activities. There are some studies claiming that daylight prevents diseases by vitamin D deficiency (Hwang, 2011). Moreover, these studies on the field of eye health show that daylight usage affects people visual perception and mood (Hwang, 2011). It enhances occupant satisfaction and studies on the field of health also show that exposure to daylight improves psychological health, work abilities such as concentration levels and productivity levels as well (Xue, Mak, & Cheung, 2014) .

Human beings biorhythm is based on the natural change from day to night, the duration and intensity of sunshine and also the spectral composition of light (Müller & Schuster, 2012). If we consider human beings origins of living in outdoor spaces instead of enclosed spaces, the inappropriateness of artificial lighting conditions for humans can be easily understood. When the lighting is based on artificial lighting in enclosed spaces, it is inevitable to deal with illnesses that this kind of factitious light causes. These illnesses are basically and mainly; winter depression, biorhythm problems, concentration problems, hormone production problems and visual problems etc. (Müller & Schuster, 2012).

A positive psychological effect of light is obtained when a room appears bright and open. An enclosed space, which is black has an entirely different effect on people than a room with sufficient light. Another important issue about psychological health is that there should not be any obstructions through windows (Müller & Schuster, 2012).

According to Galasiu and Veitch (2006), daylight is better for psychological comfort, pleasantness, general health, visual comfort and color appearance (Galasiu & Veitch, 2006). The type of outside view and the view content were one of the most important factors effecting visitor health and comfort that leads closer views triggering the selection of wider windows than the more distant views. In this manner, obstructions should be prevented as mentioned before. In this manner, "a view out" is very significant because of the abilities it allows such as; "to see the weather outside", "to see the view outside", "to open the window for ventilation" (Galasiu & Veitch, 2006, p. 729).

Another health effect when daylight is used is that less pollution occurs as mentioned before. This issue is also related with art museum visitors. Air pollution is a significant threat for the preservation of museum collections since atmospheric pollutants such as; sulphur, nitrogen oxides, ozone and particulates can cause degradations and corrupt various collection elements in a significant degree (Zannis, *et al*., 2006). Moreover, pollutants can cause poor indoor air quality, which effect visitor comfort and health negatively (Zannis, *et al*., 2006).

3.3. Perception

Daylight offers a wide spectrum. It offers a high power density over the whole range of visible frequencies. These features of daylight make it unique since it is the only light source that allows human beings to have accurate perception of the true colors that is exists in the environment (Anthierens, *et al*., 2008).

However, there are some points related to daylight characteristics that should be considered carefully for efficient perceptual qualities of interior spaces. Compared to artificial light, the primary drawback of daylight is its perceptual variations. Daylight changes with the seasons according to the attitude of sun and daylight duration. Furthermore, it also changes with the time depending on orbit of sun between sunrise and sunset. Besides, different weather conditions, such as albedo variation due to water or snow, presence of a building, obstructions etc., have effects on perception. These conditions makes daylight unpredictable, as a result it is difficult to handle daylight issues with any sound reliability. However, even if daylight has a dynamic character and even if perception is mostly a subjective issue related with humans satisfaction with the correct design strategies and control issues which are discussed before, optimal perceptual conditions can be obtained in public spaces such as art museums where visitor's perception is an important aspect (Anthierens, *et al*., 2008).

The sensitivity of light to human eye ranges from 380 to 760 nanometers (Müller & Schuster, 2012). It is optimally adapted to solar radiation. The greatest sensitivity lies in the range of the maximum radiation intensity at 550 nanometers (yellow), diminishing as it reaches the short and long wave radiation spectrum (Müller & Schuster, 2012). Retina of the human eye has different types of receptors approximately six million cones for color perception in daylight and over 100 million rods, which are sensitive to light and react to low light intensity (Müller & Schuster, 2012). A third type of receptors that influences the circadian behavior of humans was only discovered in recent years (Müller & Schuster, 2012).

Adaptation is an important process not only for visual comfort but also for perception of interior spaces. Adaptation is basically achieved through adjustment in the pupil and biochemical process in the retina (Müller & Schuster, 2012). However, the important issue is that this process takes time, particularly adaptation to very high to very low luminance. If an interior space such as art museums does not provide illuminance design according to adaptation issue that some important art objects might not be perceived efficiently by the visitors of the museum which will make the museum design unsuccessful (Müller & Schuster, 2012).

Although less noticeable, extreme contrast of luminance in the visual field of perception is just as uncomfortable because the eye attempts to simultaneously adapt to the bright and the dark areas (Müller & Schuster, 2012). This is the reason for exposure to contrast glare over long periods, especially in the workplace, causes fatigue and discomfort (Müller & Schuster, 2012).

According to Volf (2010), our most important sense vision and the influence of it with daylight is crucial for cognition and perception of aesthetics and art. Volf (2010) believes that natural light makes it possible to cognize the environment effectively and artificial light cannot do that. It is stated that 'window', 'wind-ow' means fresh air and light, if daylight is neglected than things that are basis of being a human will lost their meaning. Perception and cognition will be not as effective.

Both for visual comfort and perception display cabinets of art museums are very important. High brightness sources such as daylight or artificial light can make reflections in the glass display elements such as display cabinets and affect the visibility and perception (Wilson, 2006). This occurs when there is a poor lighting of cabinets. This can be eliminated by additional lighting units. The perception of the veiling reflection depends on the balance between the brightness of the reflection and the brightness of the object. However, for an efficient perception of a visual environment adaptation should be considered as well. A background unit with low reflectance surface can reduce the eye adaptation and it can facilitate the visibility of displayed objects (Wilson, 2006). However, reducing adaptation level can also make the reflections become more visible as well. So, it is clear that surface color and reflectance of surfaces are an integral part of art museums lighting design (Wilson, 2006).

3.4 Satisfaction

Satisfaction should be fully analyzed to provide an effective visual comfort, to satisfy the visitors and to enhance museum experience. Visitor satisfaction in museums is a psychological state, or a "gap", felt during the consumption experience and resulting from the disconfirmation of the visitor's prior feelings and expectations about the exhibit of museums (Brida, Disegna, & Vachkova, 2013). Expectations are viewed as the primary measurement of satisfaction and if the consumption experience exceeds these expectations, the person would be satisfied. According to Ghurchill and Surprenant (1982), the complete disconfirmation paradigm consists of four levels. These four levels are; expectations which are according to performance, perceived or actual performance; disconfirmation (obtained by the comparison between expectations and performance); and dissatisfaction (Brida, Disegna, & Vachkova, 2013).

Reviewing the literature shows that there are various definitions and studies about satisfaction. According to Tessier, Crouch, & Atherton (1977), it is ultimately a state experienced inside the user’s head, therefore it can be considered as both intellectual and emotional.

Within the framework of this thesis, satisfaction is defined as the visitor experience about the visual comfort parameters such as; prevention of eye adaptation problems, prevention of glare problems, balanced daylight, prevention of high contrast illumination of spaces and prevention of inadequate daylight intensity in interior spaces of visitors.

3.5. Experiences

The noticeable character of natural light is in the quality of human experiences it offers. “Natural light is variable and contains a continuous spectrum of colors, dependent on constitute the evolving appearances of the white light. Together with defining the space and its objects, natural light gives the sense of passing time as well as a sense of place” (Behar, Capeluto & Levin, 2013, p. 2). It is obvious that with effective design of daylight it possible to transform an exhibition space visit into special unforgettable experience which leads to success of art museums as a building (Behar, Capeluto & Levin, 2013).

Daylight can be valuable for orientation and visual relief, in large public spaces such as art museums. This would make museum experiences more enjoyable and less tiring. Thus, these show that daylight contributes to visitor experiences effectively (Kim & Chung, 2010).

CHAPTER IV

4. THE CASE STUDY: ISTANBUL MODERN ART MUSEUM

This study explores the effects of daylight design strategies on visitor visual comfort of art museums. It aims to figure out the role of daylight design features on visual environmental qualities of art museums. In this chapter, objectives and method of the study, results and discussion are presented.

4.1. Objectives of the Study

How visitor responses of art museums to daylight design and how daylight design strategies effect visitor visual comfort are the key questions that are analyzed within the framework of the study. Moreover, how daylight contributes to visual environmental quality and how energy conservation of art museums is enhanced by daylight design strategies become also significant. The obtained results of the study contribute to the design literature and practice while designing art museums and increasing visitor satisfaction levels with indoor environmental qualities.

4.1.1. Research Questions

In order to find out the role of daylight design and control strategies on art museums, there are two main research questions.

1. What are the effects of daylight design features on the visual comfort experiences which are; prevention of eye adaptation problems, prevention of glare problems, balanced daylight, prevention of high contrast illumination of spaces and prevention of inadequate daylight intensity in interior spaces of visitors?
2. How the visual comfort of visitors is correlated with view out design elements of an art museum?

4.1.2. Hypotheses

The study has two main hypotheses.

1. The view out design elements are significantly related with the overall satisfaction of visitors in art museums.
2. The daylight experience of visitors is different in clear sky condition compared to overcast sky condition.

4.2. Method of the Study

The thesis is based on the user data obtained through a survey and daylight simulation data obtained by Autodesk 3D's Max 2014. The simulations were generated after the 3D modeling of the case building was done. The following sections explain how the users and case building are selected and how the simulation data is generated accordingly.

4.2.1. Sample Group

Study participants were chosen by a convenience sampling method, in which participants are selected because of their convenient accessibility and proximity to the researcher. Because the study requires two sessions on different dates depending on the two different weather condition, which are overcast sky condition and clear sky condition, participants are chosen according to their availability for both of the two sessions. The negative effects of this repeated measures design, i.e., the risk of carry-over effects from one survey to the next, is overcome by giving time break between each session. A total of 100 people participated to the study. The demographics of the participants are given in the result section.

4.2.2. Procedure

A questionnaire survey was developed to be conducted in İstanbul Modern Art Museum, Istanbul. Each survey took approximately three to five minutes and conducted with each participant individually. The survey involved three parts. First part included demographic information. In the second part, participants were asked to rate their experience level with the daylight design features of İstanbul Modern Art Museum on a five point Likert-type scale, ranging from ‘poor’ to ‘excellent’. The last part was related with the importance levels of participants for each daylight design features of art museums in general. For overcast sky condition the date was January 20, 2015 and the clear sky condition date was March 4, 2015.

İstanbul Modern Art Museum building has two floors, ground floor and first floor. The museum is located in Meclis-i Mebusan Street in Karaköy, İstanbul. It is south west located right near the Marmara Sea. For the study, İstanbul Modern Art museum is selected because of the following reasons; (i) it has daylight in the exhibition areas, (ii) it has a very convenient location that is located at the city center; and (iii) it has a visual connection with outside. See Figure4.1 and 4.2 for view and location of İstanbul Modern Art Museum.

İstanbul Modern Art Museum was renovated and opened in 2004. The museum building is situated on the shores of the Bosporus, and it faces the historical peninsula of İstanbul. It is a renovated, 8000 square meters of warehouse storage building. This art museum is the first Turkish museum of contemporary art. It is renovated as an art museum by Tabanlıoğlu architects. It has exhibition rooms, library, restaurant, terrace café, gift shop, movie theatre, seminar rooms and education rooms and service areas (Polo, 2015). The Museum is selected according to daylight issues: daylight availability; sky conditions; the site and any obstructions; the form of the building; interior planning and design; window and façade design; innovative daylight techniques; testing of the design strategy (Bougdah & Sharples, 2010).

Figure 4.1 shows the west side view of the İstanbul Modern Museum's analyzed floor windows. In this figure, Topkapı Palace and Hagia Sophia Mosques can be clearly seen. Figure 4.2 shows east side view, which includes the sea and Bosphorus. Figure 4.3 includes an outside view of İstanbul Modern Art Museum. In this figure, architectural characteristics of the museum are clearly expressed. Figure 4.4 is effective to express the view and the interior space relationship. In this figure, the window structures can be seen as well.

Figure 4.1: West view Topkapı Palace and Hagia Sophia (Taken by the author.)

Figure 4.2: East view Sea and Bosporus (Taken by the author.)

Figure 4.3: İstanbul Modern Art Museum building (Taken by the author.)

Figure 4.4: Windows and view from İstanbul Modern Museum interior (Taken by the author.)

As stated above, two different dates, one for overcast sky condition and the other for clear sky condition was selected for the study. On the overcast sky condition date, the sky was fully covered by clouds and the natural light that exists was diffused light. On the clear sky date, the sky was fully open. The survey was done between 10:00 am and 16:00 pm. for both cases in the main exhibition space of the art museum which is located in the first floor of the İstanbul Modern Art Museum. It has side windows that are ultra violet and infra-red filtered. The view from windows is Marmara Sea, Topkapı Palace and the Hagia Sophia Mosque. Figure 4.5 illustrates the first floor plan of the museum. Figure 4.6, 4.7, 4.8, 4.9, 4.10, 4.11 show the interior of the museum.

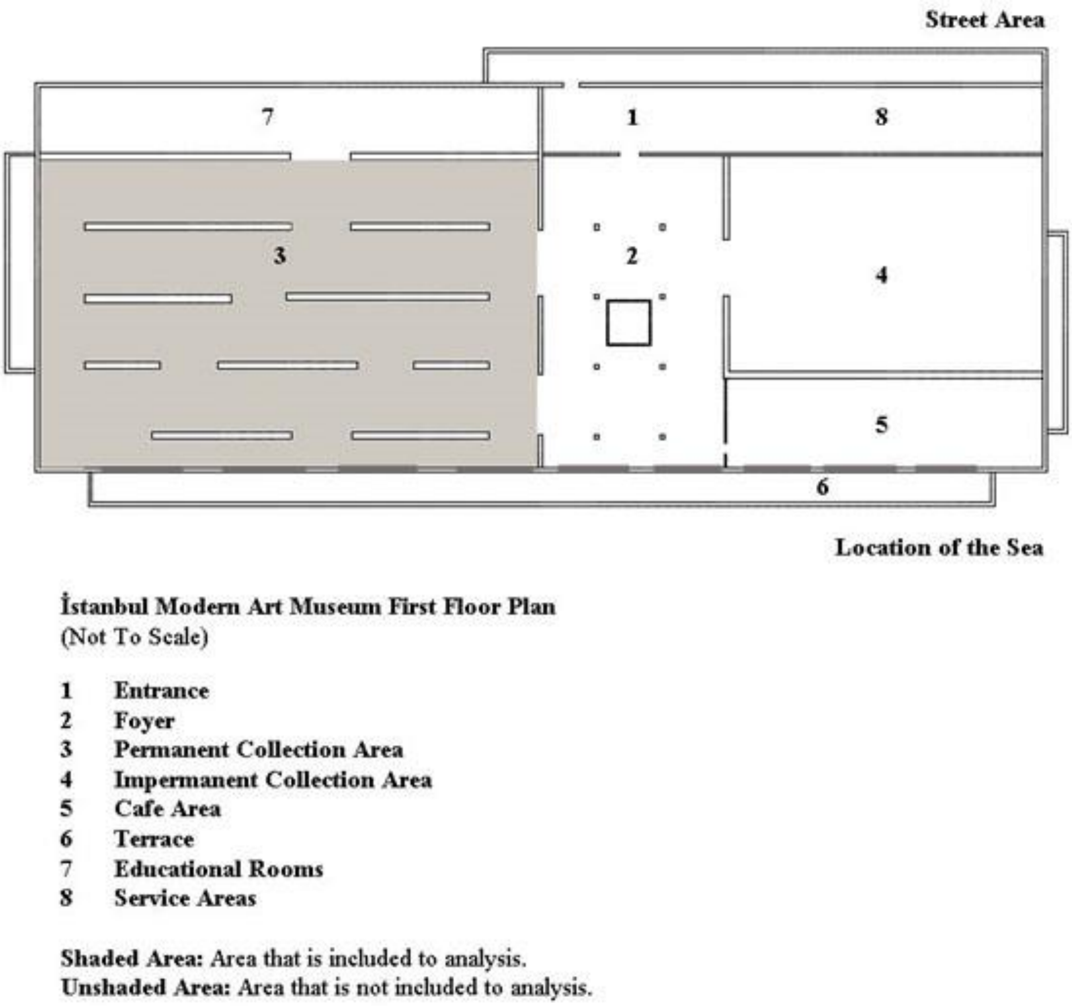

Figure 4.5: İstanbul Modern Art Museum First Floor Plan (Drawn by the author.)

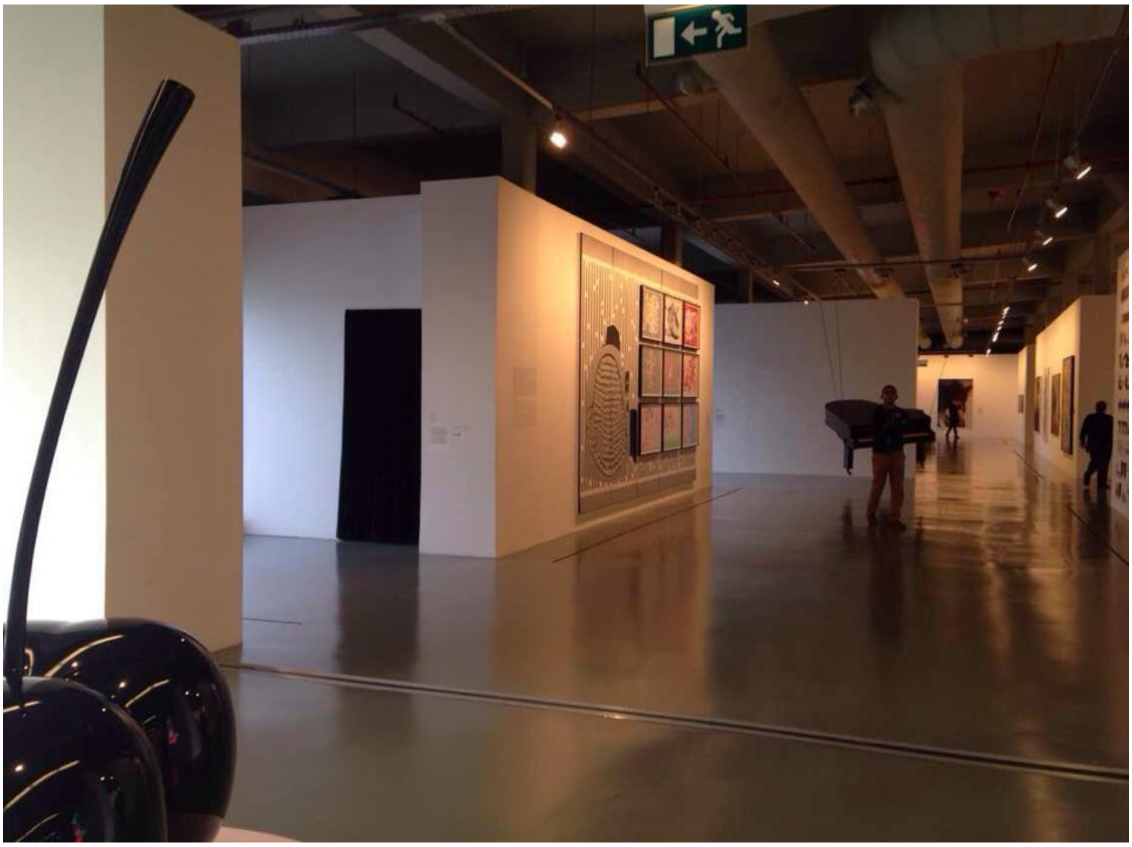

Figure 4.6: İstanbul Modern Art Museum’s analyzed area (Taken by the author.)

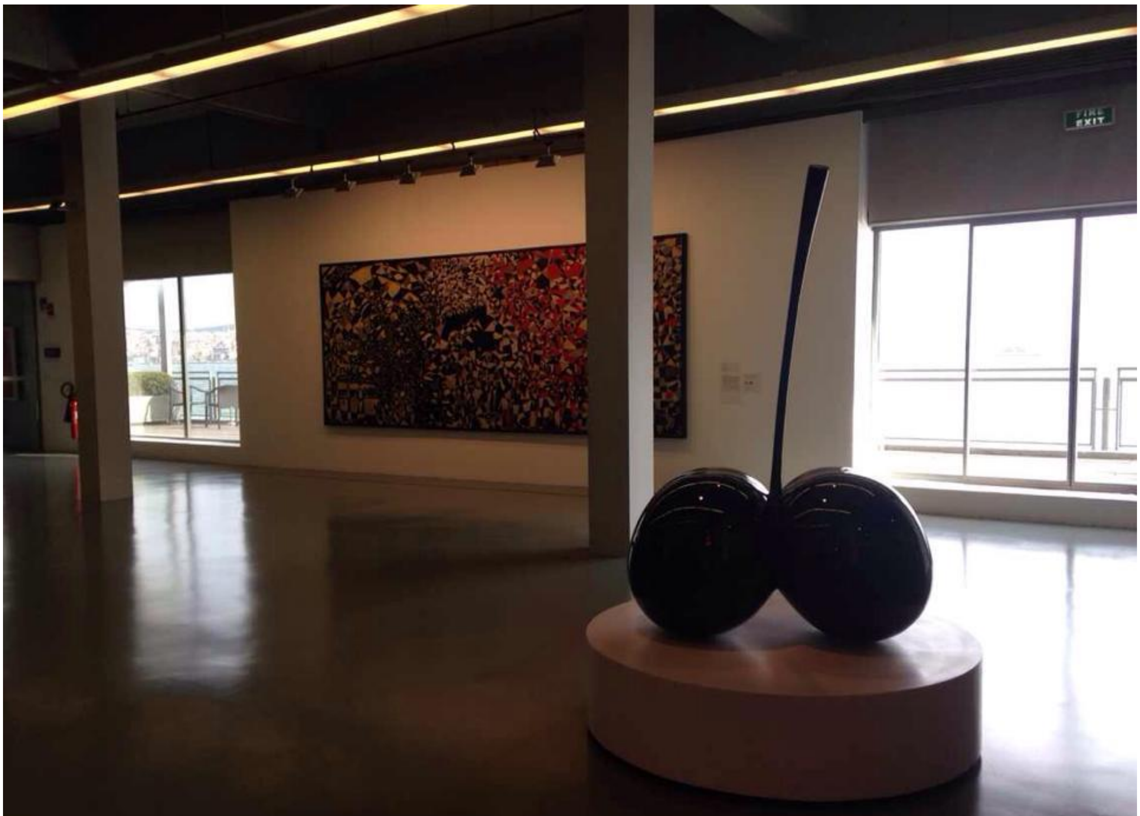

Figure 4.7: İstanbul Modern Art Museum’s analyzed area (Taken by the author.)

Figure 4.8: İstanbul Modern Art Museum’s analyzed area (Taken by the author.)

Figure 4.9: İstanbul Modern Art Museum’s analyzed area (Taken by the author.)

Figure 4.10: İstanbul Modern Art Museum's analyzed area (Taken by the author.)

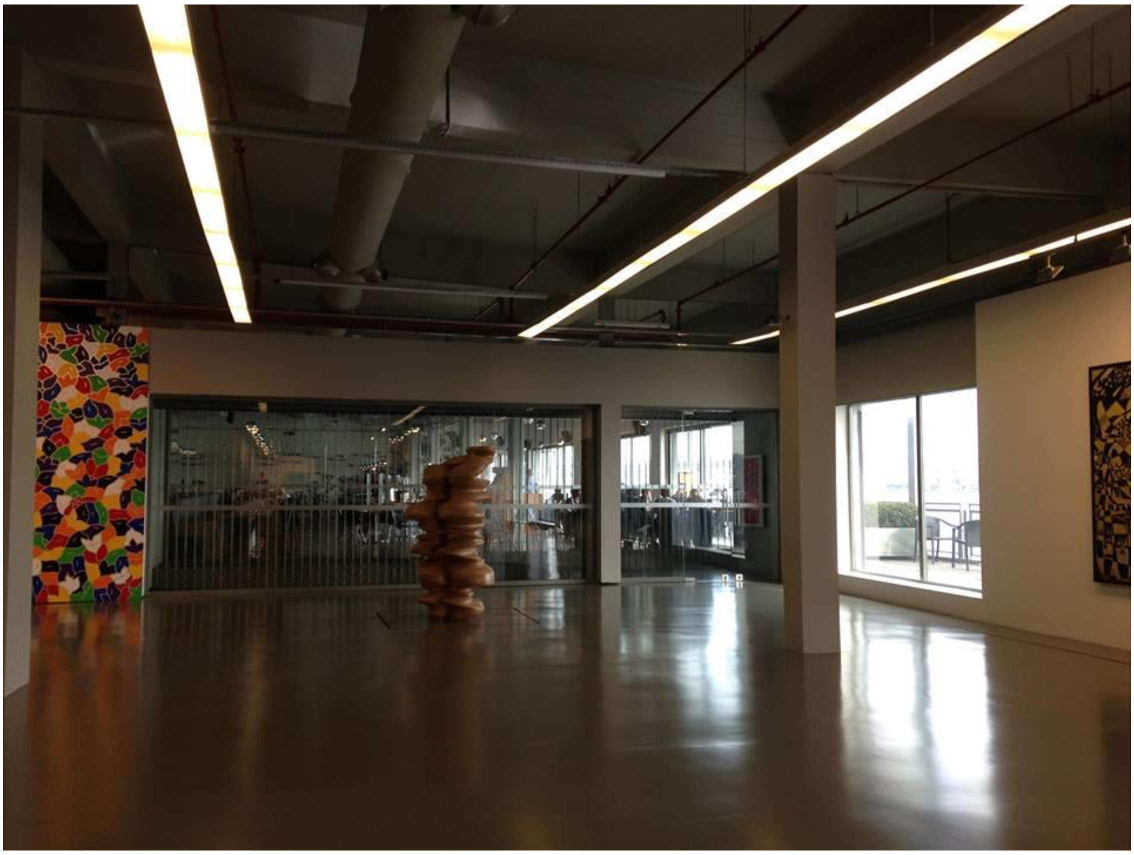

Figure 4.11: İstanbul Modern Art Museum's analyzed area (Taken by the author.)

4.2.3. Computer Simulation

To be able to analyze the daylight qualities and daylight related factors within the art museum, the daylight illuminance data is measured in a scaled model by a computer simulation program. Simulation is designed through the program Autodesk 3D's Max 2014. The main advantage of Autodesk 3D's Max 2014 is that it calculates daylight factor based on International Commission on Illumination (CIE). Moreover, Autodesk 3D's Max 2014 is capable of 3D modeling and visualization inside the building space. The program is also able to generate a daylight simulation and it is able to create daylight analysis, which is beneficial for understanding of illuminance levels of buildings. This program is very effective in rendering solutions and visual effects (Kensek & Suk, 2011). Real materials can be applied. EnergyPlus weather data file (*.EPW) supports this program as well. EnergyPlus weather data file provides 30 years information about the local weather in the study area and it contains annual data for typical conditions art an area including, temperature, humidity, wind speed and direction and direct/indirect irradiances (Hassan & Arab, 2014). Daylight illuminance levels and daylight factor can be obtained for any particular time by these data supplied. By using mental ray, which is an engine to do simulation, it calculates both daylight from all directions and indirect daylight, which are mainly the reflected daylight from interior surfaces (Hassan & Arab, 2014).

The simulation process includes drawing geometric three dimensional building in AutoCAD, which is also Autodesk production as a first step. After this step, process continues with importing the three dimensional model into 3D's Max 2014. Assigning a renderer is a significant step at this point. After these steps, daylight system should be created and EnergyPlus weather data file (*.EPW) for the selected location should be imported. Light meters are created in specific positions that give the measurement in 1m to 1m surface areas. Light meters are set in eye level for calculations. After these steps, a camera should be created for simulation. At the end, the data of the illuminance level appears on the drawing according to light meter locations in drawings. Important issue is that the orientation of the building should be arranged for accurate values. Also CIE data includes selections of overcast sky condition and clear sky condition, these selections should be stated through program for accuracy of the analysis data. For daylight analysis of this study, 18 specific points were selected (See Figure 4.4). Daylight analyses on these 18 points were done for hours of 10 am, 12 am, 14 pm and 16 pm for both of the condition types.

The computer simulation, which is done by 3D's Max 2014 program was designed by eliminating the artificial light since the analysis is based on daylight. With the reference to "Reliability of Computer Simulation on Illuminance Level of Pendentive Dome Mosque in Comparison with On-Field Data Collection" written by Ahmad Sanusi Hassan and Yasser Arab. The lighting source that was taken as daylight, obtained from indirect and direct sunlight source, coming inside the building through the openings such as doors and windows. By this way daylight availability can be observed and analyzed without other light sources influence on the existing interior space. The simulations are generated after the 3D model generations of the selected case study building which is İstanbul Modern Art Museum. 3D modeling were carefully done, other than windows and doors there were not any gaps that daylight can leak to the interior so that simulation can be more accurate (Hassan & Arab, 2014).

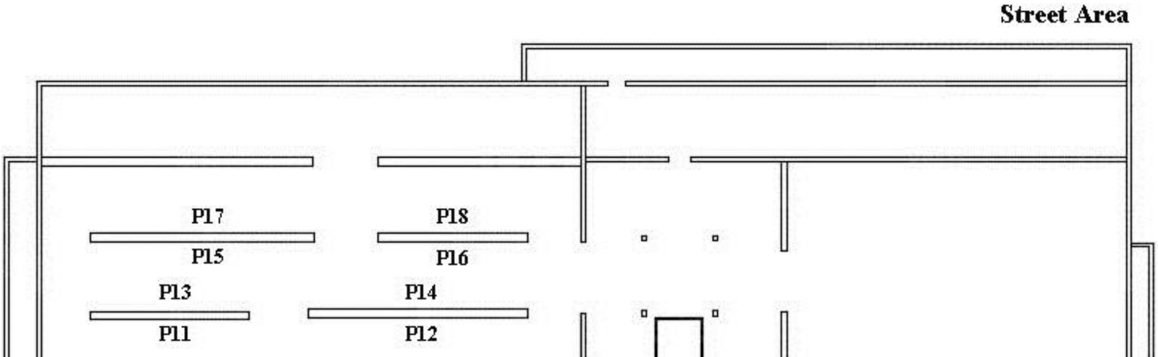
Street Area
P17
P18
P15
P16
P13
P14
P11
P12

Figure 4.12: Light meter locations as represented by 18 points within interior space of the İstanbul Modern Art Museum (Drawn by the author.)

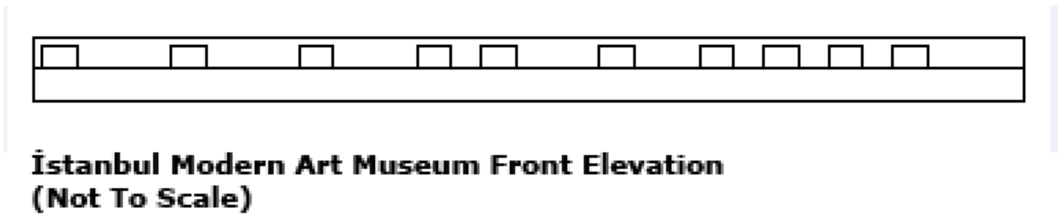

Figure 4.13: İstanbul Modern Art Museum front elevation with window design

4.3. Results

4.3.1. Survey Results

To analyze the obtained data from questionnaires, Statistical Package for the Social Sciences (SPSS) 15.0 was used. Frequencies and Pearson Correlation analysis were calculated for analyzing the data. Questionnaire is consisted of three parts. First part, which is Part A, is the demographic information. The second part; Part B is related with the ratings for visitor experiences of visual performance depending on daylight features of İstanbul Modern Art Museum. The last part, Part C, is related with ratings of importance levels of visual environmental qualities of art museums in general. Table 4.1 illustrates the percentages related with the participant demographic information. None of the participants needs an institutional care and none of them has mental disabilities.

Table 4.1: Percentages related to participant demographics.

Participant Characteristics	**Percentages**	**Frequencies**
Gender		

Female	55%	55
Male	45%	45
Age Group		
20-35 years	60%	60
36-50 years	28%	28
51-65 years	12%	12
Over 65 years	-	-
Education Level		
High School	69%	69
University	24%	24
Graduate Degree	3%	3
Post Graduate Degree	4%	4
Visit Frequency		
Twice in a Week	-	-
Once in a Week	-	-
Twice in a Month	8%	8
Once in a Month	19%	19
Less	73%	73

The second part of the questionnaire includes eleven daylight components; (1) daylight availability in museum's interior space, (2) controlled daylight intake, (3) size and division of windows, (4) visual connections to outdoors, (5) prevention of glare from windows, (6) prevention of glare from the sea and neighboring building structures, (7) color rendering of surfaces, (8) filtration of excess light exposure (UV, Infrared…), (9) homogeneous distribution of daylight on the wall surfaces, (10) thermal comfort conditions depending on daylight, and (11) overall satisfaction of the visitors.

Participant ratings of the eleven items in total were analyzed with the Statistical Package for the Social Sciences (SPSS) and correlation diagrams are constructed. Pearson's Correlation is applied for statistical analysis of relations of items listed in the questionnaire. The reason for applying Pearson's Correlation is that, it is effective to show how well the data are related with each other. It shows the linear relationship between two sets of data. Pearson's Correlation is a numerical measure or index of the amount of association between two sets of scores (Howitt & Cramer, 1999). It ranges size from plus 1.00 through 0.00 to minus 1.00. Plus sign, indicates a positive correlation and minus sign indicates negative correlation. A correlation of 1.00 indicates perfect association between the two variables (Howitt & Cramer, 1999).

According to Pearson's Correlation, correlation levels between 0,00 and 0,19 is considered as very weak and correlation levels between 0,20 and 0,39 is considered as weak. Correlation level between 0,40 and 0,59 is regarded as moderate and levels between 0,60 and 0,79 is considered to be strong. Lastly the correlation values between 0,80 and 1,00 shows that correlation is very strong (Howitt & Cramer, 1999).

While analyzing the participants' ratings of the eleven items through SPSS 15.0, correlation results showed that while there is effective daylight intake with control strategies support, color rendering effects have significant correlation values when correlated with visitor overall satisfaction level for both of the weather conditions. For overcast sky condition, correlations of daylight availability is weak (df=2, p= 0,292) as well as size and divisions of windows (df=2, p= 0,243) and direct sun penetration (df=2, p= 0,344) with overall satisfaction. For other items of overcast sky condition and for all items of clear sky condition correlation with overall satisfaction is moderate or strong with values between 0,396 to 0,623. There is also a moderate correlation between size and divisions of windows and daylight availability for both weather conditions. Another correlation is that direct sun penetration and daylight availability is moderately correlated with location and size of windows (df=2, p= 0,724). However, overall satisfaction correlation data is different for the two weather conditions. Overall satisfaction in the clear sky is strongly correlated with daylight availability, direct sun penetration and color rendering of surfaces. These results are different for overcast sky condition, in which there is a moderate correlation between overall satisfaction and color rendering of surfaces only. See Table 4.2 for clear sky condition correlation data and see Table 4.3 for overcast sky condition data.

In the Table 4.2 and 4.3, there are Pearson's Correlation analysis for clear sky conditions and overcast sky condition. In the clear sky condition, overall satisfaction is higher for many items when compared to overcast sky condition except color rendering effects. However, in overcast sky condition, overall satisfaction is higher for color rendering issues compared to clear sky condition. This can be an important issue about the study. When daylight availability is less in the indoor environment, the visitors tend their attraction to color rendering issues. Color and color related issues become more attractive visually. So, the attraction point of visitors is changing depending on different sky condition types.

Table 4.2: Pearson's Correlation for questionnaire part B- clear sky condition

Correlation

Matrix	Daylight Availability	Size and Divisions Windows	Direct Sun Penetration	Color Rendering of Surfaces	Overall Satisfaction
Daylight Availability					
Pearson Correlation	1				
Sig. (2-tailed)					
N	120				
Size and Divisions of Windows					
Pearson Correlation	**,570****	1			
Sig. (2-tailed)	,000				
N	120	120			
Direct Sun Penetration					
Pearson Correlation	**,681****	**,538****	1		
Sig. (2-tailed)	,000	,000			
N	120	120	120		
Color Rendering of Surfaces					
Pearson Correlation	,348**	,318**	**,413****	1	
Sig. (2-tailed)	,000	,000	,000		
N	120	120	120	120	
Overall Satisfaction					
Pearson Correlation	**,613****	,396**	**,623****	**,506****	1
Sig. (2-tailed)	,000	,000	,000	,000	
N	120	120	120	120	120

**Correlation is significant at the 0.01 level (2-tailed).

Correlation				Color Rendering

Matrix	Daylight Availability	Size and Divisions Of Windows	Direct Sun Penetration	of Surfaces	Overall Satisfaction
Daylight Availability					
Pearson Correlation	1				
Sig. (2-tailed)					
N	120				
Size and Divisions of Windows					
Pearson Correlation	**,509****	1			
Sig. (2-tailed)	,000				
N	120	120			
Direct Sun Penetration					
Pearson Correlation	**,724****	**,441****	1		
Sig. (2-tailed)	,000	,000			
N	120	120	120		
Color Rendering of Surfaces					
Pearson Correlation	,323**	,188**	,174**	1	
Sig. (2-tailed)	,000	,001	,000		
N	120	120	120	120	
Overall Satisfaction					
Pearson Correlation	,292**	,243**	,344**	**,523****	1
Sig. (2-tailed)	,000	,000	,000	,000	
N	120	102	120	120	120

Table 4.3: Pearson's Correlation for questionnaire part B- overcast sky condition

**Correlation is significant at the 0.01 level (2-tailed).

Another set of correlation data is among the following items; control systems of daylight intake, prevention of glare from windows, prevention of glare from neighboring building structures, filtration of excess light exposure and overall satisfaction. There is a moderate correlation with level 0,493 between prevention of glare from windows and control systems of daylight intake for clear sky condition. For overcast sky condition the correlation level is 0,597. Prevention of glare from neighboring building structures and control systems of daylight intake are moderately correlated as well. The correlation value for this correlation is 0,482 for clear sky condition and 0,570 for overcast sky condition. There is a very strong correlation between prevention of glare form windows and prevention of glare from neighboring building structures; correlation value is 0,808 for clear sky condition and 0,846 for overcast sky condition. The correlation between filtration of excess light exposure and prevention of glare from windows are moderately correlated for both cases and values are 0,496 for clear sky condition and 0,417 for overcast sky condition. Clear sky condition values are slightly higher, the reason for this might be because in clear sky participants might felt the need for more glare prevention and filtration for maintenance of their comfort. Overall satisfaction is moderately correlated with control systems of daylight intake and filtration of excess light exposure For clear sky condition overall satisfaction item's correlation with control systems of daylight intake is 0,528 for clear sky condition and 0,428 for overcast sky condition. There is a slightly higher correlation value for clear sky condition, this might be because of higher daylight illumination level in clear sky condition as well. For overall satisfaction item's correlation with filtration of excess light exposure the correlation values are 0,446 for clear sky condition and 0,509 for overcast sky condition.

There are also important differences in correlation analysis in terms of weather conditions. For the overcast sky condition, the correlation between filtration of excess light exposure and control systems of daylight intake is in a moderate level but for clear sky condition it is in a weak level. Another difference between two different weather conditions is related with the overall satisfaction item. In the clear sky condition, overall satisfaction level is moderately correlated with prevention of glare from windows and prevention of glare from neighboring building structures. See Table 4.4 for clear sky conditions data and see Table 4.5 for overcast sky conditions data.

Table 4.4: Pearson's Correlation for questionnaire part B- clear sky condition

Correlation Matrix	Control Systems of	Prevention of Glare	Prevention of Glare from Neighboring	Filtration of	Overall Satisfaction

	Daylight Intake	from Windows	Building Structures	Excess Light Exposure	
Control Systems of Daylight Intake					
Pearson Correlation	1				
Sig. (2-tailed)					
N	120				
Prevention of Glare from Windows					
Pearson Correlation	**,493****	1			
Sig. (2-tailed)	,000				
N	120	120			
Prevention of Glare from Neighboring Building Structures					
Pearson Correlation	**,482****	**,808****	1		
Sig. (2-tailed)	,000	,000			
N	120	120	120		
Filtration of Excess Light Exposure					
Pearson Correlation	,366**	**,496****	**,451****	1	
Sig. (2-tailed)	,000	,000	,000		
N	120	120	120	120	
Overall Satisfaction					
Pearson Correlation	**,528****	**,428****	**,422****	**,446****	1
Sig. (2-tailed)	,000	,000	,000	,000	
N	120	120	120	120	120

**Correlation is significant at the 0.01 level (2-tailed).

Table 4.5: Pearson's Correlation for questionnaire part B- Overcast Sky Condition

Correlation Matrix	Control Systems of Daylight Intake	Prevention of Glare from Windows	Prevention of Glare from Neighboring Building Structures	Filtration of Excess Light Exposure	Overall Satisfaction
Control Systems of Daylight Intake					
Pearson Correlation	1				
Sig. (2-tailed)					
N	120				
Prevention of Glare from Windows					
Pearson Correlation	**,527****	1			
Sig. (2-tailed)	,000				
N	120	120			
Prevention of Glare from Neighboring Building Structures					
Pearson Correlation	**,570****	**,846****	1		
Sig. (2-tailed)	,000	,000			
N	120	120	120		
Filtration of Excess Light Exposure					
Pearson Correlation	**,450****	**,417****	,358**	1	
Sig. (2-tailed)	,000	,000	,000		
N	120	120	120	120	
Overall Satisfaction					
Pearson Correlation	**,428****	,389**	,389**	**,509****	1
Sig. (2-tailed)	,000	,000	,000	,000	
N	120	120	120	120	120

**Correlation is significant at the 0.01 level (2-tailed).

The last part is consisted of importance levels of the following eleven items; (1) windows, (2) skylights, (3) shading systems (interior and exterior), (4) reflected light techniques (light shelves), (5) prevention of imbalanced daylight distribution, (6) prevention of local glare, (7) prevention of high contrast illuminated zones, (8) prevention of inadequate daylight intensity in interiors, (9) visual connection to outdoors, (10) neighboring building surfaces and visual obstructions (11) energy conservation and sustainability. This part also includes an unstructured interview part for further comments of the participants According to the results of the correlation analysis, windows and skylights are very strongly correlated with each other for both weather conditions, which are 0,903 for clear sky condition and 0,907 for overcast sky condition. Shading systems are very strongly correlated with windows (df= 5, p= 0,601) and moderately correlated with skylights (df= 5, p= 0,593) for the clear sky condition. However, for the overcast sky condition analysis, there are slightly different values because of the different intensity of daylight levels. For the overcast sky condition, shading systems are moderately correlated with windows (df= 5, p= 0,498) and skylights (df=5, p= 0,555). Prevention of local glare and adequate daylight intensity are in moderate correlation (df=5, p= 0,55) for clear sky condition and strong (df=5, p= 0,805) for overcast sky condition. These correlations shows that daylight design elements like windows and skylights are closely associated with daylight control strategies which are shading systems and reflected light techniques. It is clear that architectural design elements and control strategies are both important factors to allow efficient visual comfort for visitors and they should be considered together. See Table 4.6 for correlations of clear sky condition and see Table 4.7 for overcast sky condition correlation data.

Table 4.6: Pearson's Correlation for questionnaire part C- clear sky condition

Correlation Matrix	Windows	Skylights	Shading Systems	Reflected Light Technique	Balanced Distribution Of Daylight	Prevention Of Local Glare	Adequate Daylight Intensity
Windows							
Pearson Correlation	1						
Sig. (2-tailed)							
N	120						
Skylights							
Pearson Correlation	,903**	1					
Sig. (2-tailed)	,000						
N	120	120					
Shading Systems							
Pearson Correlation	,601**	,593**	1				
Sig. (2-tailed)	,000	,000					
N	120	120	120				
Reflected Light Technique							
Pearson Correlation	,573**	,579**	,558**	1			
Sig. (2-tailed)	,000	,000	,000				
N	120	120	120	120			

Table 4.6 Continues

Correlation Matrix	Windows	Skylights	Shading Systems	Reflected Light Technique	Balanced Distribution Of Daylight	Prevention Of Local Glare	Adequate Daylight Intensity
Balanced Distribution of Daylight							
Pearson Correlation	**,746****	**,639****	**,505****	**,518****	1		
Sig. (2-tailed)	,000	,000	,000	,000			
N	120	120	120	120	120		
Prevention of Local Glare							
Pearson Correlation	**,677****	**,596****	**,587****	**,420****	**,722****	1	
Sig. (2-tailed)	,000	,000	,000	**,000**	,000		
N	120	120	120	120	120	120	
Adequate Daylight Intensity							
Pearson Correlation	**,586****	**,592****	**,512****	**,476****	**,685****	**,556****	1
Sig. (2-tailed)	,000	,000	,000	,000	,000	,000	
N	120	120	120	120	120	120	120

**Correlation is significant at the 0.01 level (2-tailed).

Table 4.7: Pearson's Correlation for questionnaire part C- overcast sky condition

Correlation Matrix	Windows	Skylights	Shading Systems	Reflected Light Technique	Balanced Distribution Of Daylight	Prevention Of Local Glare	Adequate Daylight Intensity
Windows							
Pearson Correlation	1						
Sig. (2-tailed)							
N	120						
Skylights							
Pearson Correlation	**,907****	1					
Sig. (2-tailed)	,000						
N	120	120					
Shading Systems							
Pearson Correlation	**,498****	**,555****	1				
Sig. (2-tailed)	,000	,000					
N	120	120	120				

Reflected Light Technique							
Pearson Correlation	,604**	,591**	,626**	1			
Sig. (2-tailed)	,000	,000	,000				
N	120	120	120	120			

Table 4.7 Continues

Correlation Matrix							
Balanced Distribution of Daylight							
Pearson Correlation	,649**	,632**	,521**	,560**	1		
Sig. (2-tailed)	,000	,000	,000	,000			
N	120	120	120	120	120		
Prevention of Local Glare							
Pearson Correlation	,653**	,634**	,565**	,517**	,823**	1	
Sig. (2-tailed)	,000	,000	,000	,000	,000		
N	120	120	120	120	120	120	
Adequate Daylight Intensity							
Pearson Correlation	,682**	,640**	,487**	,504**	,729**	,805**	1
	,000	,000	,000	,000	,000	,000	
	120	120	120	120	120	120	120

Sig. (2-tailed)	
N	

**Correlation is significant at the 0.01 level (2-tailed).

For the second hypothesis, visual connection to outdoor is significantly related with the overall satisfaction of visitors in art museums, correlation analysis is also calculated. It is found that there is a moderate correlation with 0,492 value between visual connection to outdoors and overall satisfaction levels of visitors. This is because of the location of the selected art museum since it is near the Marmara Sea and has a view of Bosporus, Topkapı Palace and Hagia Sophia Mosque.

4.3.2. Simulation Results

Results of the daylight simulation analysis and perspectives show that there is a significant difference in daylight conditions between clear sky and overcast sky condition. See Figure 4.14 and 4.15 for interior perspectives with daylight simulations. With these figures the daylight illuminance difference for clear sky condition and overcast sky conditions can be seen clearly.

Figure 4.14: Clear sky perspective point 3 (Rendered by the author.)

Figure 4.15: Overcast sky perspective point 3 (Rendered by the author.)

For both of the conditions, Point 2 has a peak value of lux level and Point 1 has the second highest lux level for all analyzed hours. See Figure 4.16 and 4.17 for clear sky condition daylight simulation for Point 1 and Point 2. And see Figure 4.18 and 4.19 for overcast sky condition daylight simulation for Point 1 and Point 2. Simulation's visual realistic perspectives are for 12 am.

Figure 4.16: Clear sky perspective point 1 (Rendered by the author.)

Figure 4.17: Overcast sky perspective point 1 (Rendered by the author.)

Figure 4.18: Clear sky perspective point 2 (Rendered by the author.)

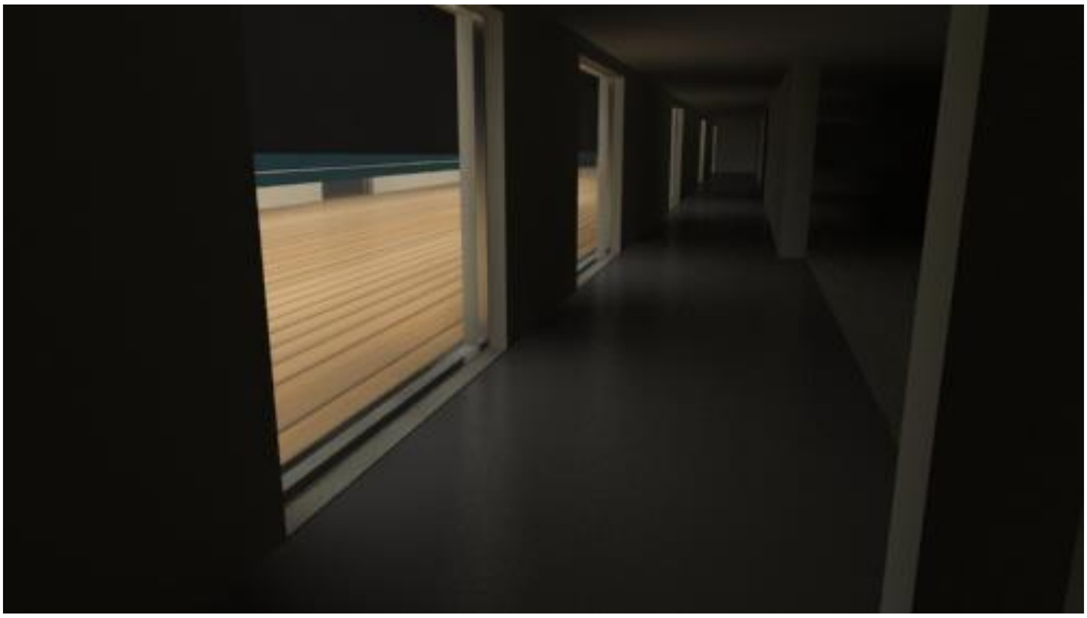

Figure 4.19: Overcast sky perspective point 2 (Rendered by the author.)

These two points have a very high lux values compared to other points since these points are the closest points to windows and they are not obstructed by any partition walls unlike some of the other points. The reason for a peak value is the south east orientation of the İstanbul Modern Art Museum. Also points 3, 4 and 9 have lux values of zero for both weather conditions and for all hours of the analyzed dates, since they are the points behind partition walls and since they are far away from windows. See Figure 4.20, Figure 4.22 and Figure 4.24 for related points for clear sky condition and see Figure 4.21, Figure 4.23 and Figure 4.25 for overcast sky condition.

Figure 4.20: Clear sky perspective point 3 (Rendered by the author.)

Figure 4.21: Overcast sky perspective point 3 (Rendered by the author.)

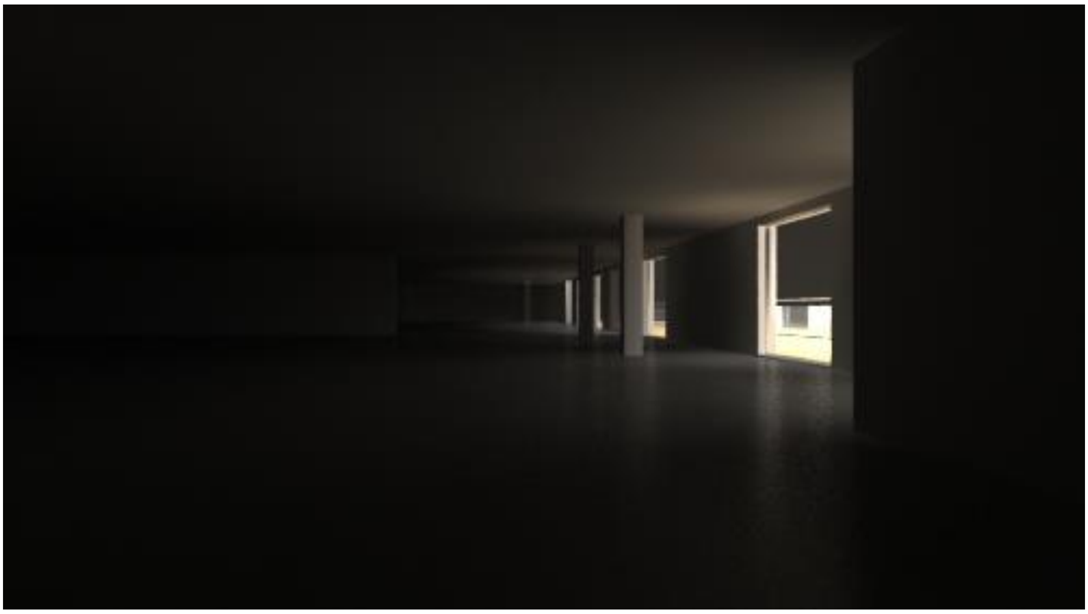

Figure 4.22: Clear sky perspective point 4 (Rendered by the author.)

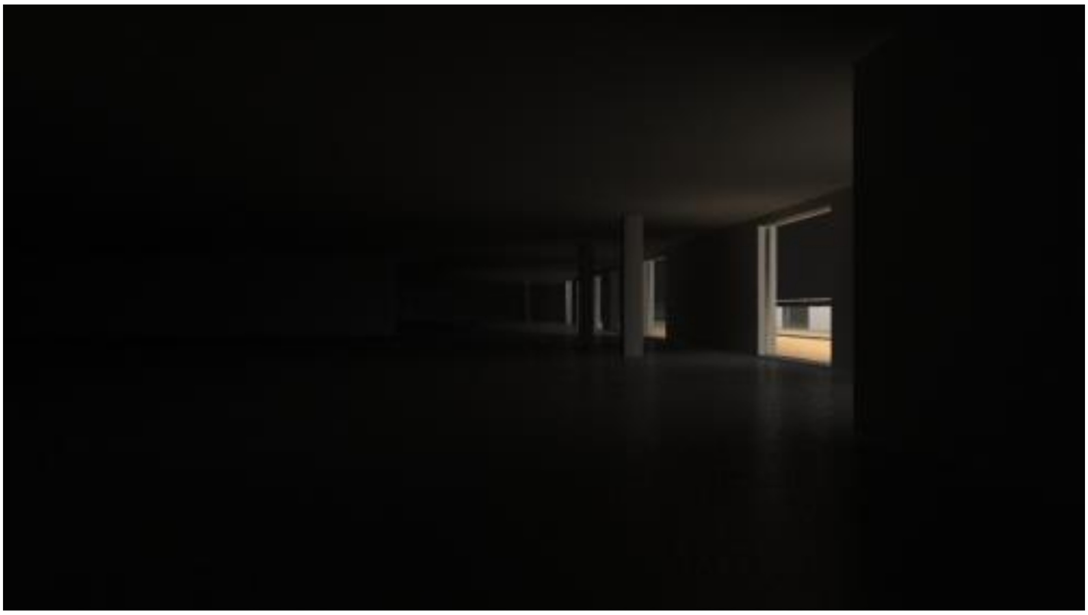

Figure 4.23: Overcast sky perspective point 4 (Rendered by the author.)

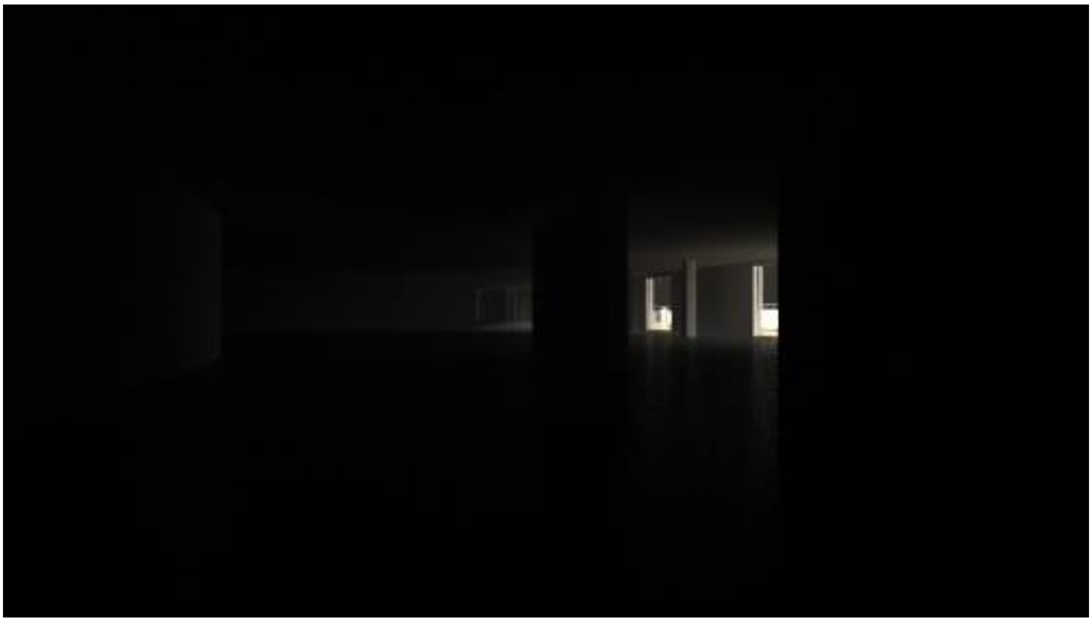

Figure 4.24: Clear sky perspective point 9 (Rendered by the author.)

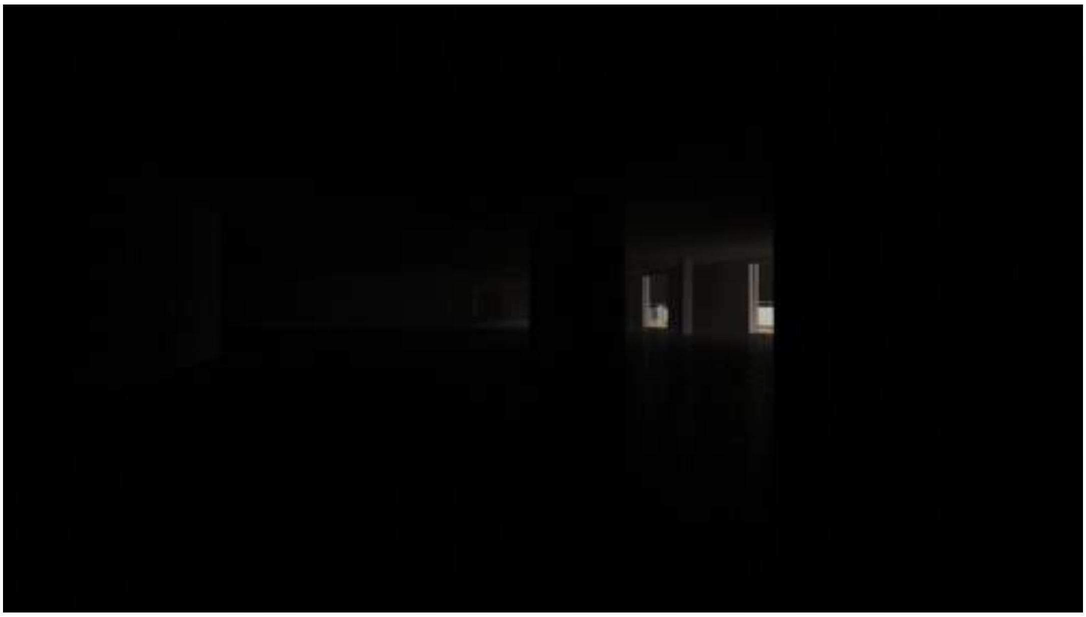

Figure 4.25: Overcast sky perspective point 9 (Rendered by the author.)

For both weather conditions there is a decrease in lux levels from points near the windows to points that are far away from the windows. There is a significant difference between clear sky condition data and overcast sky condition data even if the points of the peak and base value for the lux levels are the same for both conditions. Overcast sky condition data has a lower lux levels for all points compared to clear sky condition as expected by the study. For points 5 and 8 there are rapid increases in lux levels even if they are getting far away from windows because they are at the points where some illumination from different windows are combined and they are not fully blocked by partition walls of İstanbul Modern Art Museum. See Figure 4.26, Figure 4.27, Figure 4.28 and Figure 4.29.

Figure 4.26: Clear sky perspective point 5 (Rendered by the author.)

Figure 4.27: Overcast sky perspective point 5 (Rendered by the author.)

Figure 4.28: Clear sky perspective point 8 (Rendered by the author.)

Figure 4.29: Overcast sky perspective point 8 (Rendered by the author.)

Since there is a decrease in lux levels when the points get far away from windows, the art museum uses more artificial light to provide effective light for visitor visual comfort, which is mentioned in literature part in a detailed manner. Less usage of artificial light near the window openings is beneficial for energy conservation. According to the daylight simulation data; from 10 am to 4 pm there is a decrease in illuminance levels for most of the points (Figure 4.30 and 4.31). See Table 4.8 and 4.9 for detailed data according to daylight values of İstanbul Modern Art Museum for both of the weather conditions. Appendix A gives detailed 3D renders that shows more simulation visual analysis with render for both weather conditions. See also Table 4.8 and Table 4.9 for daylight simulation data for clear sky condition and overcast sky condition.

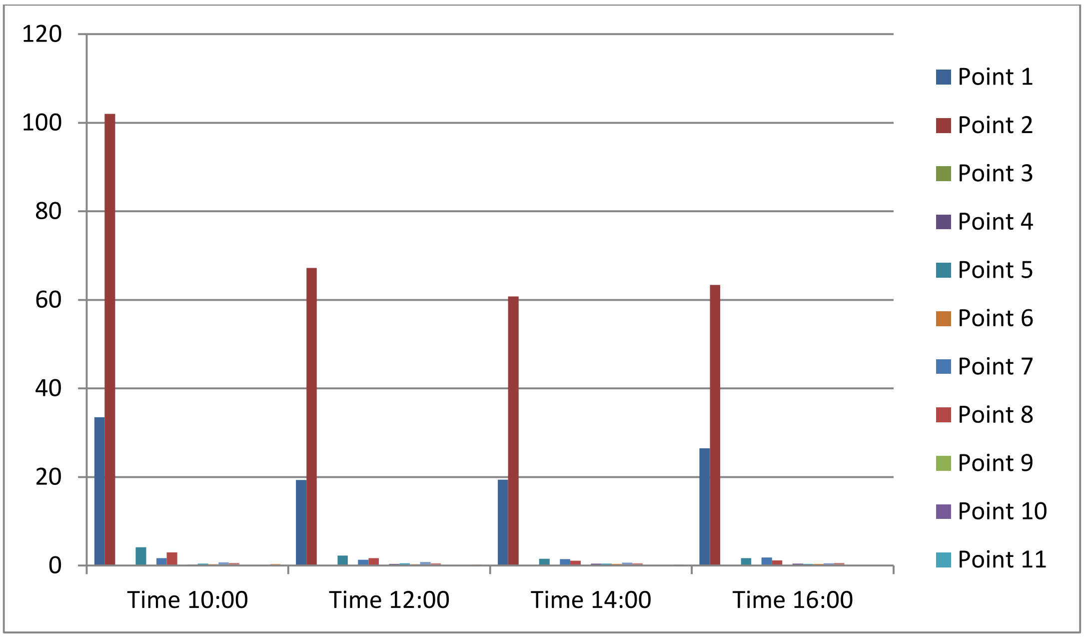

Figure 4.30: Illuminance level diagram in lux unit- clear sky condition (Drawn by the author.)

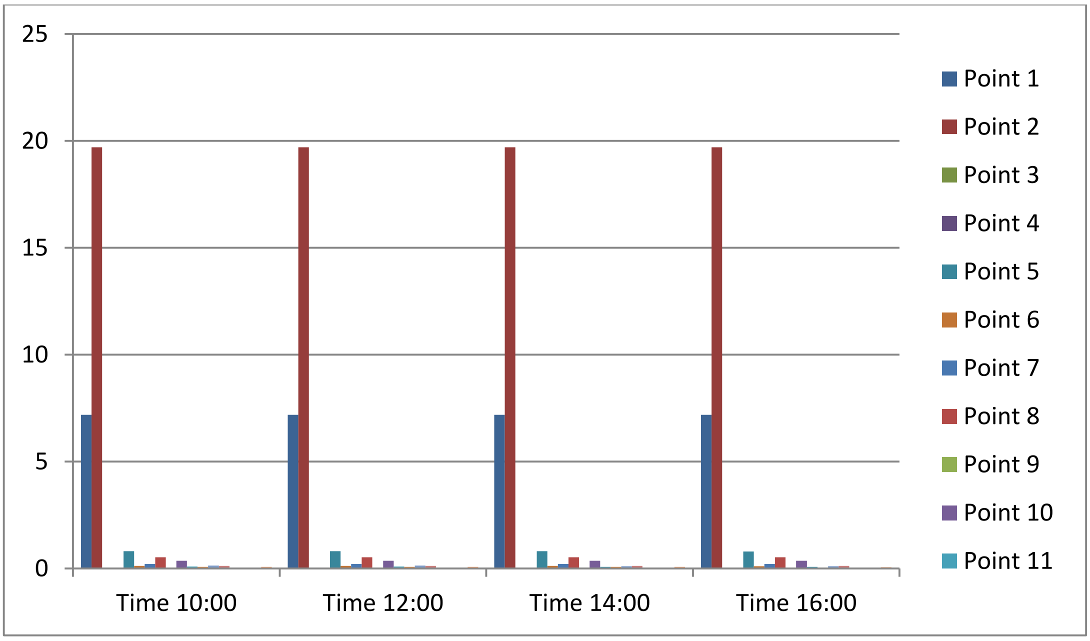

Figure 4.31: Luminance level diagram in lux unit- overcast sky condition (Drawn by the author.)

Table 4.8: Points lux levels according to hours- clear sky condition

	10:00	**12:00**	**14:00**	**16:00**
P1	33.5 lux	19.3 lux	19.4 lux	26.5 lux
P2	102 lux	67.2 lux	60.8 lux	63.4 lux
P3	0.00 lux	0.00 lux	0.00 lux	0.00 lux
P4	0.00 lux	0.00 lux	0.00 lux	0.00 lux
P5	4.15 lux	2.27 lux	1.53 lux	1.65 lux
P6	0.04 lux	0.03 lux	0.03 lux	0.05 lux
P7	1.69 lux	1.30 lux	1.47 lux	1.78 lux
P8	2.94 lux	1.67 lux	1.09 lux	1.17 lux
P9	0.00 lux	0.00 lux	0.00 lux	0.00 lux
P10	0.24 lux	0.35 lux	0.46 lux	0.45 lux
P11	0.46 lux	0.52 lux	0.42 lux	0.36 lux
P12	0.30 lux	0.33 lux	0.37 lux	0.38 lux
P13	0.75 lux	0.78 lux	0.62 lux	0.54 lux
P14	0.57 lux	0.50 lux	0.51 lux	0.57 lux
P15	0.02 lux	0.01 lux	0.01 lux	0.01 lux
P16	0.03 lux	0.02 lux	0.02 lux	0.03 lux
P17	0.12 lux	0.07 lux	0.07 lux	0.10 lux
P18	0.40 lux	0.22 lux	0.20 lux	0.29 lux

(Lux meters are set in eye level.)

Table 4.9: Points lux levels according to hours- overcast sky condition

	10:00	**12:00**	**14:00**	**16:00**
P1	7.18 lux	7.18 lux	7.18 lux	7.18 lux
P2	19.7 lux	19.7 lux	19.7 lux	19.7 lux
P3	0.00 lux	0.00 lux	0.00 lux	0.00 lux
P4	0.00 lux	0.00 lux	0.00 lux	0.00 lux
P5	0.81 lux	0.81 lux	0.81 lux	0.80 lux
P6	0.12 lux	0.12 lux	0.12 lux	0.11 lux
P7	0.21 lux	0.21 lux	0.21 lux	0.20 lux
P8	0.52 lux	0.52 lux	0.52 lux	0.52 lux
P9	0.00 lux	0.00 lux	0.00 lux	0.00 lux
P10	0.36 lux	0.36 lux	0.36 lux	0.36 lux
P11	0.09 lux	0.09 lux	0.07 lux	0.07 lux
P12	0.07 lux	0.07 lux	0.07 lux	0.05 lux
P13	0.13 lux	0.13 lux	0.11 lux	0.11 lux
P14	0.12 lux	0.12 lux	0.12 lux	0.12 lux
P15	0.01 lux	0.01 lux	0.01 lux	0.01 lux
P16	0.01 lux	0.01 lux	0.01 lux	0.01 lux
P17	0.02 lux	0.02 lux	0.02 lux	0.02 lux
P18	0.07 lux	0.07 lux	0.07 lux	0.06 lux

(Lux meters are set in eye level.)

4.4. Discussions

In this research, the effect of daylight design strategies on art museum visual environmental qualities are examined. The questionnaire analyses showed that daylight design strategies enhance the visual environmental qualities and increase the visitor visual comfort and satisfaction within art museums.

The daylight experience of visitors is different in clear sky condition compared to overcast sky condition. It was expected that when the sky condition is clear sky condition and when control strategies and effective daylight design methods are applied the visitor's of the art museum will be more visually comfortable and satisfied. And the visitors will be able to have better museum experience by this way. For overcast sky condition the visitors will be less satisfied with the art museum and they will be less visually comfortable and they will feel the need for control systems and effective daylight design methods for better museum experience and for better visual environmental qualities

Daylight design strategies and control issues are in a relationship with each other and they also contribute to visual comfort and visual environmental quality within art museums. Pearson's Correlation was conducted to test these relationships, and there were either moderate or strong relationships among items related with these daylight items for both weather conditions; clear sky and overcast sky. As stated before, the form of a building is first perceived by the light penetrating from the sun and the sky that is reflected from the building's external surfaces. The aesthetic appearance and emotional sensation of an internal space are influenced by the interplay of light and color (Bougdah & Sharples, 2010). Previously as it was mentioned in the literature review part of the study, daylight design with effective control strategies are significant for art museum visual comfort and they enhance daylight performance of art museums and contribute to energy conservation. Because of these reason; architectural lighting is both an art and a science, requiring an understanding of not only the physical properties of natural and artificial light sources but also the visual effects the lighting will create when introduced into a space (Bougdah & Sharples, 2010).

Another hypothesis was that the view out design elements are significantly related with the overall satisfaction of visitors in art museums. The results support this hypothesis as well. Since daylight is related with the outside environment, there is a link between visual environmental quality and visual connections to outdoors. Obstructions such as buildings or plants can be unfavorable for visual environmental quality of an interior. Moreover, glare caused by outside environment can be crucial. As mentioned in the Results section, there is a moderate correlation between glare caused by outside environment and overall satisfaction of visitors. This result was affected by the attractive location of the selected art museum since it is located near the Marmara Sea with a view of Bosporus and historical spaces like Topkapı Palace and Hagia Sophia Mosque.

In the unstructured part of the questionnaire's Part C, some of the participants also mentioned that they like to be in a connection with the outdoor environment. However, some participants were opposed to the idea even if they enjoy the view of İstanbul Modern Art Museum. The reason for their opposition was because of the attraction of the outside view. They stated that outside view targets their attention to the view and they cannot concentrate on the art museum's exhibitions. This makes them think that there should be some control of the outside view. Moreover in this case, it could be valuable to state that İstanbul Modern Art Museum has windows only in the first floor exhibition zone. Outside view is mostly serving the café area, which is in the first floor as well. On the other hand many of these participants who are in favor of daylight design for conservation of energy, are concerned visitors and they are also very sensitive on art museum environments protection while saving energy through daylight integration to lighting design in art museums.

CHAPTER V

CONCLUSIONS

Art museums are spaces, where people expect high visual comfort levels. Because of this reason, art museums should have a more qualified visual environment compared to other building typologies, since the visual satisfaction directly effects overall satisfaction within the museums.

In this study, to be able to investigate the relationship between daylight design and visual comfort in art museums, Istanbul Modern Museum building was analyzed in terms of daylight design strategies and their correlations to user satisfaction and importance levels. In the literature, it was found that visual comfort is related with many aspects such as; intensity, daylight temperature conditions, glare, shadow, angle, spectrum, transmittance and distribution (Hebert, Arsenault and Dubois, 2012). In the questionnaire part, these components are asked to the participants in terms of satisfaction and importance level rankings and in the simulation part, the real illumance data of the museum are analyzed in 3D rendered models and compared with the obtained findings from the visitor responses.

According to the statistical analyses and simulation analyses, daylight design is a multi-parameter task. There are many significant correlations among visual comfort, prevention of imbalanced daylight distribution, local glare and inadequate daylight intensity in interiors and other correlations among daylight design issues, such as usage of windows and skylights, and control strategies such as filtration of excess light, prevention of glare, reflected light technique and shading devices. This study aims to contribute to the research field on art museums in terms of daylight design satisfaction and sustainable daylight importance. As mentioned in the literature review, sustainability in public spaces is inevitable for energy conservation (Müller & Schuster, 2012). An efficient and sustainable museum building design can fully meet the architectural, functional, comfort, control and safety requirements and also provide radical amounts of energy savings and reduction of carbon dioxide emissions (Sala & Gallo, 2007).

The findings of this research could be used while designing a visual environment for art museums with integration of daylight design features. In addition, this study could be beneficial for interior architects and architects to satisfy art museum visitors visually and create sustainable future through sustainable buildings.

According to this study's findings of statistical analysis and simulation analysis there might be some guidelines that can be used for art museum daylight design. These guideline could be as follows:

(i) Using control strategies is a key point to prevent deterioration of art museum objects while utilizing from daylight. Daylight design elements like using windows and skylights with their size and location design, should be combined with control strategies like shading systems, filtration of daylight and reflected daylight techniques.

(ii) Prevention of glare from openings such as; windows and skylights is a crucial aspect for visual comfort issues. Glare from neighboring buildings surfaces or location settings (sea, lake etc.) near the buildings should also be considered for effective design.

(iii) For enhanced visual environmental qualities, imbalanced daylight distribution and high contrast zones should be monitored, because of eye adaptation issue which is a significant issue related with visual comfort as stated within the scope of this study.

(iv) There should be homogeneous distribution of daylight on the wall surfaces of the art museum for efficient visual comfort and enhanced museum experiences.

(v) A daylight design for art museum should consider outside view and neighboring structures. A design with controlled outside view can motivate visitors and enhance their art museum experience. However, outside view should not be considered as a main element of design since the priority is in the exhibited objects of art museums.

(vi) Through the effective daylight design art museum visitors should be able to benefit from visual environmental qualities such as effective color rendering qualities and prevention of glare with enhanced eye adaptation to light levels within interiors.

(vii) Art museum building elements such as windows, skylights other structural elements should be considered for effective daylight availability for interior spaces for daylight intake.

The limitation of this study is that it is based on a limited number of participants. As a future research, more participants could be participated to the survey. Moreover, the participants of the study were mostly high school and university students that might be influential on the results based on user data. As a further study, it could be more diverse participants with different age and education levels.

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APPENDICES

APPENDIX A

Figure A.1: Clear sky perspective point 6 (Rendered by the author.)

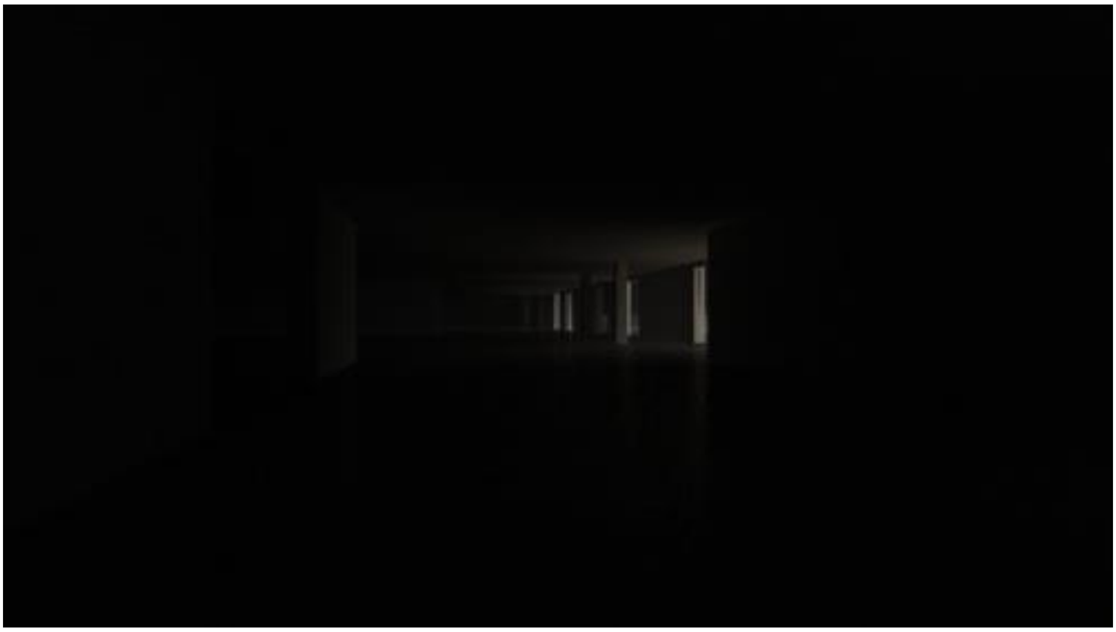

Figure A.2: Overcast sky perspective point 6 (Rendered by the author.)

Figure A.3: Clear sky perspective point 7 (Rendered by the author.)

Figure A.4: Overcast sky ğerspective point 7 (Rendered by the author.)

Figure A.5: Clear sky perspective point 10 (Rendered by the author.)

Figure A.6: Overcast sky perspective point 10 (Rendered by the author.)

Figure A.7: Clear sky perspective point 11 (Rendered by the author.)

Figure A.8: Overcast sky perspective point 11 (Rendered by the author.)

Figure A.9: Clear sky perspective point 12 (Rendered by the author.)

Figure A.10: Overcast sky perspective point 12 (Rendered by the author.)

Figure A.11: Clear sky perspective point 13 (Rendered by the author.)

Figure A.12: Overcast sky perspective point 13 (Rendered by the author.)

Figure A.13: Clear sky perspective point 14 (Rendered by the author.)

Figure A.14: Overcast sky perspective point 14 (Rendered by the author.)

Figure A.15: Clear sky perspective point 15 (Rendered by the author.)

Figure A.16: Overcast sky perspective point 15 (Rendered by the author.)

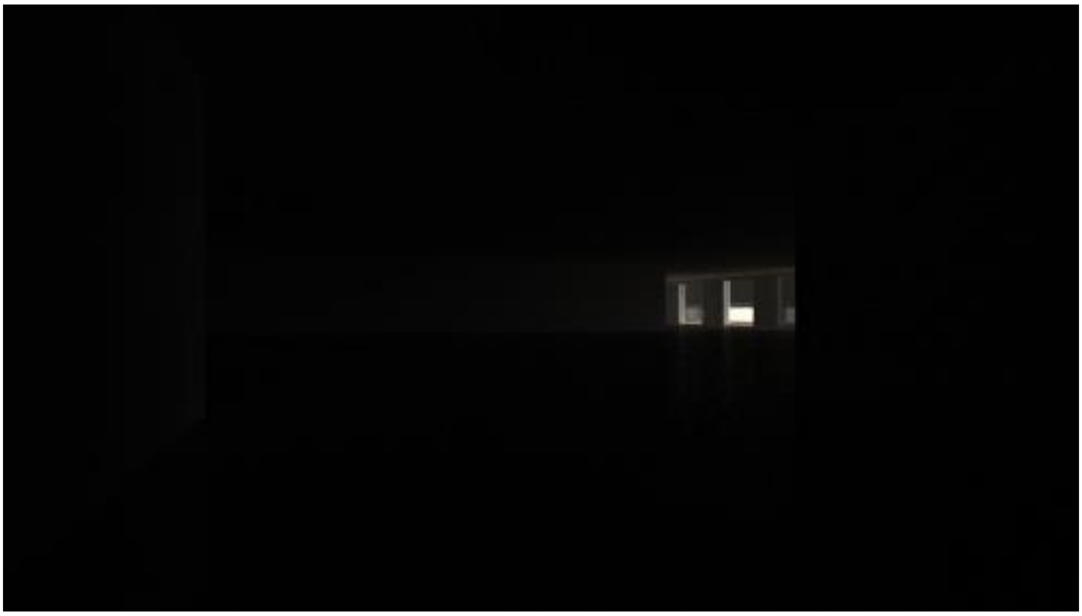

Figure A.17: Clear sky perspective point 16 (Rendered by the author.)

Figure A.18: Overcast sky perspective point 16 (Rendered by the author.)

Figure A.19: Clear sky perspective point 17 (Rendered by the author.)

Figure A.20: Overcast sky perspective point 17 (Rendered by the author.)

Figure A.21: Clear sky perspective point 18 (Rendered by the author.)

Figure A.22: Overcast sky perspective point 18 (Rendered by the author.)

APPENDIX B

QUESTIONNAIRE

Bilkent Üniversitesi *Interior Architecture and Environmental Design Department*

The Effects of Daylight Design Features on Art Museum's Visual Environmental Quality and its Visitor's Visual Comfort

Note: Duration: approx. 3 minutes.

A. Demographics

			Male (Bay)	Female (Bayan)
A1	Gender	*Cinsiyet*	☐	☐

			21-35	36-50	51-65	65+
2	Age group	*Yaş*	☐	☐	☐	☐

			2+ /week (hafta)	1 /week (hafta)	2+ /month (ay)	1 /month (ay)	Less (daha az)
3	Visit frequency*	*Ziyaretlerin Sıklığı*	☐	☐	☐	☐	☐

			High School (Lise)	University (Üniversite)	Graduate (Yüksek Lisans)	Post Graduate (Doktora)
4	Education level	*Eğitim Düzeyi*	☐	☐	☐	☐

B. Overall Ranking – Below are listed components of **daylight** and **daylight design**. Please select the levels of these components effects on your experiences and visual comfort within Istanbul Modern Art Museum. *(Aşağıda **günışığına** ve **günışığı tasarımına** bağlı unsurlar listelenmiştir. Lütfen bu unsurların sizin İstanbul Modern Sanat Müzesindeki deneyiminize ve görsel konforunuza etkilerinin derecelerini işaretleyiniz.)*

	1.Very Poor (Çok zayıf)	3.Poor (Zayıf)	3.Neutral (Nötr)	4.Good (İyi)	5.Excellent (Çok iyi)
B1 – **Daylight Availability In Museums Interior Space** *Günışığının Müze İçerisindeki Kullanılabilirlik Durumu*	☐	☐	☐	☐	☐
2 – **Controlled Daylight Intake** *Günışığının Müze İçerisine Kontrollü Alımı*	☐	☐	☐	☐	☐
3 – **Size and Division of Windows** *Pencerelerin Büyük Oluşu ve Konumlandırılması*	☐	☐	☐	☐	☐
4 – **Visual Connections to Outdoors** *Dış Mekân ile Görsel Bağlantı*	☐	☐	☐	☐	☐
5 –**Prevention of Glare from Windows** *Pencerelerden Yansıyan Işığın Yaptığı Parlamanın Engellenmesi*	☐	☐	☐	☐	☐
6 – **Prevention of Glare from Sea and Neighboring Building Structures** *Deniz ve Komşu Bina Yapılarından Kaynaklanan Parlamanın Engellenmesi*	☐	☐	☐	☐	☐

7- **Color Rendering of Surfaces** *Yüzeylerin Renksel Efektleri ve Renksel Geriverimleri*	☐	☐	☐	☐	☐
8 – **Filtration of Excess Light Exposure (UV, Infrared…)** *Aşırı Günışığına Maruz Kalıma Karşı Filtreleme*	☐	☐	☐	☐	☐
9 –**Homogeneous Distribution of Daylight on the Wall Surfaces** *Günışığın Duvar Yüzeylerinde Homojen Dağılma Durumu*	☐	☐	☐	☐	☐
10 – **Thermal Comfort Conditions Depending on Daylight** *Günışığına Bağlı Müze İçerisindeki Isıl Konfor Koşulu*	☐	☐	☐	☐	☐

C. Importance Level - Below are listed components of **daylight** and **daylight design**. Please select the importance level for each component for art museums in general. Please consider that artificial light also exists in museum interiors.
(*Aşağıda* ***günışığına*** *ve* ***günışığı tasarımına*** *bağlı unsurlar listelenmiştir. Lütfen bu unsurların size göre önem derecelerini işaretleyiniz. Bu bölüm genel olarak tüm sanat müzeleri için geçerlidir. Lütfen aynı zamanda yapay aydınlatma elemanlarının da kullanıldığını göz önünde bulundurunuz.*)

		1.Not Important (Önemli Değil)	2.Slightly Important (Az Önemli)	3.Neutral (Nötr)	4.Important (Önemli)	5.Very Important (Çok Önemli)
C1	**Windows** *Pencereler*	☐	☐	☐	☐	☐
2	**Skylights** *Tavan Pencereleri*	☐	☐	☐	☐	☐
3	**Shading Systems(Interior & Exterior)** *Gölgelendirme Sistemleri (İç & Dış)*	☐	☐	☐	☐	☐
4	**Reflected Light Techniques (Light Shelves)** *Işığı Yansıtma Teknikleri (Işık Rafları*)	☐	☐	☐	☐	☐
5	**Visual Comfort for Daylight** *Günışığı Görsel Konforu*					
a)	**Prevention of Imbalanced Daylight Distribution** *Günışığı Dağılım Dengesizliğinin Engellenmesi*	☐	☐	☐	☐	☐
b)	**Prevention of Local Glare**	☐	☐	☐	☐	☐

	Lokal Parlamanın Engellenmesi					
c)	**Prevention of High Contrast Illuminated Zones** *Günışığı Açısından Tezat Olan Bölgelerin Engellenmesi*	☐	☐	☐	☐	☐
d)	**Prevention of Inadequate Daylight Intensity In Interior Space** *İç Mekânda Günışığı Şiddetinin Nitelik Olarak Yetersizliği*	☐	☐	☐	☐	☐
6	**Visual Connection to Outdoors** *Dışarısı ile Görsel Bağlantı*	☐	☐	☐	☐	☐
7	**Neighboring Building Surfaces and Visual Obstructions** *Bina Çevresindeki Yapılar ve Görsel Engeller*	☐	☐	☐	☐	☐
8	**Energy Conservation and Sustainability** *Enerji Tasarrufu ve Sürdürülebilirlik*	☐	☐	☐	☐	☐
x	**Anything else you want to add?** *Size göre, diğer önemli şeyler var mı?*					