

**BAŞKENT UNIVERSITY  
INSTITUTE OF SCIENCE  
DEPARTMENT OF ARCHITECTURE  
MASTER OF SCIENCE IN ARCHITECTURE**

**ARTIFICIAL LIGHTING AND VISUAL PERCEPTION OF EXHIBITED  
OBJECTS IN MUSEUMS**

**BY**

**RASUDANA BAGHIRZADE**

**MASTER OF SCIENCE THESIS**

**ANKARA - 2024**



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**ADVISOR**

**PROF. CÜNEYT KURTAY**

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**BAŞKENT UNIVERSITY**  
**INSTITUTE OF SCIENCE**

This study, which was prepared by Rasudana Baghirzade, for the program of Materis of Architecture with thesis, has been approved in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Department of Architecture by the following committee.

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**Examining Comitee Members**

**Signature**

Prof. Cüneyt KURTAY (Advisor), Baskent University

.....

Assoc. Prof. Aysu SAGUN KENTEL, Baskent University

.....

Assoc. Prof. Zeynep Yeşim İLERİSOY, Gazi University

.....

**APPROVAL**

Prof. Dr. Dilek ÇÖKELİLER SERDAROĞLU

Directore, Institute of Science

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Öğrencinin Numarası: 22210615

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# ABSTRACT

**Rasudana BAGHIRZADE**

## **ARTIFICIAL LIGHTING AND VISUAL PERCEPTION OF EXHIBITED OBJECTS IN MUSEUMS**

**Başkent University Institute of Science**

**Department of Architecture**

**2024**

The primary factors which affect the exhibited objects in museums are the intensity and type of artificial lighting, color, the distance between the light source and the artwork, and external factors like sound, odor etc. Within the scope of this thesis, the impact of visual perception and artificial lighting in museums is the focus of study. The Abdürrahim TUNCAK Atatürk House Museum at Baskent University campus is selected as a case study. The aim of this study is to analyze the artificial lighting and visual perception of four exhibition rooms of Abdürrahim TUNCAK Atatürk House Museum and propose an alternative model to achieve optimum conditions. A digital lux meter is used to measure light levels that displayed objects are exposed to, and by considering 6 design strategies, new models are proposed using artificial lighting, modelling and rendering software – DIALux. Maximizing visitors' focus of attention and visibility of displayed objects, minimizing glare, achieving recommended light level, and categorizing artifacts according to their related concepts and susceptibility to light, are the main suggested design strategies during the design phase of the study. Finally, a guideline with 6 design outcomes is prepared, followed by mentioning possible research for future studies.

**KEYWORDS:** artificial lighting in museums, visual perception, light level, susceptibility to light

# ÖZET

**Rasudana BAGHIRZADE**

**MÜZELERDE SERGİLENEN NESNELERİN YAPAY AYDINLATMA VE GÖRSEL ALGILAMASI**

**Başkent Üniversitesi Fen Bilimleri Enstitüsü**

**Mimarlık Anabilim Dalı**

**2024**

Müzelere sergilenen nesnelere algılanmasını etkileyen başlıca faktörler yapay aydınlatmanın şiddeti ve türü, renk, ışık kaynağı ile eser arasındaki mesafe, ses/gürültü, kokudur. Bu tez kapsamında, müzelerdeki görsel algı ve yapay aydınlatmanın etkisi araştırma konusu olarak ele alınmıştır. Başkent Üniversitesi kampüsünde yer alan Abdürrahim TUNCAK Atatürk Evi Müzesi, örnek çalışma olarak seçilmiştir. Çalışmanın amacı, Abdürrahim TUNCAK Atatürk Evi Müzesi'nin dört sergi odasındaki yapay aydınlatmayı ve görsel algıyı analiz etmek ve ideal koşullara ulaşmak için alternatif bir model önermektir. Sergilenen nesnelere maruz kaldığı ışık seviyelerini ölçmek için dijital bir lüksmetre kullanılmış ve altı tasarım stratejisi dikkate alınarak DIALux adlı yapay aydınlatma, modelleme ve render yazılımı kullanılarak yeni modeller önerilmiştir. Tasarım aşamasında ziyaretçilerin dikkatini ve sergilenen nesnelere görünürlüğünü maksimize etmek, kamaşmayı en aza indirmek, önerilen ışık seviyesine ulaşmak ve nesnelere ilgili kavramlarına ve ışığa duyarlılıklarına göre kategorize etmek için ana tasarım stratejileri tavsiye edilmiştir. Son olarak, altı tasarım sonucuyla bir kılavuz hazırlanmış ve gelecekteki çalışmalar için olası araştırma konuları önerilmiştir.

**ANAHTAR KELİMELELER:** müzelerde yapay aydınlatma, görsel algılama, aydınlatma seviyesi, ışığa duyarlılık

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## LIST OF ABBREVIATIONS AND TERMINOLOGIES

CIE	International Commission on Illumination (Commission internationale de l'éclairage)
Efficacy	Measure of how much light a light source produces for the energy put in to it.
IESNA	Illuminating Engineering Society of North America
Illuminance	Total luminous flux incident on a surface, per unit area
Luminous flux	Measure of the power of visible light produced by a light source

# 1. INTRODUCTION

Traditional museums and art exhibitions are the public places which demonstrate the culture of the country where it is located while also giving information about the styles and traditions of native people in visual terms. Modern museums, on the other hand, can address a greater mass of people. The concept of general contemporary museum reflects a dynamic and multidimensional nature, characterized by an amalgamation of traditional preservation, curation, and exhibition practices, alongside a burgeoning emphasis on community engagement, interactive technologies, and interdisciplinary approaches, thereby facilitating diverse narratives, fostering inclusivity, and encouraging active visitor participation. While each type of museum has its own theme by exhibiting artworks with the purpose of giving certain messages, some factors affect the way visitors perceive these exhibits. Lighting design: both natural and artificial light, lighting color, exhibited object color, wall color as well as other environmental factors such as soundscape and odor of the surrounding are among the main variables that impact the human perception in museums and exhibitions.

## The scope of the study

There are several issues which affect both exhibited objects and human visual perception. The intensity of light, the type of luminaire, the distance between the light source and the artwork are the main determinants which highly influence the deterioration period of the object. In this context, the type of object material is a significant variable. Achieving a safe lighting design for the work of arts and keeping the visual comfort and visitor experience for optimum human perception at the maximum level, simultaneously, is a challenging task. By detecting the main priority level of the museums considering its theme and related concept, followed by designing the variables of the exhibit, accordingly, is one alternative of obtaining this balance.

## The purpose of the study

The purpose of this study is to analyze artificial lighting and color usage in museums, and its effect on human perception. This is followed by proposing an alternative model to achieve optimum conditions in 6 design outcomes.

## The methodology of the study

The methodology of the study is divided into two phases: theoretical and design phase. In the theoretical phase, various sources are researched to gather thorough information about human psychology, museology, and the link between them. This includes the general factors affecting human cognition i.e., light, color, sound, odor, specific standards of lighting and color in the context of museums and galleries. By paying attention to the facts researched in the theoretical phase, several museums are visited in the practical phase. The main aim of visiting the museums is to select the one which is the most open to improvement. This is followed by making corresponding measurements and calculations to suggest alternative models. The artificial lighting, display techniques and user experience of four exhibition rooms on 2<sup>nd</sup> floor of the selected museums are enhanced based on 6 topics. The research process of the study is summarized in the flow chart in Figure 1.1.

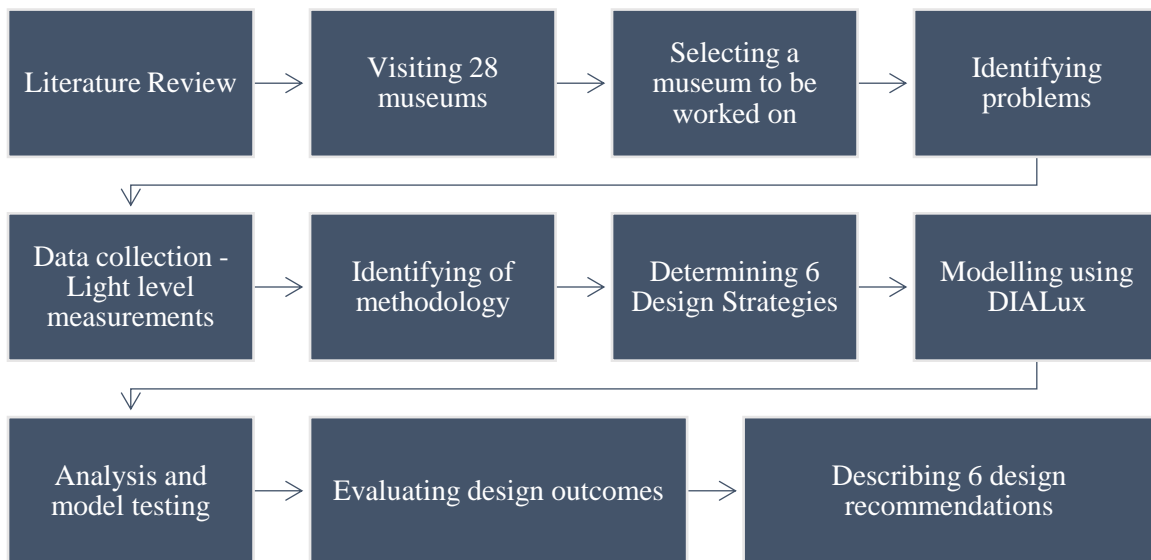


Figure 1.1. Flow chart describing research process

## Literature review

To develop a comprehensive understanding about the topic, identify relevant theories, concepts, methodologies, and gaps in the field of museology, a literature review was carried out. This process not only helped avoiding a duplication of efforts but also establishing the theoretical framework and context for the thesis, ensuring that the research contributes to the existing scholarly discourse. Theoretical information about standards and guidelines, as well as psychological aspects and factors affecting human perception is gathered from indexed sources, from journal articles, books, book sections and other thesis studies.

One of the significant sources for gathering standards and guidelines data is the book called *Human Factors in Lighting* by Peter Robert Boyce. The fundamentals of lighting, how certain lighting standards are dealt with in various public places etc. are detailly explained in the book. Chapters 1, 4, 5 and 6 are used to gather the essential information for the theoretical framework. The names of the chapters are *Light*, *Lighting and Work*, *Lighting and Visual Discomfort*, *Lighting and the perception of spaces and objects*, respectively.

Another valuable source is the ninth edition of the IESNA (Illuminating Engineering Society of North America) *Lighting Handbook*. It is prepared and published by the IESNA in 2000. In Chapter 14, *Lighting for Public Places and Institutions*, design guidelines are explained. These are supported with tables of demonstrating standards as a result of certain calculations. The handbook also gives information about different types of exhibition techniques, which have explanatory diagrams showing required locations of luminaires with necessary angle.

The book named *Lighting Design Basics* written by Mark Karlen and James R. Benya is published by John Wiley & Sons, Inc. in 2004. This book aims to serve as a guide for acquiring the essential knowledge and abilities to address lighting design challenges in common rooms and spaces. It emphasizes the technical aspect of design to formulate a lighting concept and strategically choose and position light fixtures to attain the intended outcomes. It gives technical information about the types of lamps and luminaires, as well as methods of lighting distribution.

In the booklet, named *Good Lighting for Museums, Galleries and Exhibitions'18* is published by Fördergemein-schaft Gutes Licht (FGL) (Funding Association for Good Light) to provide information on good artificial lighting. In the booklet specifics of lamps and luminaire

types are mentioned as well as standards of lighting used in exhibitions and museums, which are also supported by visual examples. This knowledge is used to shape Section 3 of the thesis. The quantitative sections of the booklet are referenced from international standards which makes the source reliable.

As for the information about psychological aspects and factors affecting human perception, a master's thesis from University of Washington in 2017, *Is Wall Color Significant to Museum Visitors? Exploring the Impact Wall Color in an Exhibit has on the Visitor Experience* by Amy Elizabeth Gorton proposes useful information about museology. The paper focuses more on the wall color without considering features of lighting and their effects of lighting on exhibited objects as well as human perception. Additionally, in this thesis, the influential factors that impact human perception within museum and art exhibition settings, consequently shaping their overall experiences will be analyzed, which are absent in the articles and relatable thesis examples that have been researched. Furthermore, the study endeavors to propose alternative models aimed at attaining optimal conditions in such contexts.

A research article called *Psychology of Light: How Light Influences the Health and Psyche* written by Rosella Tomassoni, Giuseppe Galetta, Eugenia Treglia, and published in the *Journal of Psychology* by Scientific Research Publishing in 2015, examines light through a psychological lens, exploring how emotions and behaviors are influenced by light and how individuals perceive and respond to illuminated environments in various experiential situations.

Another article within the literature review, is called *What is Museum Fatigue?* By Gareth Davey is published in *Journal of Visitor Studies Today* in 2005. It describes study results which show behavioral changes of people during their museum visits. The significance of different environmental factors impacting visitors' behaviors, and thus the effect of this on their perception is discussed in the paper.

All the information gathered is used to examine and pay attention to the specific factors during museum visits. Guidelines and standards helped to comply with minimum and maximum requirements such as reports by IESNA, while data on psychological aspects allowed to focus on the visual perception and behavioral point of view. Distinctly from the mentioned studies in the literature review, in this thesis, a museum which does not coordinate with the standards is selected.

## Visited Museums

During the practical phase of the study, 28 museums are visited in total. Among them 20 museums are in Ankara, 5 of them are in Eskisehir, and 3 of them are in Turkish Republic of Northern Cyprus (T.R.N.C.). The properties of visited museums are compared with each other and the one which is the most open to improvement – The Abdürrahim Tuncak Atatürk House – is selected to be worked on. Below, Table 1.1 **Error! Reference source not found.** demonstrates the list of all visited museums.

Table 1.1. The list of visited museums

VISITED MUSEUMS			
#	Ankara, Turkey	Eskisehir, Turkey	T.R.N.C.
1.	Abdürrahim Tuncak Atatürk House	Museum of Woodworking	Car Museum
2.	Ankara Art and Sculpture Museum	Museum of Modern Glass Art	Shipwreck Museum
3.	Ankara University Toy Museum	Liberation Museum	Günsel Art Gallery
4.	Ankara Foundation Works Museum	Meerschaum Museum	
5.	Doğan Taşdelen Contemporary Arts Center	O.M.M.	
6.	Cin Ali Museum		
7.	Erimtan Archaeology and Art Museum		
8.	Gökyay Foundation Chess Museum		
9.	Keçiören Municipality Ethnography Museum		
10.	Museum of Words		
11.	Museum of Anatolian Civilization		
12.	Kuğulu Art Gallery		
13.	MTA Şehit Cuma Dağ Natural History Museum		
14.	Mustafa Ayaz Museum and Plastic Arts Center		
15.	Polis Museum		
16.	PTT Stamp Museum		
17.	Museums of Rahmi M. Koç		
18.	TRT Museum of Broadcasting History		
19.	The Museum of Turkish Bar Association		
20.	Ankara University Veterinary Anatomy Museum		

The propositions are made using artificial lighting design, modelling, and rendering software, DIALux. The analysis procedure is achieved by obtaining required drawings of the building: plans and sections of the selected museum from authorities, which help to create 3D modelling and to compare existing and proposed models.

DIALux is a software used to create, analyze and visualize lighting plans. It has a user-friendly interface which allows 3D modelling (with appropriate openings for windows and door), material applications and rendering, as well as luminaire selection (Figure 1.2). The most practical feature of DIALux is that it enables users both to install the desired luminaire model from its built-in light fixture catalogue or from external sources, and to adjust any properties of that luminaire, such as color temperature, luminance power, the angle between the light source and the mounted surface (Figure 1.3). To add to that, the software can also measure the light level exposed to an adjustable working plane. After adjusting the color temperature, or illuminance level of the luminaire, the software practically re-measures the light levels in lux (Figure 1.4). The flexibility of its usage allowed DIALux software to be selected in the study.

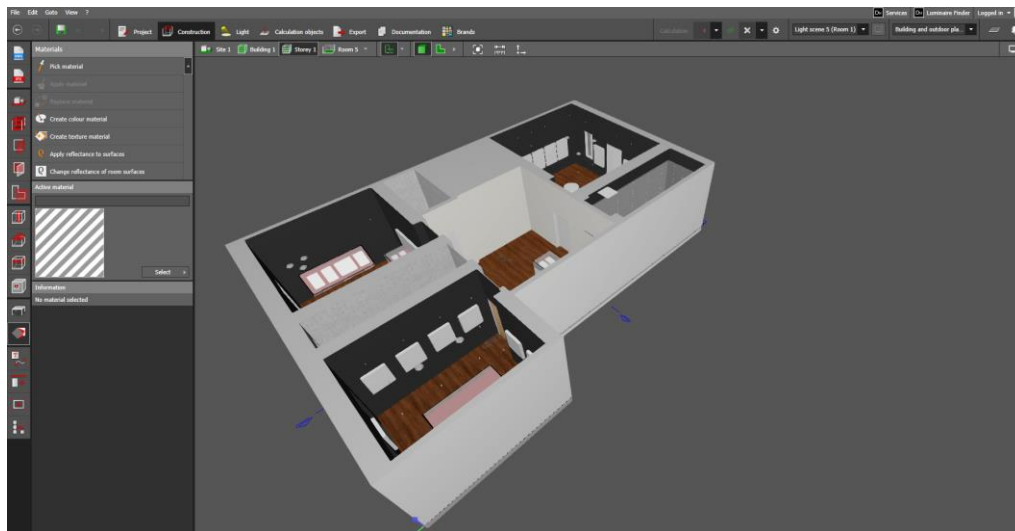


Figure 1.2. The user interface of the software DIALux

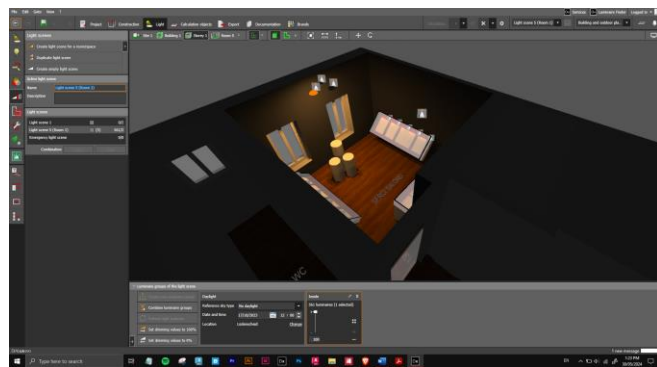
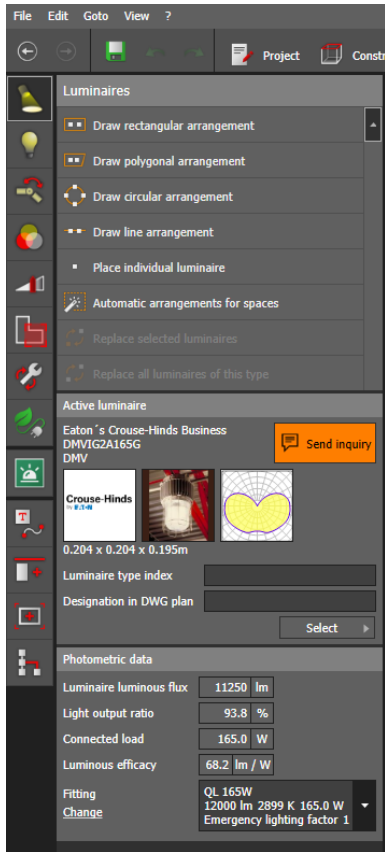


Figure 1.3. The adjustment of luminaire window in DIALux

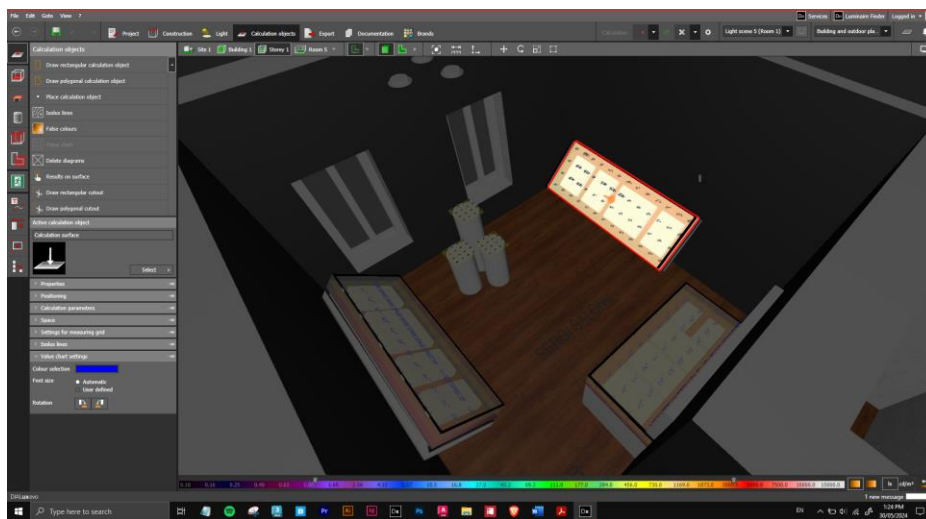


Figure 1.4. Calculation of light level measurement window in DIALux

## **2. FACTORS AFFECTING HUMAN PERCEPTION IN MUESUMS AND MANAGEMENT OF THESE FACTORS**

Human perception is the process in which human beings interpret and understand the world around them via their senses, which are sight, hearing, taste, smell, and touch. In other words, the perception is how the brain receives, reacts, and defines the sensory information from its surroundings, and demonstrates it in a physical manner. Given the fact that several different senses allow us to perceive things around us, it can be said that human perception depends on external factors, such as color, light, and other environmental circumstances (noise/sound level, temperature, smell/odor of the surrounding). To add to that, achieving visitors' perfect perception in museums and exhibitions is a challenging task. In this section, general effects of artificial lighting, color, and environmental circumstances impacting human perception, and each of their impact on visiting time period and visual comfort in museums are mentioned. This is followed by suggesting possible measures which can minimize any discomfort and enhance focal attention of visitors. The effects of environmental factors on human perception in museums are beside the point of main study focus on this thesis.

### **2.1. General Effects of Artificial Lighting**

Both artificial lighting and daylighting are the main necessity in an individual's everyday life routine. According to Tomassoni et al., [1], apart from being perceptually effective, light also has an influence in terms of cognitive, sensitive, and behavioral reactions in various everyday contexts. Moreover, the human brain can be manipulated by different light techniques which includes the opposite of light, dark or shadow. The absence of light, when focusing the emptiness or fullness, affects the environment in such a way that it can alter the whole context as well as focus of attention.

As for emotion and cognitive point of view, light reinvigorates disparate set of emotions. For instance, while flashing light evokes danger, nervousness, and aggressiveness; constant light has a calmer and smoothing effect. As Lam [2] stated, regardless of the source of environmental information - be it a home, workplace, urban area, store, building interior, museum, or art gallery

- light consistently guides our visual system in deciphering the meaning of that information. Essentially, it can be said that the way humans perceive light shapes the world around them. Critical, in this sense, light becomes an influential mechanism on object's aesthetic quality when it is exposed to a light source. The specialized cortex in our brain has indicated that the electrical signals generated by photoreceptor neurons, which scan light photons, dictate the aesthetic quality of the reality we perceive. This demonstrates a link between perceptual processes and the visual brain [1].

Given these facts, human psychology is closely connected with lighting. Keeping in mind that people can comprehend objects in a space only when light is perceived, and reflected by it, light greatly influences the environmental sense which people experience. Therefore, lighting not only impacts human perception but also indirectly affects other factors that human perception is dependent on, by influencing the environmental circumstances people encounter.

### The Impact of Artificial Lighting on Visiting Time Period and Visual Comfort

Artificial light is a type of lighting that is created by humans and can emit light from various sources such as LED lamps, halogen lamps, tungsten filament lamps, filament lamps etc. In one way, lighting has the potential to improve indoor environmental quality and enhance visitors' experience. However, in certain situations, lighting, especially in places such as museums and art exhibitions, can damage exhibited objects when they are exposed for a long time. Apart from the damaging factors and related protection measures of artificial lighting, poor arrangement of lighting design also causes visual discomfort. Visual discomfort occurs when the level of brightness is insufficient or when there are minimal variations in brightness, creating an unpleasant lighting environment. Excessive differences in brightness strain the eyes due to the constant need for readjustment, while excessively bright areas cause glare, further hindering visual comfort [3]. Luminance (L) refers to the perceived brightness of a luminous or illuminated surface as observed by the human eye. It is quantified in candelas per unit area ( $\text{cd}/\text{m}^2$ ). The distribution of luminance across the visual field plays a critical role in visual performance because it determines the state of adaptation of the eye. According to FGL [3], higher luminance levels are associated with improved visual acuity, contrast sensitivity, and overall performance of ocular functions. In the context of an exhibition, to increase the visual

performance the exhibit areas are often more illuminated than their surroundings. However, in some cases, higher luminance causes visual impairment as well as deterioration of artwork. Therefore, for the protection of materials against artificial lighting, there are certain artificial lighting standards, lighting management techniques as well as recommended types of lamps and luminaires used in museums and exhibitions.

## **2.2. General Effects of Color**

The experience of color is a prominent aspect of our psychology, influencing numerous aspects of human cognition and behavior, including basic vision, recognizing objects and scenes, aesthetics, and communication. According to their claims, in human perception, there is a direct correlation between color and psychological functioning [4]. The wavelength of light that is reflected or emitted from surfaces as well as objects around us enables our visual system to build up a perceptual experience. These experiences serve as a crucial indicator in distinguishing between similar objects. Gegenfurtner and Rieger [5] believe that color plays a crucial role in fundamental vision as it serves as a significant indication. It assists in the perception and understanding of objects by acting as a helpful hint.

The impact of color which evokes our psychology is affected by the culture and environment people are exposed to. Different colors have different wavelengths, and human eyes can distinguish the wavelengths as the differences the colors. People can only see colors of light in the range of visible spectrum. Warm colors have longer wavelengths, while cold colors have shorter ones. It is universally accepted that warm colors such as red, yellow, and orange (colors with longer wavelengths) stimulate positive feelings such as love, excitement, warmth, romance, happiness, joy etc. Whereas cold colors (colors with shorter wavelengths) such as green, blue, and violet recall calmer memories such as tranquility, freshness, freedom, nature, mystery, in people's perception. To add to that, bold, aggressive, danger, courageous, cheerful, friendly, and confident feelings are also represented by red, yellow, and orange colors; green, blue, and violet colors represent balance, harmony, health, trustworthiness, and creativity [5]. This is illustrated in the Figure 2.1. Considering that colors have a fundamental effect on human psychology and perception, wavelengths of colors impact the performance of people achieving both simple and complex tasks.

<p>LOVE EXCITEMENT PASSION WARMTH RAGE AGGRESSION</p>	<p>HEALTH HAPPINESS FUN ENERGETIC DESOLATION</p>	<p>OPTIMISM WARMTH JOY DANGER</p>
<p>TRANQUILITY FRESHNESS FREEDOM COLD SADNESS DEPRESSION</p>	<p>MYSTERY FUTURE MAGIC ILLUSION ROYALTY</p>	<p>NATURE GROWTH HOPE LIFE HARMONY</p>

Figure 2.1. Colors and Meanings [5]

A further significant effect of color on human perception results from the impact of it on mood changes. It is believed that object color not only carries different meaning to everyone, but it also influences the cognition, and thus behavior of people to others [4]. The reason for this might come from the fact that color is usually used to describe things, such as street labels, people's looks, buildings etc. Since it enables us to communicate in an efficient way, encountering the color we have used to describe certain things has the possibility to awaken specific memories from our subconsciousness. Therefore, colors used in museums and exhibition spaces have a great influence on how we perceive exhibited works, which in turn can affect the staying time, comfort as well as the focus of attention on artworks.

Apart from light influencing emotions, the color of light, in which each light color has different temperatures expressed in Kelvin (K) does also impact both bio-psychological and neuropsychological levels, such as psychological mood, hormonal activity, body temperature etc. [6]. The color temperature diagram is shown in Figure 2.2 [7]. Since light color affects the psychological mood of people, correct selection of it in public spaces plays a significant role. For example, to create a relaxed environment calmer and warmer light colors, such as light green, light blue, are suggested to be used in waiting lounges in places like airports, hospitals, clinics etc. What is more, according to Tiller [8], in a competitive or production-oriented environment, like an office or a boxing ring, where the emphasis is on dynamic production rates,

the use of high lighting and colder chromatic temperatures can lead to increased work efficiency and productivity, as well as greater aggression and competition.

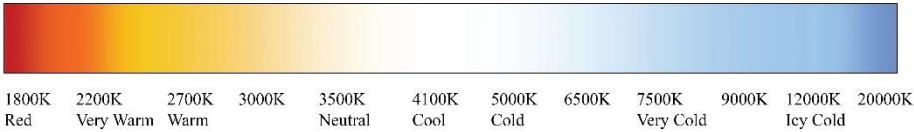


Figure 2.2. Color Temperature in Kelvin [7]

The Impact of Color on Visiting Time Period and Visual Comfort

Humans typically obtain 80% of their information from the surrounding environment. Considering that color is always present in our environment, it can be mentioned that color constantly provides us with information and facilitates communication. According to the extensive research [6] that has been conducted to investigate the emotional responses triggered by different colors, it is safe to say that various colors elicit distinct information and have the potential to impact us both psychologically and physically. However, various contexts awaken different emotions and cognitions in humans. According to their report [9], the perception of color on walls can differ from the general associations and effects that color evokes within an individual. When observed on different surfaces, colors tend to impact people differently.

Although this compilation of associations can serve as a valuable reference when selecting wall colors for museum galleries, it is crucial to recognize that it should not be the sole determining factor in the final color decision-making process. One alternative can be using various wall colors according to the current concept and theme. On the other hand, it might not be considered as time and cost efficient for every distinct exhibition. As reported by Gorton [10], maintaining the existing color of the walls is typically a more convenient and cost-effective approach for museums. This is also why museums often avoid using vibrant colors for painting gallery walls, as a neutral wall color tends to be compatible with a greater variety of exhibitions. Moreover, neutral colors offer various advantages to the exhibit gallery. White color, for instance, has the ability to reflect light, creating an illusion of spaciousness and brightness within rooms. Additionally, white color possesses the capability to absorb ultraviolet radiation, which aids in safeguarding museum objects from potentially harmful light that may enter through

windows. It is likely that the prevalence of white and other neutral colors in museum galleries stems from their multifaceted benefits, which are not typically associated with bold colors. One should bear in mind that having criteria of wall color alone might not be a healthy evaluation. Although it is not a changeable feature, the color of the artworks exhibited in front of the wall impacts the perception as well. It not only creates a contrast but also a harmony with the whole museum concept.

Different color combinations stimulate various emotions in the human brain. It has been documented [11] that the perception of object colors can be influenced by variations in the background against which they are observed. For instance, in Figure 2.3, which is demonstrated in his book, Boyce [11] implies that when a gray object is viewed against a black background, it appears brighter compared to when it is viewed against a white background. This phenomenon is further intensified if there is a distinct dividing edge positioned along the border between the black and white areas. Figure 2.4 illustrates this comparison more clearly, where the artwork is hung above white and dark blue colored wall. In the blue colored wall, the ambiance becomes more theatrical. This allows visitors to engage deeper feelings and expressions. This observation demonstrates that human perception in art centers is not solely influenced by the luminosity of the environment but also by the background color of the exhibition as well as. To add more, visitors who experience various emotions in an exhibition tend to stay more focused, which in turn increases their visiting time. What is more, research [12] conducted in the field of museum atmospherics has indicated that the interior color of a store can have an influence on the amount of time individuals spend in that store. Additionally, as stated in the report [13], research suggests that interior color can also play a role in regulating the flow of visitor traffic within a museum by impacting the walking pace of visitors. Although environmental factors might play a vital role in visiting time period, the conceptual theme of the museum and type of exhibited objects also have an inevitable effect. Therefore, human perception is not solely dependent on single variable, but rather multiple and interconnected factors.



Figure 2.3. Demonstration of the interaction of two-colored elements [11]

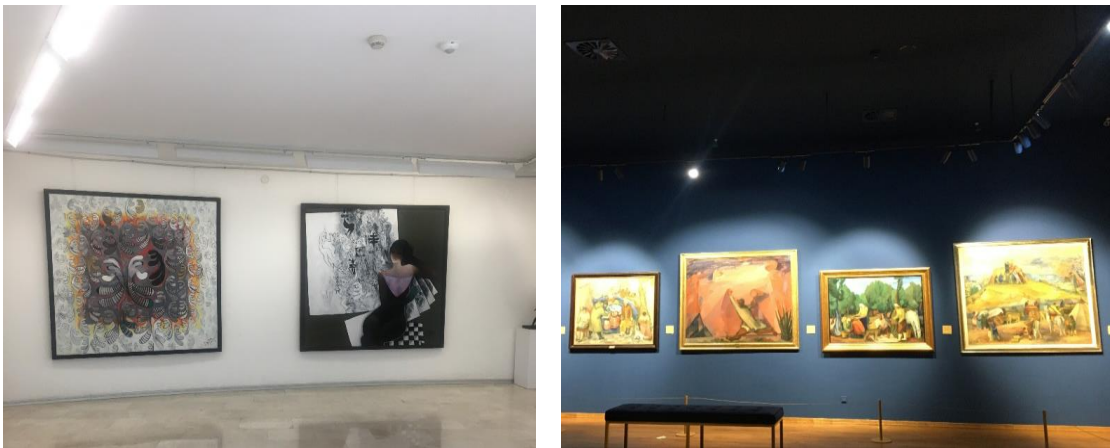


Figure 2.4. The comparison of paintings above light and dark colored background (Author)

Visual performance does not only rely on the lighting design. It is true that it is influenced by several factors, including the visual acuity of the eye, which refers to its ability to discern fine details, and its sensitivity to variations in brightness and darkness. The eye's capacity to perceive and distinguish different levels of light and dark, various choices as well as tones of colors, also play a crucial role in visual performance. As it has a powerful visual impact, color plays a significant role in the design of exhibition spaces. Colors can capture public attention and evoke psychological associations [14]. The arrangement and sequence of colors in the

design of display spaces can also influence people's psychology as well as visual comfort. Therefore, while some visitors can be regarded as visually comfortable in certain exhibition spaces, others can get distracted given the fact that colors possess the inherent ability to stimulate our senses intuitively and trigger physiological responses. To add to that, according to Yu [14], individuals are influenced by their daily habits, religious beliefs, social norms, worldview, and living environment, which further shape their perception of color. When people encounter shades of colors under different illumination levels, they naturally develop specific associations or abstract emotions, adding depth and meaning to the experiences during the exhibition and museum visit. According to the survey done by Gorton [10], museum visitors generally were not aware of the wall color. However, this outcome does not necessarily show that such environmental factors are affectless. Although visitors were unaware of the background of the exhibit, the way they cognize the artwork was influenced even unconsciously. The object exhibited in front of the white wall is surely seen differently than that of black wall. The same comparison is valid for the case of brighter or darker exhibition areas.

Extremely vivid background color or highly illuminated art object might cause a distraction. For instance, other research on the psychology of yellow color has found that yellow can evoke strong emotions and responses in individuals, including feelings of distraction or heightened alertness. While yellow is often associated with positive attributes such as happiness and energy, it can also be perceived as intense or overpowering by some individuals. These findings suggest that the impact of color, including yellow, can be subjective and may elicit diverse reactions from different people [10]. Since different notions in colors might evoke different perceptual emotions, in museums and exhibition centers, than universal cognition, the demonstration of artworks in the context of exhibition requires a delicate design and calculation.

### **2.3. General Effects of Environmental Circumstances**

Environmental factors that influence human perception other than color and light include the level of noise/sound, temperature, and smell/odor of the surrounding. According to Wu et al., [15], in an indoor environment people's perception, health and work performance can be greatly affected simultaneously by various factors such as thermal, acoustic, luminous environments and indoor air quality. It is not surprising that bad air quality when combined with a hot environment will not favor the productivity of people. This affects not only human

performance but also human perception, creating a discomfortable environment. This in turn, might remind unsettled memories setting up a restless atmosphere. As a result of a study done by Wu et al., [15], noise distraction caused a decrease of 66% work performance and concentration.

Combining all the information, it is crystal clear that apart from object color and illuminance, human perception is easily influenced by environmental factors like noise, temperature, and odor. In other words, several different environmental factors work together to influence how people perceive and perform. For this reason, it is rational to consider how different environmental factors combine to impact overall human comfort. The sum of all these factors – which are object color, light, acoustics, illuminance, temperature, and smell – determine the psychophysical behaviors of humans. For that reason, architects and designers have a significant role in influencing the way people discern artworks in both public and semi-public spaces.

#### The Impact of Other Environmental Factors on Visiting Time Period and Visual Comfort

It is a fact that human perception of the exhibited objects in museums is highly dependent on the artificial lighting as well as the color encountered, both object color, wall color, and lighting color. All these factors unconsciously affect the way visitors perceive the artworks in exhibitions, altering overall visual comfort and focal attention thereby, their staying time. Environmental factors inside the museums which affect the visitor satisfaction level include indoor environments and technology use, visual locomotors, and signage availability, circulation complexity, density of the visitors, noise levels, temperature, humidity, and the size of the museum [16]. However, the indoor environmental conditions also affect the displayed artifacts. Therefore, achieving an optimal balance between the preservation of artwork and human comfort is significant.

Museums are the places where people can experience various perceptions based on the general environmental factors of the surrounding. In museum displays, the creation and interpretation of meanings occurs through a blend of different elements working together, such as exhibited objects, written explanations, lighting arrangements, colors, and sounds (Figure 2.5). When visitors explore the museum, they communicate using a mix of spoken words,

gestures, facial expressions, and movements within the exhibition space. These diverse modes of expression are utilized to fulfill distinct roles in the process of conveying and generating meaning [17].



Figure 2.5. Different display methods (Author)

In his article “What is Museum Fatigue?” [18], mentions that studies conducted in the 1920s and 1930s discovered a term known as "Museum Fatigue." This term refers to the observed decline in visitor interest towards museum exhibits as their visits progress. It is stated that visitors may become less engaged or enthusiastic during their museum experience, which can affect their overall enjoyment and attention to the exhibits. Museum fatigue or in other words, the lack of attention, impacts visiting time period as well. There are several reasons for this reduced interest. The first one can be a demographic distinction. Some types of exhibits are more appealing to certain groups of people. Museum visitors exhibit a wide range of differences stemming from their diverse past experiences, individual interests, specific visit agendas, intellectual capabilities, and levels of familiarity and comfort with the museum environment. These factors collectively influence the ways in which people interact with museums. Each visitor's unique background and preferences shape their engagement, appreciation, and overall experience within the museum setting. As a result, some may delve deeply into the exhibits and actively participate, while others might have a more casual or reserved approach based on their

personal traits and inclinations. Understanding and catering to these individual variations can significantly impact the effectiveness and appeal of museum displays and programs. [19]. The other and more significant one is the environmental circumstances. According to Davey [18], these design factors consist of size of the exhibition room, harmony, and contrast with the background as well as general theme, lighting, artwork composition, and sensory features such as sound or smell. The link between these factors and the visiting time period is that, if one or more of these stimulates negative emotion. This creates great discomfort and thus, people do not tend to spend much time in the exhibition as they lose the focus of attention.

This thesis study embodies the design and impact of artificial lighting, color, and the categorization of displayed artifacts in museums. The psychological effects of environmental factors such as noise/sound, temperature, and smell/odor of the surrounding are not considered in the analysis phase of the study.

#### **2.4. Possible Measures to Provide Visitors' Comfort and Enhance Focal Attention**

Museum and exhibition visitors need to have a distinctive experience that is uneasy to forget. Therefore, several design techniques, which outweigh environmental discomfort should be employed. Various design factors, including the presence of vertical and horizontal patterns, the quantity of information presented, symmetry, and figure-ground relationship, are thought to impact aesthetic preferences due to their capacity to aid cognitive processing and focal attention [18]. To achieve comfort and catch visitors' attention, several factors should be considered [20];

1. Increasing exhibit distinctiveness through various means such as adjusting size, contrasting with the setting background, and strategically placing them in the line of sight can attract attention and make exhibits more memorable. Placing exhibits in relation to traffic flow, considering landmark objects, hotspots of visitor attention, inertia, and the right-turn bias can also optimize engagement.
2. Reducing the mental effort required to understand exhibits is crucial. This can be achieved by carefully designing how information is presented, making it easier for visitors to comprehend and process the content.
3. Motivating visitors to engage with exhibits can be achieved through various techniques. Asking thought-provoking questions, addressing misconceptions, providing interesting content, incorporating mental imagery, offering handouts, showcasing 3D objects, and

providing opportunities for interaction can all stimulate curiosity and active involvement.

4. Minimizing distractions. This includes reducing disruptive sounds, minimizing competition from other exhibit elements, and avoiding excessive novelty in the surroundings that could draw attention away from the exhibits.
5. Recognizing the importance of attention replenishment, providing opportunities for visitors to take breaks can help maintain overall interest and energy during extended museum visits. By considering these factors and implementing thoughtful design strategies, museums can create enriching and enjoyable experiences for their visitors.

General discomfort in museums and art exhibitions is a complex factor that affects the focal attention and thus, staying time of visitors. As human perception is susceptible to changes in their physical environment it is acceptable that environmental circumstances in exhibition spaces have an impact on how they conceive the artwork as well.

### **3. ARTIFICIAL LIGHTING IN MUSEUMS AND EXHIBITIONS**

It is a well-known fact that sunlight and its warmth are the main elements that impact human perception and allow them to live in harmony. In museums and exhibition centers both daylight and artificial light play an important role in terms of the way visitors perceive the exhibited artworks. In this thesis, artificial lighting in museums and exhibitions is the focal research area. The different types of lamps, the usage of artificial lighting, lighting standards and their deterioration factors, light measurement and protection of different materials against artificial lighting in museums and exhibitions will be explained in this section.

#### **3.1. Types of Lamps Used**

A lamp is a device which emits light. In the spectrum of light, lamps emit white light. The majority sources of light can be evaluated based on two aspects: Color temperature and Color rendering index (CRI) [21]. As described in her book “Lighting Design Basics” [21] Hunt mentions that color temperature refers to the perceived warmth (reddish), neutrality, or coolness (bluish) of light. The concept of temperature is associated with the light emitted by a heated metal object reaching incandescence. For instance, an incandescent lamp has a color temperature of approximately 2700K, resembling the light emitted by a metal object heated to 2700° Kelvin (2427° Celsius or 4400° Fahrenheit). The color rendering index (CRI), on the other hand, is a measure that indicates the quality of light on a scale ranging from 0 (poor) to 100 (excellent). It evaluates how accurately colors are rendered under a given light source. Both color temperature and color rendering index are used to assess all white light sources. Color temperature is a more apparent measure, as two light sources with the same color temperature but different CRI will appear more similar than two light sources with similar CRI but different color temperatures. Natural light is commonly defined as having a perfect CRI value of 100, indicating its superior color rendering capabilities.

Most lamp types used in museums include halogen lamps, fluorescent lamps, and Light-Emitting Diodes (LEDs). Halogen lamps (Figure 3.1) emit whiter light and have a lamp life ranging from 2000 hours to 10,000 hours. The color temperature of halogen lamps is about

3000K. Fluorescent lamps, on the other hand, use a mechanism of fluorescence in which the minerals exposed to UV light are caused to emit light. In fluorescent lamps (Figure 3.2) color temperature can be adjusted; cool white, warm white, and daylight. What is more, most fluorescent lamps are commonly manufactured in linear shape. The longest standard fluorescent lamps measure about 2.5 meters in length, while the shortest ones are about 10 centimeters long [21]. Among the mentioned type of lamps, in museums, the most used one is LEDs (Figure 3.3). LED lighting offers a range of notable features that contribute to its prominence in the lighting industry. One key advantage is its long lifetime, with an impressive 50,000 hours of operation while maintaining 70% of its initial lumen output. This prolonged lifespan reduces the need for frequent replacements, resulting in cost savings and decreased environmental impact. Additionally, LED lights exhibit high energy efficiency, with a remarkable efficacy of 100 lumens per watt (100Lm/W). In terms of durability, LED lighting possesses inherent ruggedness due to its non-fragile construction. This sturdiness enhances reliability and minimizes the risk of damage during handling, transportation, or installation. Moreover, LED lights offer the advantage of instantaneous light output, eliminating the need for warm-up time. As a result, they provide immediate illumination, ensuring prompt visibility and convenience in various applications. Furthermore, LED lights can be infinitely dimmed, enabling precise control over the intensity of illumination according to specific needs and preferences. Another significant benefit of LED lighting is its ability to deliver high-quality light with enhanced color saturation. This feature allows for vibrant and vivid illumination, creating visually appealing and engaging environments, particularly in places where light display is significant [22].



Figure 3.1. Halogen lamps



Figure 3.2. Light Emitting Diodes (LEDs)



Figure 3.3. Fluorescent lamps

### 3.2. The Usage of Artificial Lighting

There are different methods of lighting that are used in museums and exhibitions to display artifacts. These methods are used to create a system of lighting display. Different types of luminaires enable designers to demonstrate artwork with various levels of sensitivity at maximum visibility and minimum damage rate. The term "luminaire" encompasses the complete electric light fixture, including all the necessary components for lamp mounting and operation [3]. When a luminaire is permanently attached to the wall of the building, it is called a light fixture [7]. Luminaires have more than one function, such as protecting lamps, distributing their light, and preventing glare. When designing luminaires in museums and exhibitions, important considerations include lighting quality, cost-effectiveness, reliability, ease of installation, as well as user-friendliness. High-quality luminaires not only offer functional features but also pay attention to aesthetic elements, such as the shape of the housing, finish, and color. The selection of luminaires is influenced by the choice of lamps and is further guided by the architectural design of the space, its furnishings, and the overall design concept.

### 3.2.1. Methods of lighting

Luminaires can be categorized in terms of the way light they emit. Methods of light distribution are classified as follows; a) Direct b) Indirect c) Diffuse and d) Direct/Indirect lightings. Below mentioned information about the different methods of light distribution is summarized in Table 3.1.

#### a) Direct Lighting

In direct lighting, light is directly guided onto the specific area, which forms dark ceilings and upper walls. According to Karlen and Benya [7], direct lighting primarily emits light in a downward direction, encompassing various recessed lighting options like downlights and troffers.

#### b) Indirect Lighting

Indirect lighting emits light upwards, which then reflects off the ceiling to illuminate a given space. Examples of such luminaires include suspended luminaires, sconces, and certain portable lamps. This type of light distribution often creates a comfortable and soft light, which in turns forms a spacious feeling about space.

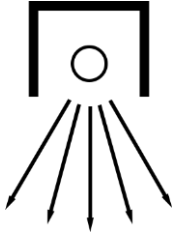
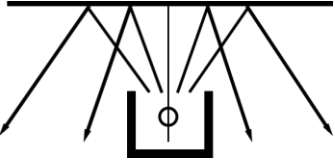
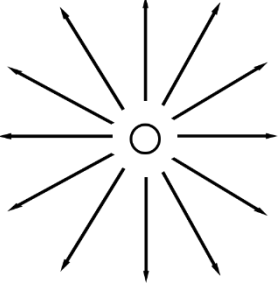
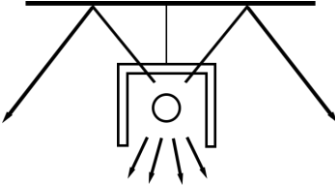
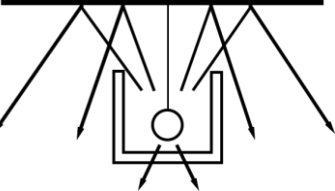
#### c) Diffuse Lighting

Diffuse lighting emits light uniformly in all directions. Since there is no side shielding in diffuse lighting, glaring can easily occur. Therefore, it is significant to complement diffuse lighting with additional lighting to sustain the harmony. When used alone without supplementary light sources, diffuse lighting can produce a dull and unremarkable illumination that is frequently uncomfortable.

#### d) Direct/Indirect Lighting

Direct/indirect luminaires emit light both upwards and downwards, excluding the sideways direction. This type of lighting consists of various suspended luminaires and table lamps. Direct/indirect luminaires can be categorized as semi-direct or semi-indirect, depending on the proportions of upward and downward light they emit. In semi-direct lighting, 10-40% is up light and 90-60% is downlight, while in semi-indirect lighting, these percentages are reversed.

Table 3.1. Methods of Light Distribution

METHOD OF LIGHT DISTRIBUTION	EXPLANATION	DEMONSTRATION
<b>Direct Lighting</b>	Emits light in downward direction.	
<b>Indirect Lighting</b>	Emits light in upward direction.	
<b>Diffuse Lighting</b>	Emits light uniformly in all directions.	
<b>Semi-direct Lighting</b>	Semi-direct luminaires emit light in both directions, mainly in downward direction, excluding the sideways direction.	
<b>Semi-indirect Lighting</b>	Semi-indirect luminaires emit light in both directions, mainly in upward direction, excluding the sideways direction.	

### 3.2.2. Exhibition display techniques

Methods of lighting distributions are used to form techniques to display art objects properly in museums and exhibitions. These techniques can be categorized into four groups: a) Flat Displays on Vertical Surfaces, b) Display Cases, c) Three-dimensional Objects, and d) Realistic Environments [23]. In this section each group is explained in detail.

#### a) Flat Displays on Vertical Surfaces

Flat displays on vertical surfaces can be achieved by wall washer and spotlights. Generally, the lighting should ensure uniform brightness across the entire area, which can be created by placing the luminaires with the center of axis at  $30^\circ$  angle from the vertical [23]. This results in minimal shadows and allows visitors to closely observe artifacts without creating glare or casting their own shadows on them. Wall washers are generally used to illuminate a large vertical surface uniformly as illustrated in Figure 3.4 [24]. Apart from the angle arrangement, to accomplish uniform light distribution in wall washers, reflectors with asymmetrical optics are utilized. It is crucial to ensure effective shielding towards the observer's direction. Incorporating mounting accessories on the luminaire, such as filters or anti-glare flaps, can be advantageous. The most used type of linear lamps in wall washers include fluorescent lamps, elongated compact fluorescent lamps, and linear high-voltage halogen lamps [3]. For small and medium sized artworks spotlights are used to illuminate the vertical surface uniformly (Figure 3.5). The distance between the light source and the wall is significant.

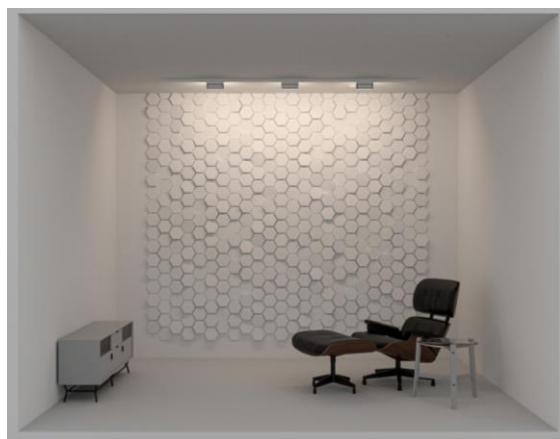


Figure 3.4. Wall washer in vertical surfaces [24]

According to the IESNA report [23], the placement of lighting can be determined using the guidelines demonstrated in Figure 3.6. Adjusting the "X" value as needed is to prevent shadows caused by oversized frames on paintings. To avoid glare for viewers, calculating the angle of incidence and reflection is a significant factor. Allowing some spill-light to fall to the enclosed area can have a softening and smoothening effect. In cases where a separate picture label is used, it should be positioned away from the shadow created by the frame.



Figure 3.5. Using spotlights to illuminate vertical surfaces (Author)

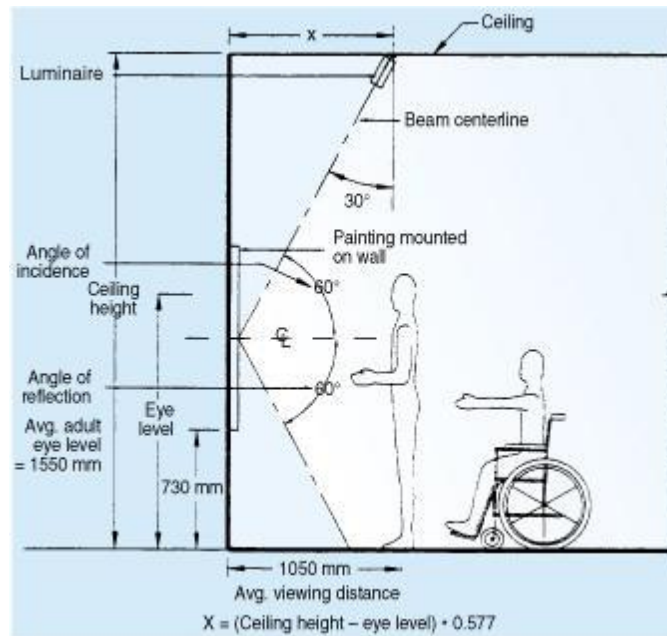


Figure 3.6. Guidelines for luminaire mounting position for flat displays on vertical surface [23]

### b) Display Cases

Display cases in museums allow people to observe sensitive and delicate objects in a closer look, while also ensuring the security of valuable objects. It is a small version of exhibition spaces, and the objects they display require appropriate lighting, which can be either diffuse or directional. The sizes of these cases are usually between 50 mm and 3 m acrylic cube exhibiting jewel and rare clothing, respectively. The display case offers three options for its corners: mullions, clear acrylic or tempered glass panels fixed at the edges [23]. These display cases provide the flexibility of having internal or external lighting. The lamps used can range from low-voltage incandescent to fluorescent and to high-intensity discharge. However, there are some challenges regarding lighting of display cases. These include reflections (Figure 3.7) appearing in the glazing, shadows cast by visitors or exhibited artifacts, and the potential accumulated of heat. As for IESNA (2000), to solve these issues, it is essential to place a transparent or translucent barrier between the lighting fixture and the artifact (Figure 3.8), which helps to reduce any unwanted heat effects. As for the reflections, these are the most discomforting feature, especially in dark interiors. However, in most cases, a slight reflection

might be kept. If the displayed artifact is brighter than the reflection, then this case is tolerable (Figure 3.9). There are some solutions to overcome reflection problem [23]:

- Placing the case towards a black wall so that the visitors' sight will not be reflected through the glazing.
- Employing angled glass towards the viewer, directing primary reflections of the gallery to the darkened floor.
- Utilizing custom curved viewing glass to reflect a dark surface.
- Considering alternatives to glass, such as railings, taut wires, and alarmed motion sensors.
- Establishing a high luminance ratio (10:1) between the interior and exterior of the case.



Figure 3.7. Reflections appearing in the glazing in display cabinet (Author)

The illumination of the display cabinets can be both internally and externally. According to IESNA report [23], when external light sources are used to illuminate display cases, it is recommended to position the lights above the front of the case directing straight downwards. Placing luminaires in other positions can create shadows within the case, even if there are no

opaque supporting structures. To prevent strong shadows and achieve a self-lighted effect, diffusing material like milk-white diffusing acrylic can be placed on top of the case, although this diffusion material may cause a reflection from the case top onto the ceiling. Additionally, external light sources can generate heat within the case due to the greenhouse effect. This problem can be reduced by using dichroic reflector lamps and heat filters.

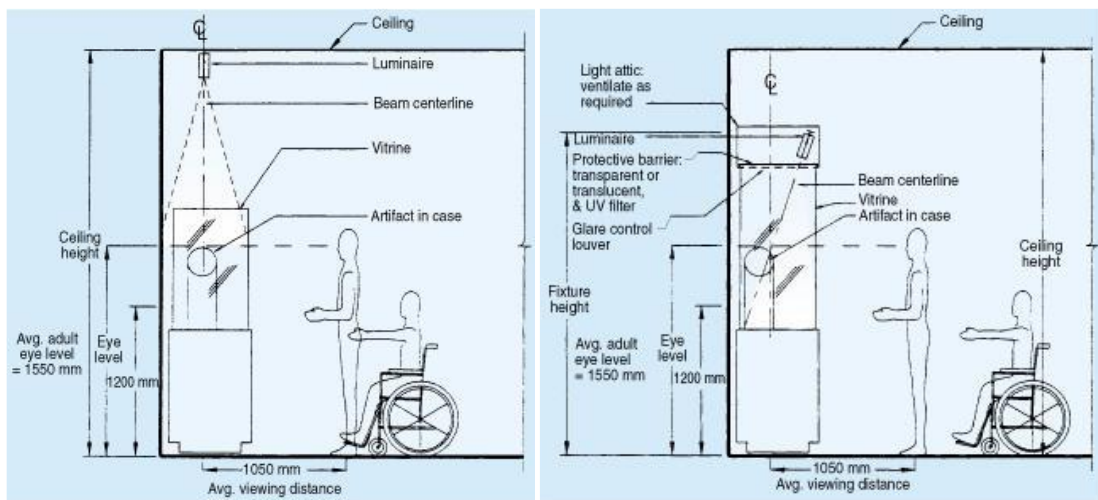


Figure 3.8. Guideline for luminaire position [23]



Figure 3.9. Slight acceptable reflection (Author)

Internal lighting is commonly used in freestanding or built-in display cases where the illumination can be either from the side, from the top, or even from below. This depends on the size and the location of the cabinet in the exhibition hall, as well as the type of experience a designer wants visitors to have (Figure 3.10). Internally illuminated display cabinets have light attics or light boxes positioned overhead. This can be either partial light attic or full light attic [23]. In partial light attic, display cases that are consistently viewed from one direction can have a partial light attic located just above the viewing window, featuring sloping light-attic glazing (Figure 3.11). Within this light attic, fluorescent lamps can provide soft illumination, fixed or adjustable incandescent lamps can offer controlled and directional lighting, or a lighting track can accommodate both options. It's essential for light attic luminaires to be simple, functional, and easily maintainable. Swivel lamp holders provide the greatest flexibility in positioning. For display cases viewed from all sides (freestanding), a full light attic is used. A light attic should be of the same size as the case top. Fluorescent lamps work well to achieve soft and uniform illumination. If spotlights are needed, a deeper light attic (300 to 600 mm) is required, with the spots directed through small apertures in opaque material or a louver (Figure 3.12). To avoid glare, the light source should be shielded from the viewer using parabolic wedge louvers or lenses. Careful positioning of spotlights helps avoid projecting the pattern of the apertures or louvers [23]. Moreover, supplementary lighting from the side, back, or bottom of the cases is practical and enhances the appearance of three-dimensional objects, particularly ceramics, glass, and polished-metal pieces, by revealing their texture and shape.



Figure 3.10. Internally illuminated different kinds of display cabinets (Author)

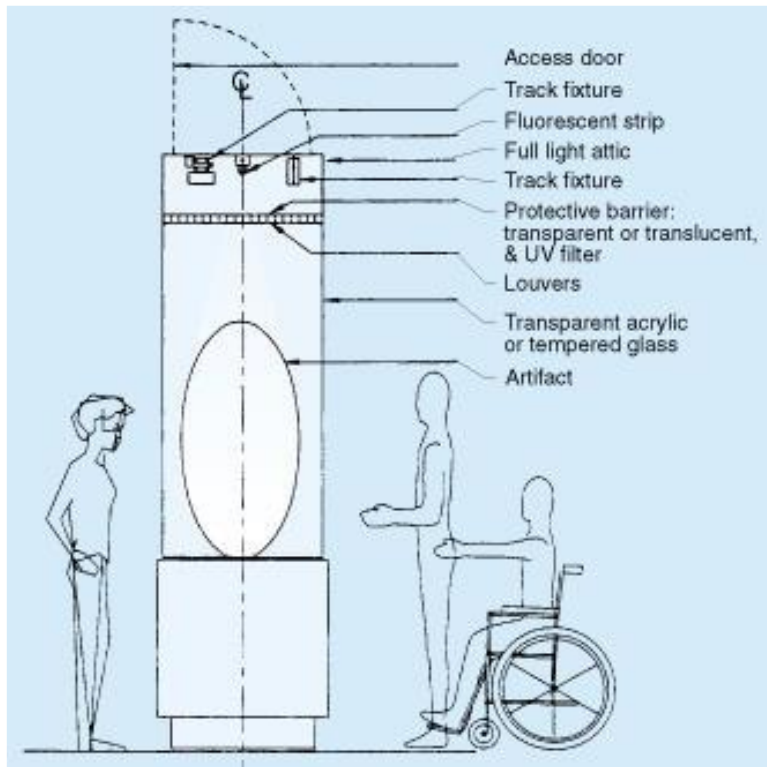


Figure 3.11. Display case guideline where the luminaire inside a partial [23]

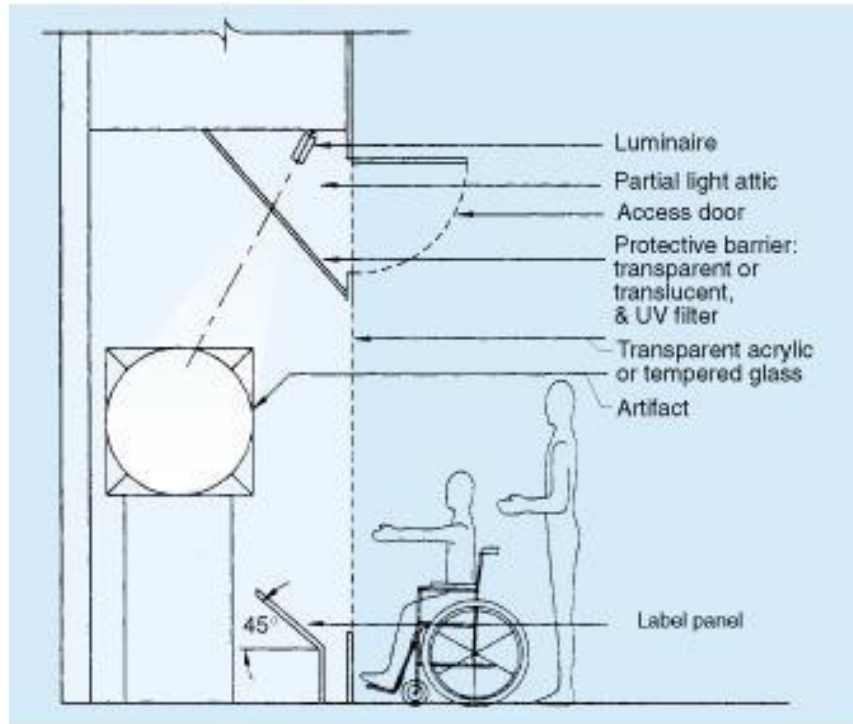


Figure 3.12. Display case guideline where the luminaire inside a full light attic [23]

c) Three-dimensional Objects

As for three-dimensional objects (Figure 3.13), they should be illuminated from more than one direction. According to IESNA [23], light coming from multiple directions creates highlights and shadow, thus expressing depth. While highlights serve as useful visual cues for identifying surface characteristics, shadows are valuable indicators of surface forms and textures, as long as they are not overly strong and do not obscure important details. When lighting an object at eye level or below, illuminating it from all sides with the luminaire's center beam axis at  $30^\circ$  or less from the vertical generally poses minimal issues for viewers. However, for small and low objects, the luminaires should be positioned at steep angles to minimize the risk of glare for observers on the opposite side [23]. Tall objects may pose challenges as some light can spill beyond the display area, resulting in glare for viewers on the far side who are looking upward at the object. To address this, IESNA reported potential solutions as illustrated in Figure 3.14:

- Angling the luminaires sharply downwards and using a highly reflective pedestal to mitigate shadows.
- Ensuring that light beams remain within the mass of the display and do not spill excessively.
- Forming bottom-up lighting if it does not distort the appearance of the object.
- Utilizing overall soft lighting (fill light) in the display area to ensure clear visibility of all objects, while employing focused narrow beams (key light) to highlight essential parts of each object.
- Adding background lighting behind the artifact to enhance its visibility.

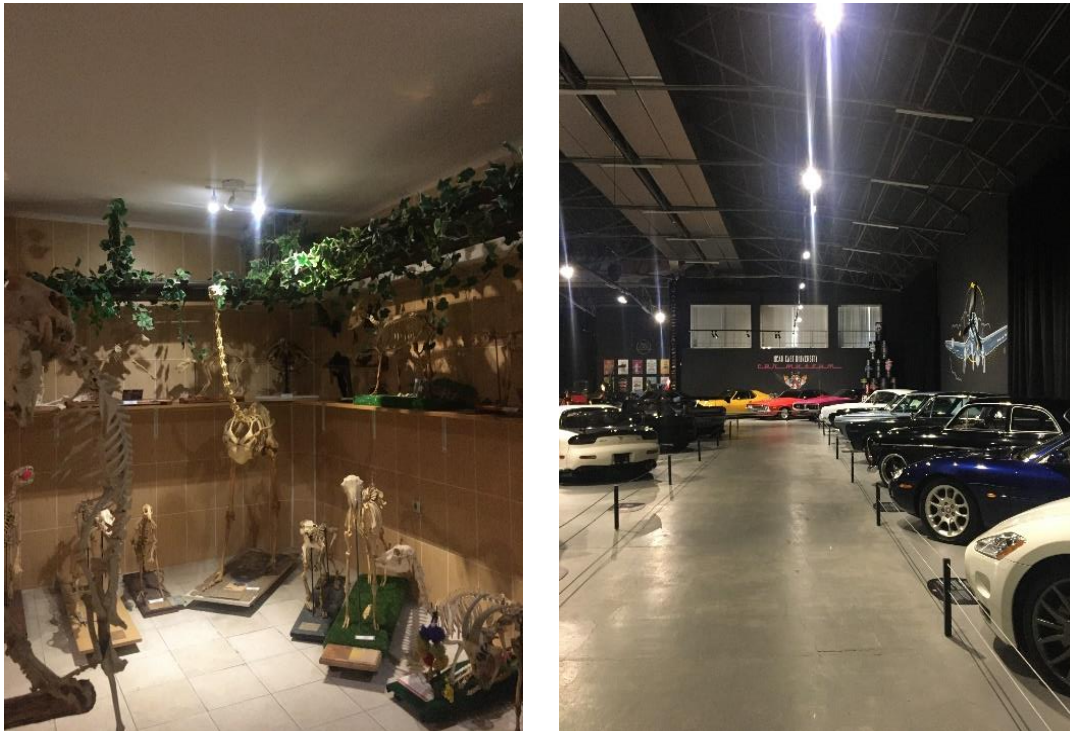


Figure 3.13. Examples of exhibition of a three-dimensional object (Author)

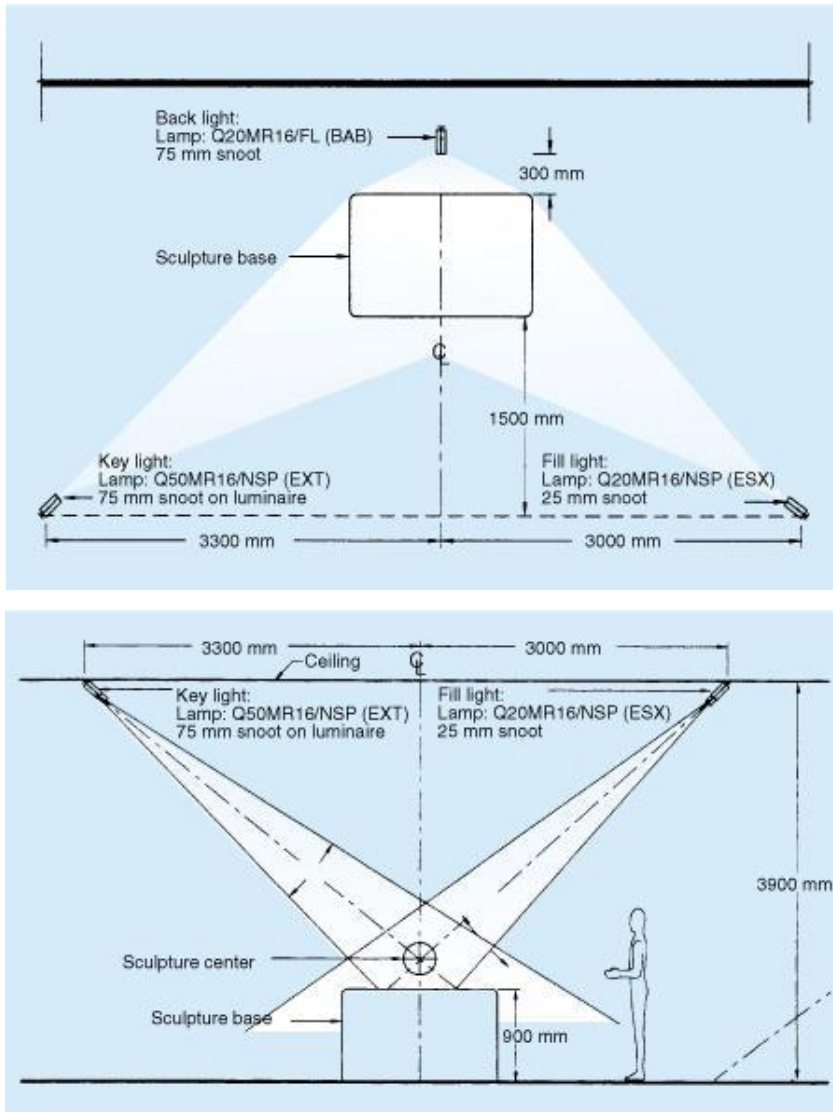


Figure 3.14. Guidelines for exhibiting three-dimensional objects [23]

#### d) Realistic Environments

Realistic environments are a type of display technique in some museums where a designer is willing to give a certain message by allowing visitors to feel the environment with special lighting and sound effects as if it is real. As illustrated in Figure 3.15, such examples include outdoor scenes, historic houses, war scenes, torture rooms etc. Lighting especially should be designed very carefully in this type of display technique. It should not be such bright that it diminishes the whole effect, or too dark that it creates serious discomfort for the visitors. The main purpose is to enable people to feel exactly like dwellers in that period by designing correct

ambiance. According to IESNA [23], the lighting designer has two main techniques at their disposal to achieve realistic environment lighting: concealed lighting positions and dual lighting systems. The concealed lighting method involves strategically positioning light sources in a way that ensures specific viewing angles, emphasizes key display features, and provides sufficient illumination for the safety of visitors. The dual lighting system, on the contrary, utilizes specialized control equipment that can switch between realistic lighting and optimal display lighting, either automatically or manually. The display lighting is carefully chosen to complement the realistic lighting in terms of both style and color. To ensure safety and conservation, electric lighting is used as a substitute for original flame source lighting like candles, mantles, or gas jets. An influential approach involves gradually alternating the electric light's glow, imitating the flickering effect of a gas jet, while also maintaining appropriate intensity for easy viewing.



Figure 3.15: Examples of exhibition of realistic environments (Author)

### **3.3. Basic Artificial Lighting Standards and Deterioration Factors**

Artificial lighting design in museums necessitates the fulfillment of a diverse array of standards. However, its utmost significance lies in its ability to enable maximum visibility of exhibited artwork, adhering to specific limitations in their visual representation, while concurrently safeguarding their preservation to the greatest extent feasible [25]. Collections in museums can be adversely affected by light, as it has the potential to cause damage. The extent of damage is influenced by factors such as the intensity and type of light, duration of exposure, and the inherent resilience of the object's constituents. Light-induced harm extends beyond mere fading, as prolonged exposure can lead to deterioration, discoloration, yellowing, and increased fragility [26].

As for the report published by Conservation Center for Art and Historic Artifacts, artifacts included in the exhibition should be categorized based on their susceptibility to light and its conditions, and thus duration of exposure should align with this classification. Objects made from organic materials such as documents, letters, photographs, artworks on paper, textiles, clothing, and accessories are notably susceptible to light sensitivity. This sensitivity can lead to irreversible and cumulative harm on upon museum artifacts [27]. To minimize light exposure, the design of the exhibition case should incorporate strategies such as keeping the exhibit area in darkness when closed to the public. Motion sensors or curtains can be employed to ensure that the artifact is only illuminated in the presence of visitors [26]. According to Ajmat, Sandoval, Odoneli, & Gor (2011), the light exposure experienced by museum collections consists of three constituents: ultraviolet (UV) radiation at one end of the spectrum, visible light in the middle, and infrared radiation at the other end. Minimizing UV radiation in the exhibit can be achieved by selecting light sources that do not emit UV or by incorporating UV filters into existing light sources. UV-filtering acrylic should be utilized for framed objects and display cases. The impact of daylight should be mitigated through strategic positioning of the exhibit case and the use of filtering techniques. Nonetheless, eliminating or minimizing UV light does not solve all the problems. It is essential to mention that all light, regardless of its position on the spectrum, embodies energy, which drives the chemical reactions resulting in object fading [27]. International Commission on Illumination (CIE), generated a table demonstrating a classification of deteriorating factors in museums (Table 3.2),

Table 3.2. Deterioration factors in artwork pieces [27]

<b>External Factors</b>	<b>Direct (related with the irradiation from the light source)</b>	Irradiance – Illuminance
		Exhibition Time
		Spectral composition of the source`
	<b>Indirect</b>	Relative Humidity
		Temperature
		Gases in atmosphere
<b>Internal Factors (Related to the artwork)</b>	Nature of the material	
	Selective capacity to absorb energy	

The classification in Table 3.2 is mainly divided into two groups: external and internal factors. External factors can either be direct or indirect, in other words, related or not related factors to the light source. The direct factors can be classified as irradiation of energy from the light source, the duration of the exhibition and the spectral location of a light source. The indirect factors, on the other hand, are humidity, temperature, and the gas content in the atmosphere. Other groups, internal factors, include invariable elements such as the nature of the material, its capacity to absorb energy.

Light can be measured with a light meter or datalogger. The exposure to direct sunlight for 1 hour is 100,000 lux. While visible light is measured in lux or footcandles, ultraviolet (UV) light is measured in microwatts per lumen ( $\mu\text{W}/\text{lm}$ ) [26]. Microwatts per lumen ( $\mu\text{W}/\text{lm}$ ) is the fraction of ultraviolet radiation in visible light. As the light level increases, the total UV increases as well while the ratio remains stable. As demonstrated in the Equation 1, the exposure of an artifact to light is a product of illumination level and time [26]:

Equation 1: The exposure of an artifact to light [26]

$$\text{Light level (lux)} \times \text{Time (hours)} = \text{Exposure (lux hours)}$$

From the formula, it can be said that the exposure to sunlight for 1 hour is equivalent to 200 hours of museum lighting, which is usually 50 lux. This means that when compared to direct sunlight, museum lighting enables a longer time before deterioration of the artwork. The susceptibility of artworks to light in museums changes according to the content of their materials. Therefore, different measures of protection and management techniques are required for each type of material, and their maintenance should be regarded accordingly. In Table 3.3 [23], IESNA summarizes recommended total exposure limits in terms of illuminance hours per year for classified susceptibility of museum artifacts. In this thesis study, maximum illuminance standards mentioned by IESNA are taken into consideration.

Table 3.3. Recommended Total Exposure Limits in Terms of Illuminance Hours per Year [23]

Type of Materials	Maximum Illuminance	Lux-Hours Per Year
<b>Highly susceptible displayed materials:</b> Textiles, cotton, natural fibers, furs, silk, writing ink, paper documents, lace, fugitive dyes, watercolors, wool, some minerals	50 lux	50,000
<b>Moderately susceptible displayed materials:</b> Textiles with stable dyes, oil paintings, wood finishes, leather, some plastics	200 lux	480,000
<b>Least susceptible displayed materials:</b> Metal, stone, glass, ceramic, most minerals	Depends on exhibition situation	

To avoid damaging factors of artificial lighting several measurements can be taken. The most basic precautions include using low-wattage bulbs, diffusing the light, reducing exposure time, and eliminating UV and Infrared radiation. Within the context of preserving displayed

objects, there exist two main strategies for attenuating the deleterious effects of ultraviolet (UV) radiation [28]. The first approach centers on diminishing the UV flux incident upon the object during illumination. This can be effectively achieved through the thoughtful selection of light sources that emit minimal UV radiation, the judicious reduction of light intensity, or the implementation of UV filters to screen out harmful wavelengths. The second method entails regulating the object's exposure to UV radiation. When complete avoidance of UV exposure proves unfeasible, adopting this approach allows for the prudent limitation of the duration the object is subjected to such radiation, thereby minimizing its adverse consequences. Control of exposure can be achieved by limiting the light intensity, the duration of exposure, or employing a combination of both factors. To ensure appropriate light levels, it is recommended that sensitive objects be exposed to illuminance within the range of 50-100 lux. The design of the exhibition should be based on adhering to this range. Regular measurements of illuminance within the display case should be conducted to verify compliance with the prescribed exposure limits. What is more, the artifacts showcased in an exhibition should be categorized based on their sensitivity to light, and the lighting scheme and duration of exposure should be adjusted accordingly to accommodate these distinctions [26]. As for the standards regarding ultraviolet (UV) light, the design of the exhibit should prioritize the minimization of it. This can be achieved by either selecting light sources that do not emit UV or by incorporating UV-filters into existing light sources. Table 3.4 [26] gives detailed information about the different types of materials that were categorized in three sensitivity levels mentioned in Table 3.3.

Table 3.4. Light Level Standards for Storage and Exhibitions [26]

<b>Material</b>	<b>Visible Light Level</b>	<b>Ultraviolet Light</b>
<ul style="list-style-type: none"> <li>• Fragile paper</li> <li>• Silk</li> <li>• Albumen &amp; tinted photographs</li> <li>• Sensitive pigments and dyes</li> </ul>	5 footcandles, 50 lux for three months or less	< 75 u/lum
<ul style="list-style-type: none"> <li>• Watercolors</li> <li>• Paintings with organic pigments and dyes</li> <li>• Textiles in poor condition or with organic dyes</li> <li>• Colored Papers</li> </ul>	5 footcandles; 50 lux for six month or less	< 75 u/lum
<ul style="list-style-type: none"> <li>• Paintings with mineral pigments</li> <li>• Paper in good condition</li> <li>• Pastels</li> <li>• Textiles in good condition or with aniline dyes</li> <li>• Dyed leather</li> <li>• Photographs</li> <li>• Pencil Drawings</li> <li>• Tempera paintings</li> </ul>	5-10 footcandles; 50-100 lux for 12 months or less	< 75 u/lum
<ul style="list-style-type: none"> <li>• Ivory and bone</li> <li>• Wood</li> <li>• Oil paintings</li> <li>• Undyed leather</li> <li>• Enamels</li> </ul>	5-15 footcandles; 50-150 lux for 24 months or less	< 100 u/lum
<ul style="list-style-type: none"> <li>• Stone</li> <li>• Metal</li> <li>• Glass</li> <li>• Ceramics</li> </ul>	Unlimited	Unlimited

#### 4. CASE STUDY – THE ABDÜRRAHİM TUNCAK ATATÜRK HOUSE

“The Abdürrahim Tuncak Atatürk House” is located at the campus of Baskent University (Figure 4.1) and was constructed in accordance with the directives of Prof. Dr. Mehmet HABERAL, faithfully replicating all measurements of the house located in Istanbul Akaretler on the 75th Anniversary of Republic of Turkey. The house reflects the characteristics of the late Ottoman collective housing architecture. Within the Atatürk House, there are 213 negative films, 143 framed photographs, and 32 different types of objects on display, including personal belongings of Atatürk and his mother, Zübeyde Hanım [29].

Among the visited museums, the Abdürrahim Tuncak Atatürk House is decided to be the museum which is the most open to development. The purpose of selecting this museum is to improve the used artificial lighting, display techniques and the user experience.



Figure 4.1. The location and the exterior of Atatürk House (Author)

#### 4.1. Existing Conditions and Critical Analysis

The Atatürk House is a three-story structure. Floor plans of each floor are illustrated in Figure 4.2, Figure 4.3 and Figure 4.4. The 2nd floor, which consists of 4 rooms, is selected to be worked on. The plan of the 2nd floor is divided into 4x5, 4x4 and 4x2 squares according to the dimensions of rooms as illustrated in Figure 4.5. After detecting the center of divided squares, the amount of light exposed perpendicularly on each point over 90 cm, is measured in lux by using digital lux meter. To understand the amount of light exposed perpendicularly on wall surfaces, the same measurement is repeated on walls at a height of 155 cm – average adult eye level. The light exposure on both floors and walls of each room is measured using the same technique. After measurements are done, the 2nd floor of Atatürk House is modelled by using DIALux Lighting Design software to show the existing lighting conditions. Each room is rendered from different angles.

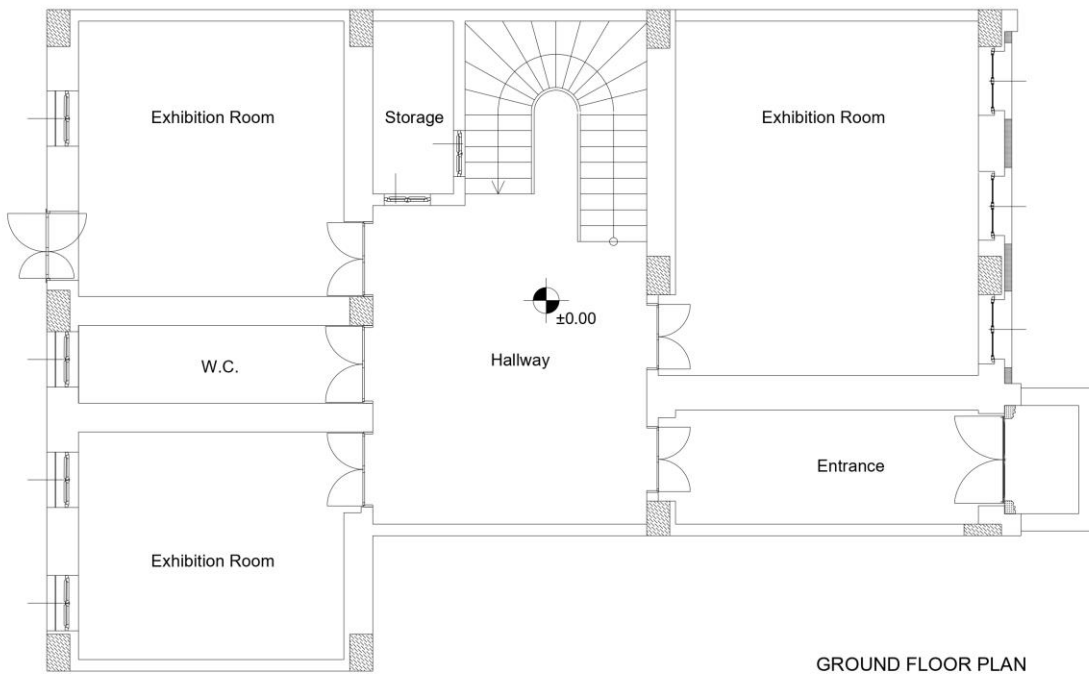


Figure 4.2. The ground-floor plan of the Atatürk House

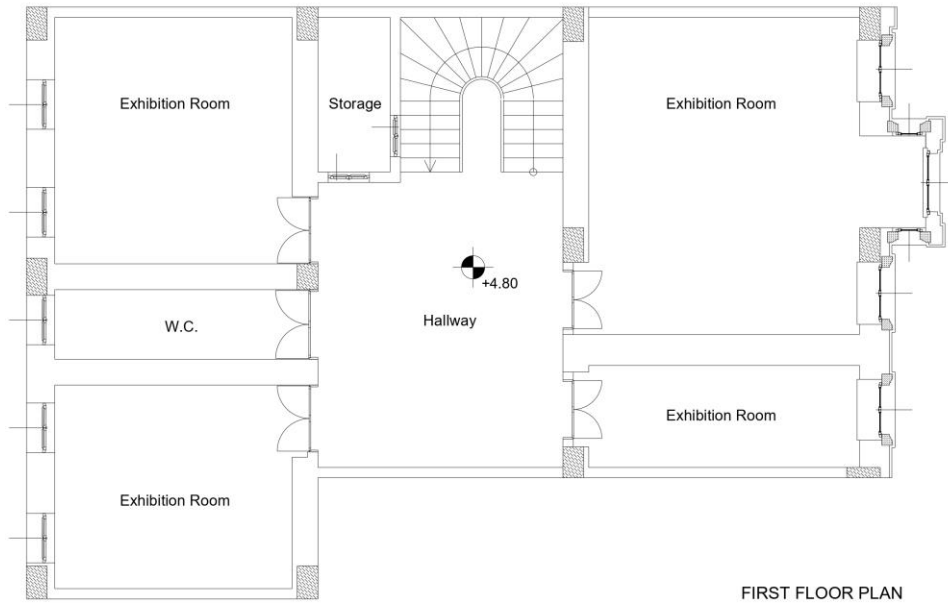


Figure 4.3. The first-floor plan of the Atatürk House



Figure 4.4. The second-floor plan of the Atatürk House

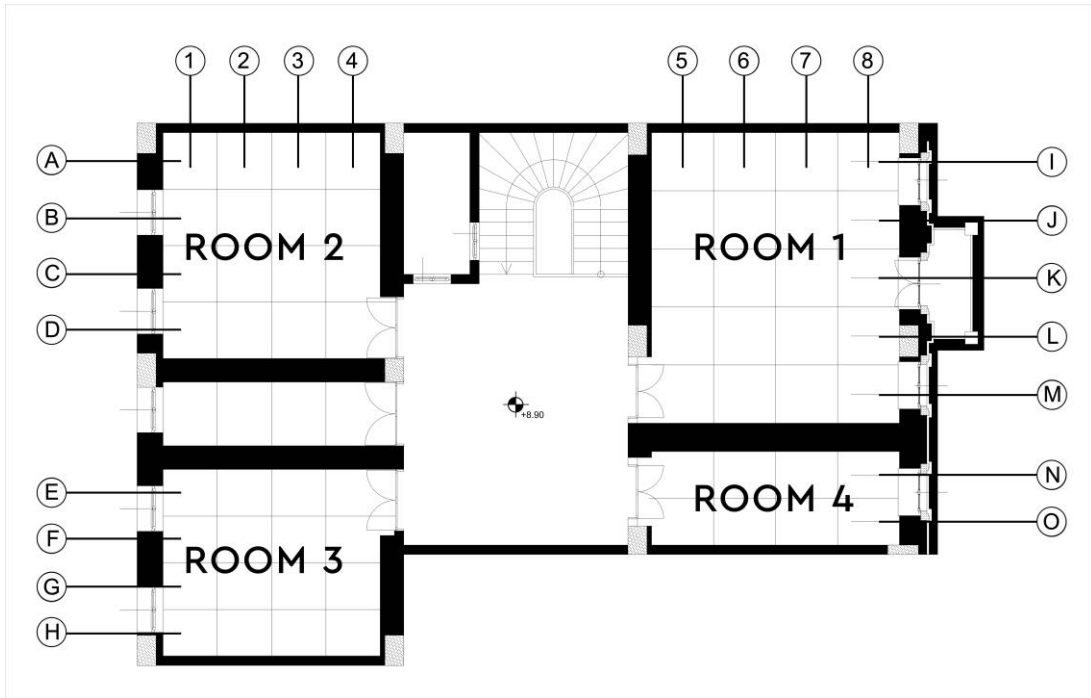


Figure 4.5. The divided working plan of the second floor

a) Room 1

The measurement results and photographs of existing condition of Room 1 are shown in Figure 4.6 and in Figure 4.7, respectively.

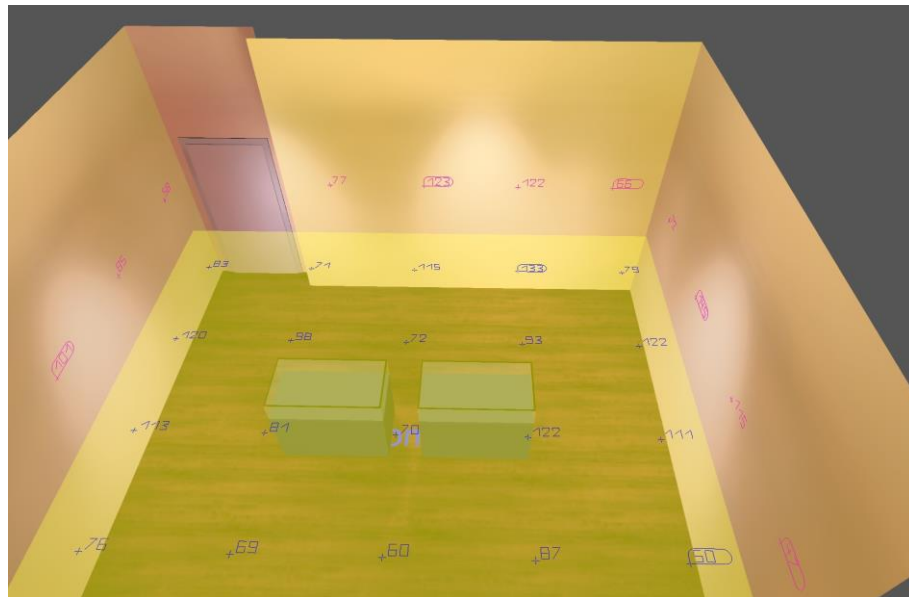


Figure 4.6. Light level (in lux) measurement results of Room 1

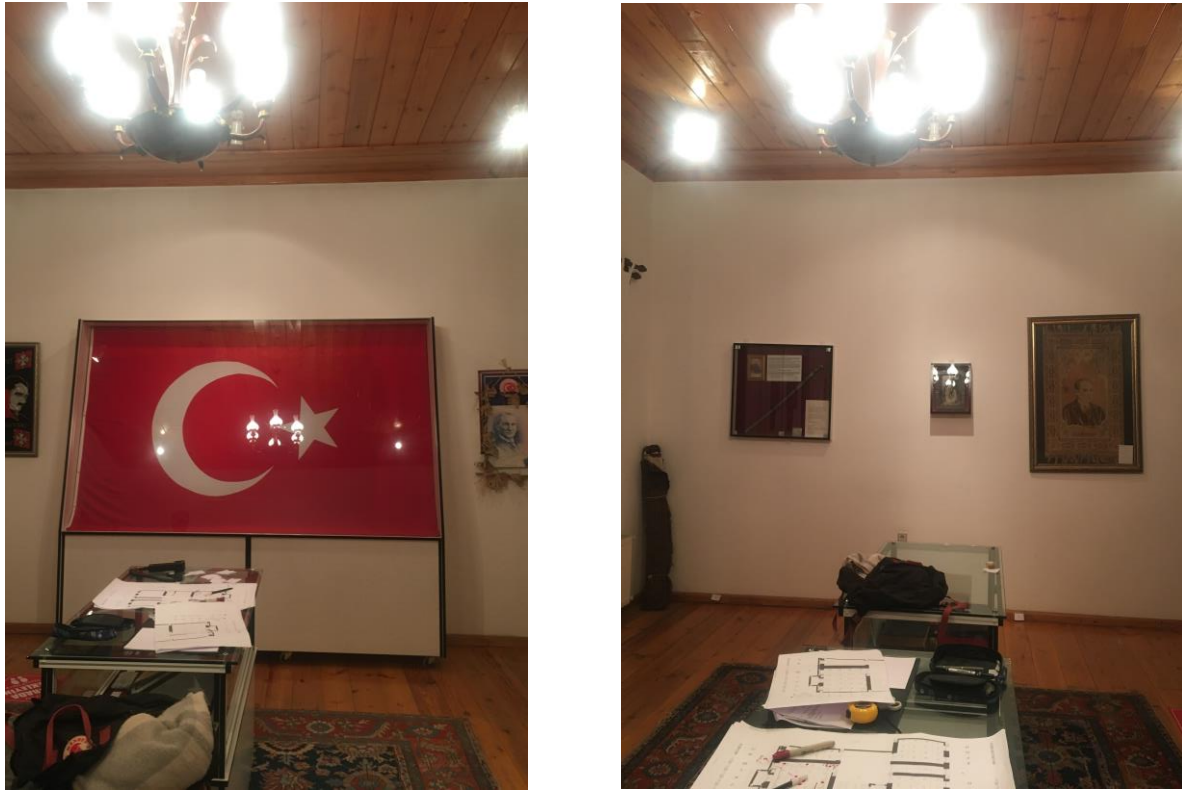


Figure 4.7. Existing condition of Room 1 (Author)

Room 1 is used to display multiple kinds of objects: books of different sizes and paper types, metal typewriters, Turkish flag, small metal, ceramic and copper objects, drawings, and photographs. Regarding the analysis, the following are the criticisms of Room 1 that are required to be improved.

1. Objects are not displayed according to their susceptibility to light. For example, old books, which are the most susceptible, are put together in the display cabinet with metal objects which are the least susceptible (Figure 4.9). This creates deterioration of the displayed objects.
2. The amount of light levels which books, drawings, and paintings are exposed to (Figure 4.6), are greater than the mentioned recommended light levels in Table 3.3 and Table 3.4 by IESNA. This creates both visual discomfort and deterioration of the displayed objects.

3. The beam of light on drawings hung on walls, is not directed to the displayed object, but on the top of it, illuminating the wall above (Figure 4.8). This distracts the focus of visitors' attention.
4. Proper display techniques of museology are not used. For instance, books are put on top of each other, in piles, with irrelevant objects on a table (Figure 4.10). This disorder of exhibition creates distraction, breaks the flow of visitor traffic, and decreases visiting time.
5. There is not any contrast between the background and the displayed object.



Figure 4.8. Moderately susceptible objects displayed in Room 1 (Author)



Figure 4.9. Highly, moderately, and least susceptible objects displayed in Room 1 (Author)



Figure 4.10. Highly and least susceptible objects displayed in Room 1 (Author)

b) Room 2

The measurement results and photographs of existing condition of Room 2 are shown in Figure 4.11 and in Figure 4.12, respectively.



Figure 4.11. Light level (in lux) measurement results of Room 2



Figure 4.12. Highly and moderately susceptible objects displayed in existing condition of Room 2 (Author)

Room 2 is used to display drawings and photographs, 2 luggage in display cabinets, and framed fabric works hung on the wall. Regarding the analysis, the following are the criticisms of Room 2 that are required for improvement.

1. Objects are not displayed according to their susceptibility to light. Luggage, which are moderately susceptible, are placed in the same displayed cabinet with cotton fabric clothes, which are the most susceptible (Figure 4.12). This creates deterioration of the displayed objects.
2. The amount of light levels which, drawings, photographs and fabrics are exposed to (Figure 4.11), are greater than the mentioned recommended light levels in Table 3.3 and Table 3.4 by IESNA [23]. This creates both visual discomfort and deterioration of the displayed objects.

3. Luggage is placed in different display cabinets without complying with any attractive display techniques to visitors (Figure 4.12). This disorder of exhibition creates distraction, breaks the flow of visitor traffic, and decreases visiting time.
4. Spotlights at each corner, and white, fluorescent tubes at the center of the ceiling are used as luminaires. It not only creates a glare reflected from the display cabinet but also over-illuminates the room.
5. There is not any contrast between the background and the displayed object.

c) Room 3

The measurement results and renders of existing condition of Room 3 are shown in Figure 4.13 and in Figure 4.14, respectively.

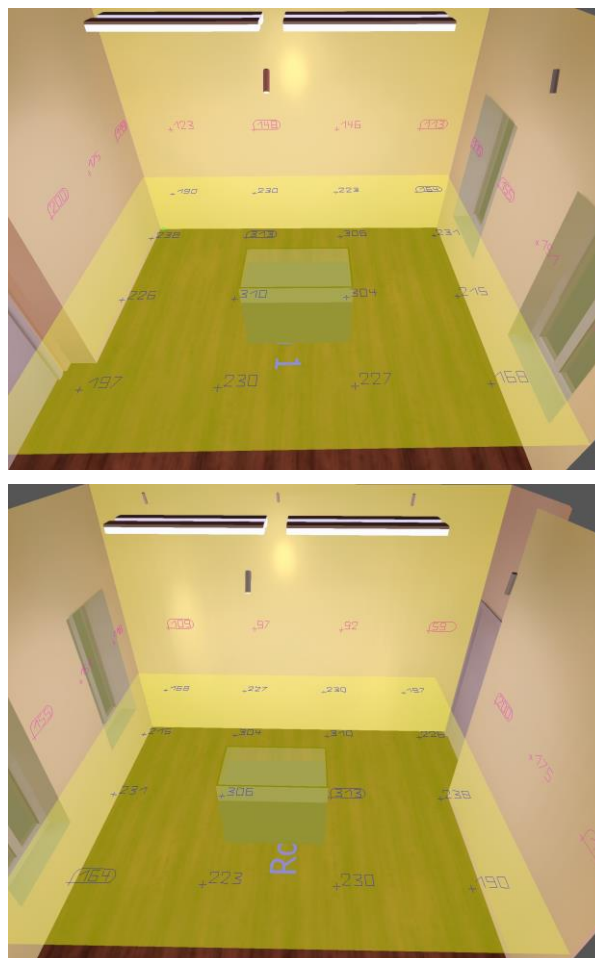


Figure 4.13. Light level (in lux) measurement results of Room 3



Figure 4.14. Existing condition of Room 3 (Author)

Room 3 is used to display fabric framed works, books, metal objects and natural stones rosaries. Regarding the analysis, the following are the criticisms of Room 3 that are required to be improved.

1. Objects are not displayed according to their susceptibility to light. Books, which is the most susceptible, are placed in the same displayed cabinet with metal objects and natural stone rosaries, which are the least susceptible (Figure 4.15). This creates deterioration of the displayed objects.
2. The amount of light levels which, fabrics are exposed to (Figure 4.13), are greater than the mentioned recommended light levels in Table 3.3 and Table 3.4 by IESNA [23]. This creates both visual discomfort and deterioration of the displayed objects.
3. As in Room 2, spotlights, and white, fluorescent tubes at the center of the ceiling are used as luminaires (Figure 4.16). It leads to a glare to be reflected from the display



d) Room 4

The measurement results and photographs of existing condition of Room 4 are shown in Figure 4.17 and Figure 4.18.



Figure 4.17. Light level (in lux) measurement results of Room 4



Figure 4.18. Existing condition of Room 4 (Author)

Room 4 is used to display drawings, photographs, and fabric framed works on both sides of the wall (Figure 4.19). Regarding the analysis, the following are the criticisms of Room 4 that are required to be improved.

1. Objects are not displayed according to their susceptibility to light. Cloth fabrics, which are the most susceptible, are illuminated by the same luminaire as moderately susceptible photographs (Figure 4.19). This creates deterioration of the displayed objects.
2. The amount of light levels which, fabrics are exposed to (Figure 4.17), are greater than the mentioned recommended light levels in Table 3.3 and Table 3.4 by IESNA [23]. This creates both visual discomfort and deterioration of the displayed objects.
3. White, fluorescent tubes at the center of the ceiling over-illuminate the room, which has a damaging effect on framed fabrics hung on the wall. It leads to a glare to be reflected from the display cabinet at the center of the room, and over-illuminates the room, which has a damaging effect on framed fabrics hung on the wall.
4. There is not any contrast between the background and the displayed object.
5. Due to its dimensions, Room 4 is not eligible for exhibition purposes as the flow of visitors' traffic is not practical.



Figure 4.19. Moderately and highly susceptible objects displayed in Room 4 (Author)

Table 4.1 is categorized as headings; ‘Type of Displayed Material’, ‘Displayed Artifact’, ‘Recommended Max. Illuminance’, ‘Used Luminaires’, and ‘Max. Illuminance exposed by the luminaires, which is also the results of measurements. It must be mentioned that in each room, each type of luminaire illuminates all types of objects.

Table 4.1. Exhibition categories of existing model

	Type of Displayed Material	Displayed Artifact	Recommended Max. Illuminance	Used Luminaires for all type of material	Max. Illuminance exposed by the luminaires
<b>Room 1</b>	• Highly susceptible	• Books, hand drawings	• 50 lux	<ul style="list-style-type: none"> <li>• Fluorescent light bulb-Pendant Light (at the center)</li> <li>• Track spotlight</li> </ul>	• 133 lux
	• Moderately susceptible	• Photographs	• 200 lux		• 145 lux
	• Least susceptible	• Metal objects	• Depends on the exhibition situation		
<b>Room 2</b>	• Highly susceptible	• Fabric clothes, hand drawings	• 50 lux	<ul style="list-style-type: none"> <li>• Fluorescent tube light (4 tubes at the center)</li> <li>• Track spotlight</li> </ul>	• 266 lux
	• Moderately susceptible	• Photographs, luggage	• 200 lux		• 149 lux
<b>Room 3</b>	• Highly susceptible	• Books, fabric framed artwork	• 50 lux	<ul style="list-style-type: none"> <li>• Fluorescent tube light (4 tubes at the center)</li> <li>• Track spotlight</li> </ul>	• 313 lux
	• Least susceptible	• Metal small objects	• Depends on the exhibition situation		• 200 lux
<b>Room 4</b>	• Highly susceptible	• Fabric framed artwork	• 50 lux	• Fluorescent tube light (2 tubes at the center)	• 167 lux

## **4.2. Suggested Models on the Environmental Perception in “Baskent University Abdürrahim TUNCAK Atatürk House Museum”**

By using software DIALux, the 2nd floor is re-modelled, and each room is re-designed as a proposal model. Before starting a designing process, 6 strategies are taken into consideration:

1. Creating a focus of attention to the displayed objects.
2. Minimizing the glare and reflection of light from surfaces.
3. The visibility of displayed objects.
4. Selecting luminaire types which emit light that is among the recommended light level range by IESNA, demonstrated in Table 3.3 and Table 3.4.
5. Categorizing artifacts within each room, according to their susceptibility to light.
6. Categorizing artifacts according to display techniques as well as their relatability to each other, for each room.

After selecting the type of luminaire, and the display location of each artifact, the light level exposure is adjusted by calculating the amount of illuminance (in lux) of each surface that artifacts are going to be displayed. Measured lux calculations are shown in related figures, with average lux measure on each type of display object. Subsequently, each value in the value chart is compared with the recommended value by IESNA. To make the displayed objects a focus of attention, a contrast is created between the hung frames and the wall. Dark gray color (color code of R:226 G:225 B:221) with reflective factor of 3% and reflective coating of 0% is used as a wall paint in all rooms. Forming a contrast color between the displayed objects and the wall not only creates visual comfort but also enhances the visitor experience and thus increases their visiting time. To add to that, with these reflective factors undesired glare reflected from frames and glass display cabinets are also reduced to a minimum level.

So as to make the exposed light level be in the recommended range, the color of paint used for the wall, the reflectance of the paint color used, the distance between the luminaire and the artifact, and the gross luminance of the luminaire are adjusted accordingly.

a) Room 1

Regarding the mentioned analysis and critics, the following are considered design strategies in Room 1.

1. Displayed objects are categorized according to their susceptibility to light; highly and moderately susceptible objects are exhibited in Room 1. This allows visitors to follow the exhibition easily.
2. The amount of light levels which cotton clothes, framed fabrics, hand drawings (highly susceptible) and luggage (moderately susceptible) are exposed to (Figure 4.24 and Figure 4.25), are in the range of mentioned recommended light levels in Table 3.3 and Table 3.4 by IESNA. This eliminates visual discomfort and allows protection of the displayed objects.
3. Suitable display techniques are used; cotton clothes, framed fabrics, hand drawings are hung on the wall, luggage are displayed on cylindrical platforms which vary in height (Figure 4.21 and Figure 4.22). The order of the exhibition creates attention, makes the flow of traffic more attractive, which increases the visiting time.
4. The angle of the luminaire is arranged at 20° and directed to the center of the displayed object (Figure 4.23). This directs visitors' focus of attention directly to the object.
5. A contrast is created between the background and the displayed object. Dark grey wall color is used. This makes the displayed object the focus of attention.

Highly susceptible objects – cotton clothes, framed fabrics, hand drawings – are hung on the wall, while moderately susceptible 3 luggage are displayed on cylindrical platforms which vary in height (Figure 4.21 and Figure 4.22). Framed objects are hung at a height of 73 cm from the floor, to allow efficient visibility. AA' section in Figure 4.23 illustrates the details of mounted luminaire positions in Room 1.

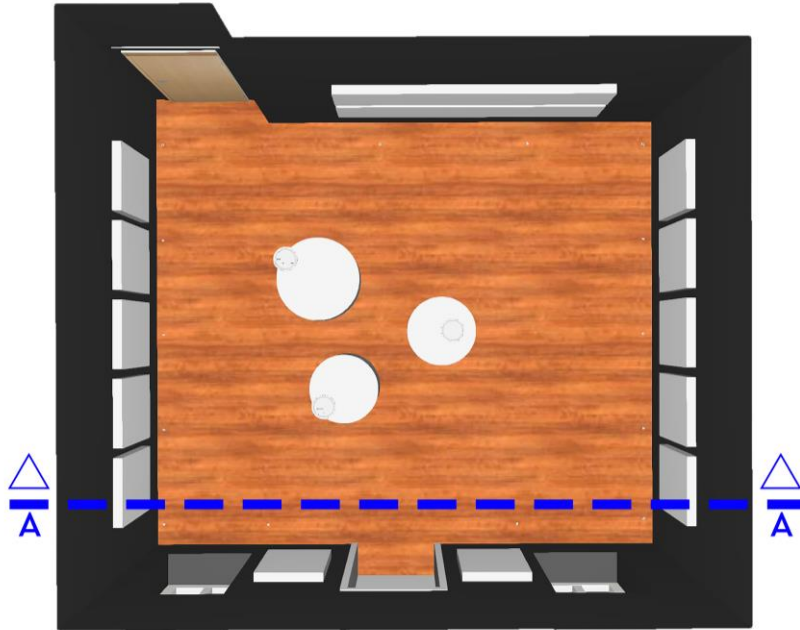


Figure 4.20. The perspective plan of Room 1



Figure 4.21. Proposed model of Room 1



Figure 4.22. Proposed model of Room 1

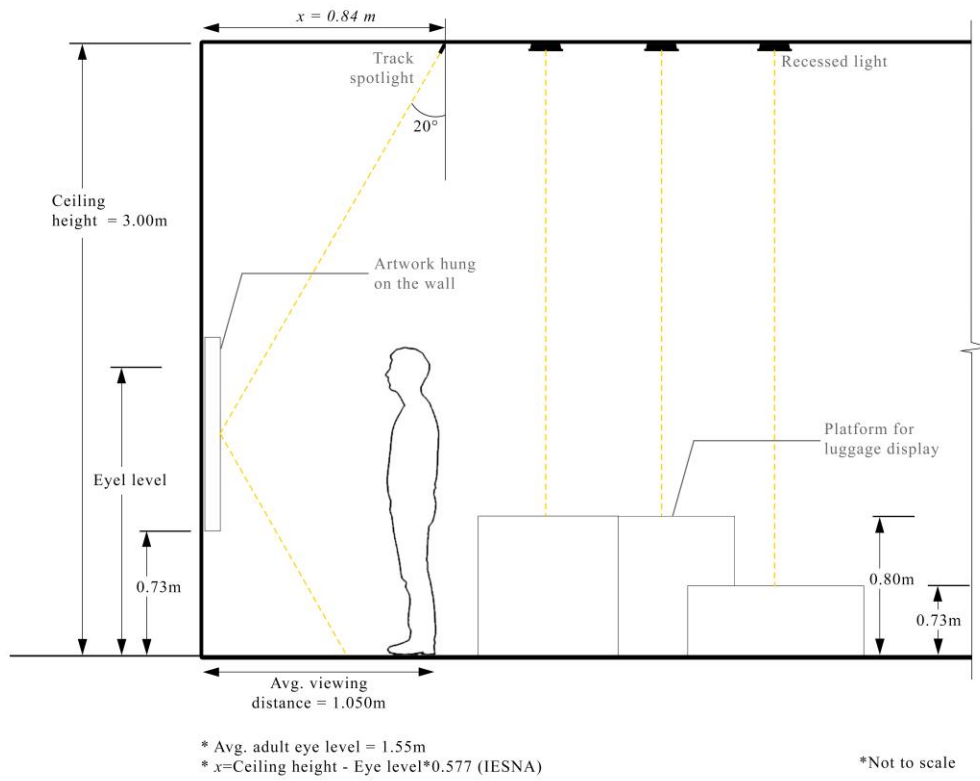


Figure 4.23. AA' Section - The mounted luminaire details in Room 1

As for the used luminaires, track lights are used for illuminating highly susceptible artifacts that are displayed on walls, such as cotton clothes, framed fabrics, hand drawings. For moderately susceptible luggage, a recessed ceiling light is used. The maximum illuminance exposed by spotlights and recessed light is 68 lux and 146 lux, respectively, which are in the range mentioned by IESNA in Table 3.3. The results of calculations are shown in Figure 4.24 and Figure 4.25.

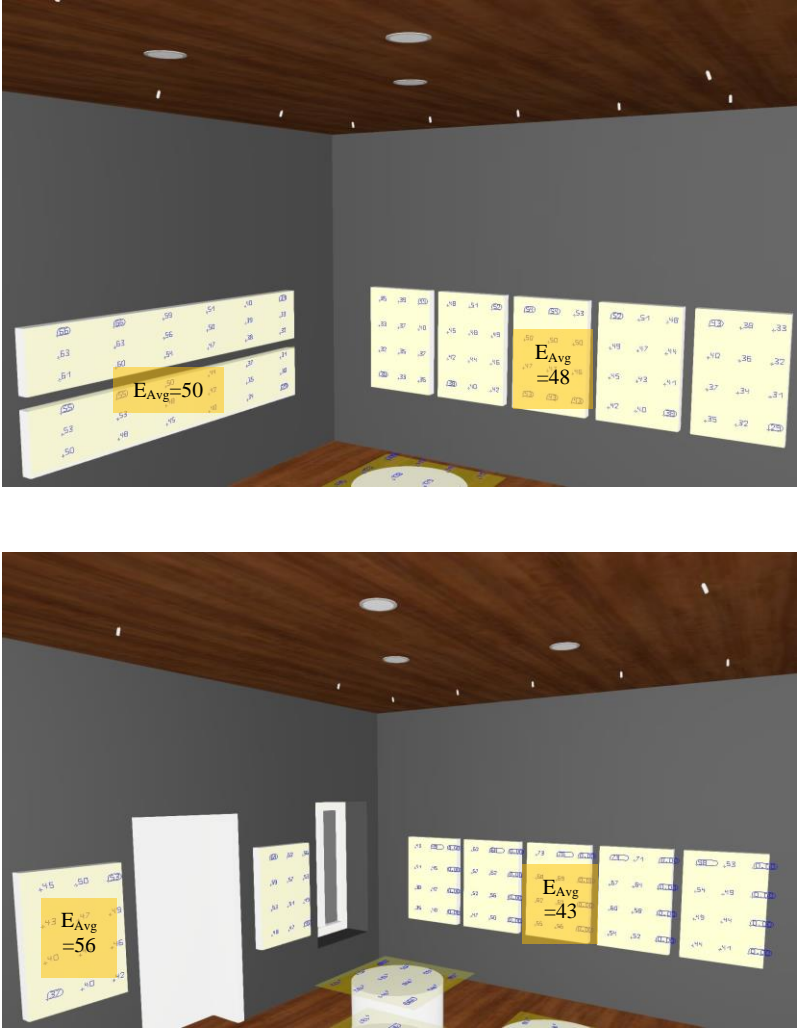


Figure 4.24. Light level calculation results (in lux) for highly susceptible artifacts (Cotton clothes, framed fabrics, hand drawings) in Room 1



Figure 4.25. Light level calculation results (in lux) for moderately susceptible luggage on platforms in Room 1

b) Room 2

Regarding the mentioned analysis and critics, the following are considered design strategies in Room 2.

1. Displayed objects are categorized according to their susceptibility to light; highly and least susceptible objects are exhibited in Room 2. This allows visitors to follow the exhibition easily.
2. The amount of light levels which drawings, photographs and fabrics (highly susceptible) and typewriters (least susceptible) are exposed to (Figure 4.31, Figure 4.32 and Figure 4.33), are in the range of mentioned recommended light levels in Table 3.3 and Table 3.4 by IESNA. This eliminates visual discomfort and allows protection of the displayed objects.
3. Suitable display techniques are used; hand drawings are hung on the wall, books are displayed in tilted and horizontal display cabinets, and three typewriters are displayed on cylindrical platforms with the height (Figure 4.27 and Figure 4.28). The order of the

exhibition creates attention, makes the flow of traffic more attractive, which increases the visiting time.

4. Recessed light for typewriters, spotlight for hung drawing and LED tape light for books in the cabinets are used for. The usage of different kinds of luminaire eliminates the over-illumination and undesired glare reflected from the display cabinets.
5. A contrast is created between the background and the displayed object. Dark grey wall color is used. This makes the displayed object the focus of attention.

Highly and least susceptible artifacts are selected to be displayed in Room 2. Among these highly susceptible artifacts, hand drawings are hung on the wall, books are displayed in tilted and horizontal display cabinets. Framed highly susceptible hand drawings are hung at a height of 73 cm from the floor, to allow efficient visibility. Three least susceptible typewriters are displayed on cylindrical platforms with the height of 130 cm and 90 cm (Figure 4.27 and Figure 4.28). BB' section and CC' section in Figure 4.29 and Figure 4.30 illustrate the mounted luminaires in Room 2, which rely on the guidelines mentioned by IESNA.

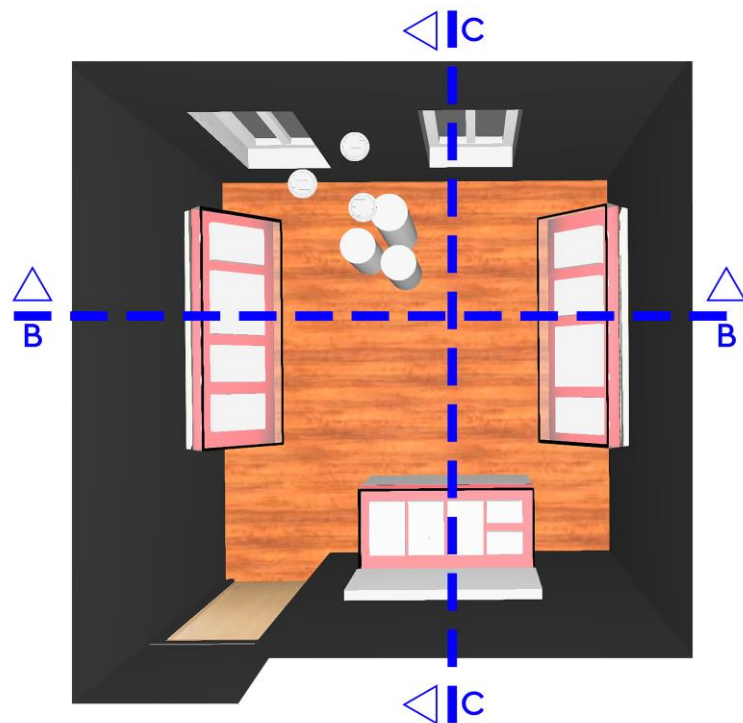


Figure 4.26. The perspective plan of Room 2



Figure 4.27. Proposed model of Room 2



Figure 4.28. Proposed model of Room 2

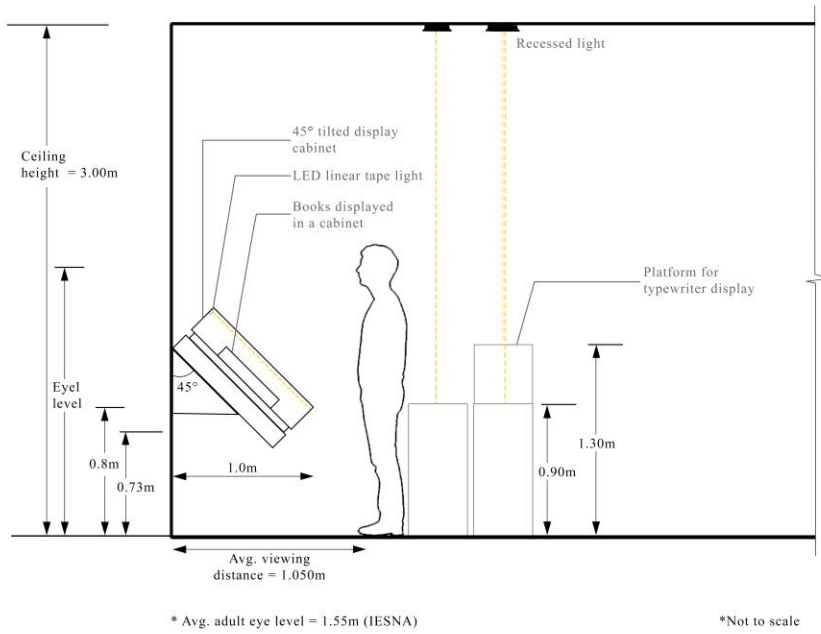


Figure 4.29. BB' Section – The mounted luminaire details in Room 2

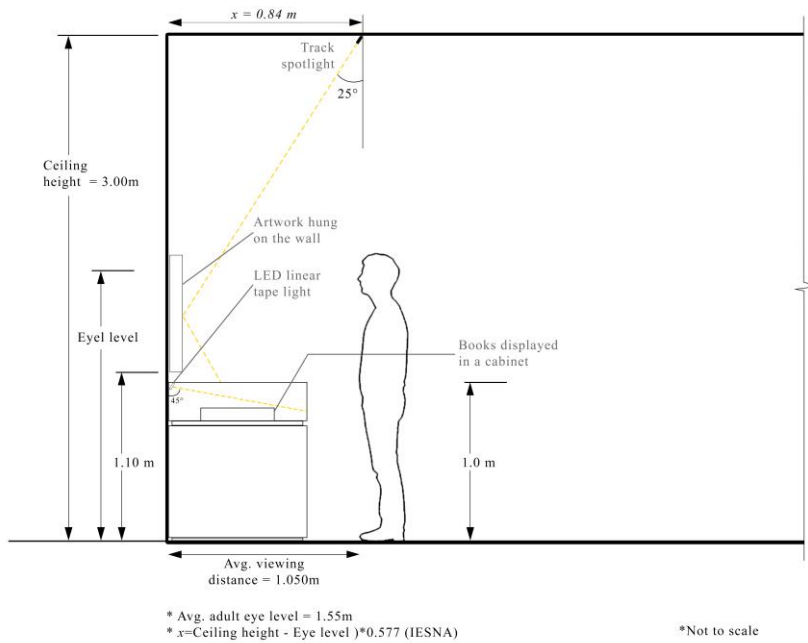


Figure 4.30. CC' Section – The mounted luminaire details in Room 2

The maximum illuminance exposed by each type of luminaire are in the range mentioned by IESNA in Table 3.3. The maximum illuminance exposed by spotlight on drawings, recessed light on typewriters, and LED linear light on the displayed books is 38 lux, 191 lux, and 70 lux, respectively. The results of calculations are shown in Figure 4.31, Figure 4.32, and Figure 4.33.

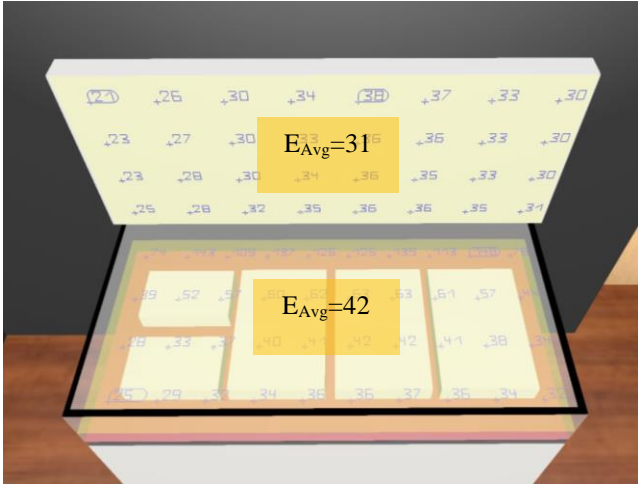


Figure 4.31. Light level calculation results (in lux) for highly susceptible books in display cabinet and hung hand drawings in Room 2

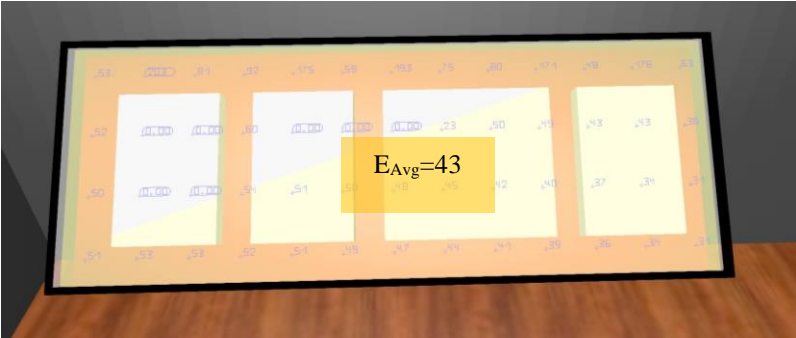


Figure 4.32. Light level calculation results (in lux) for highly susceptible books in Room 2

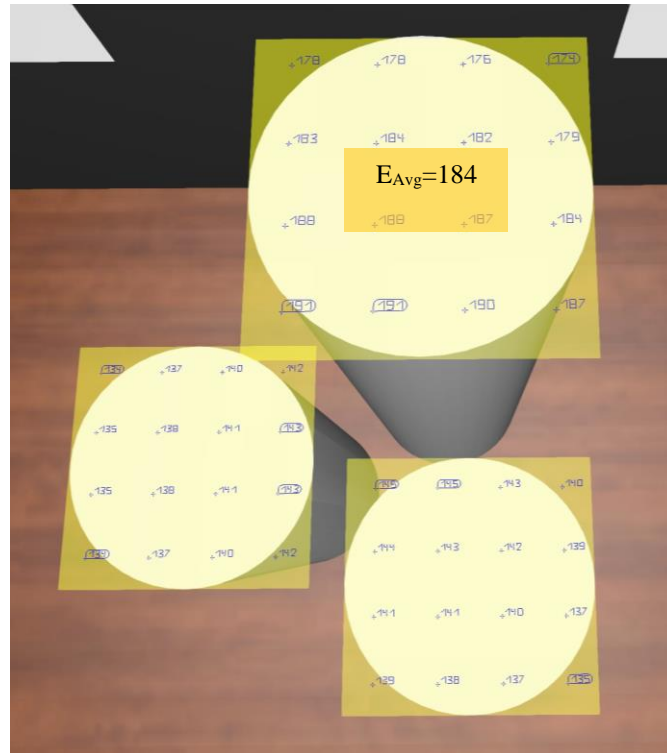


Figure 4.33. Light level calculation results (in lux) for least susceptible objects (typewriters) in Room 2

### c) Room 3

Regarding the mentioned analysis and critics, the following are considered design strategies in Room 3.

1. Displayed objects are categorized according to their susceptibility to light; moderately (photographs) and least susceptible objects (small metal objects and stone rosaries) are exhibited in Room 3. This allows visitors to follow the exhibition easily.
2. The amount of light levels which photographs (moderately susceptible) and rosery stones (least susceptible) are exposed to (Figure 4.38 and Figure 4.39), are in the range of mentioned recommended light levels in Table 3.3 and Table 3.4 by IESNA. This eliminates visual discomfort and allows protection of the displayed objects.
3. A recessed light for the least susceptible objects in the display cabinet, and a track spotlight for hung photographs are used as luminaires. The usage of different kinds of

luminaire eliminates the over-illumination and undesired glare reflected from the display cabinets.

4. A contrast is created between the background and the displayed object. Dark grey wall color is used. This makes the displayed object the focus of attention.

Moderately susceptible selected photographs are hung on the wall, least susceptible small metal objects and natural stone roseries are displayed in display cabinet at the center of the room (Figure 4.35 and Figure 4.36). Regarding their dimensions, moderately susceptible photographs are hung at a height of 110 cm from the floor, to allow efficient visibility. DD' section in Figure 4.37 illustrates the mounted luminaires in Room 3, which rely on the guidelines mentioned by IESNA.

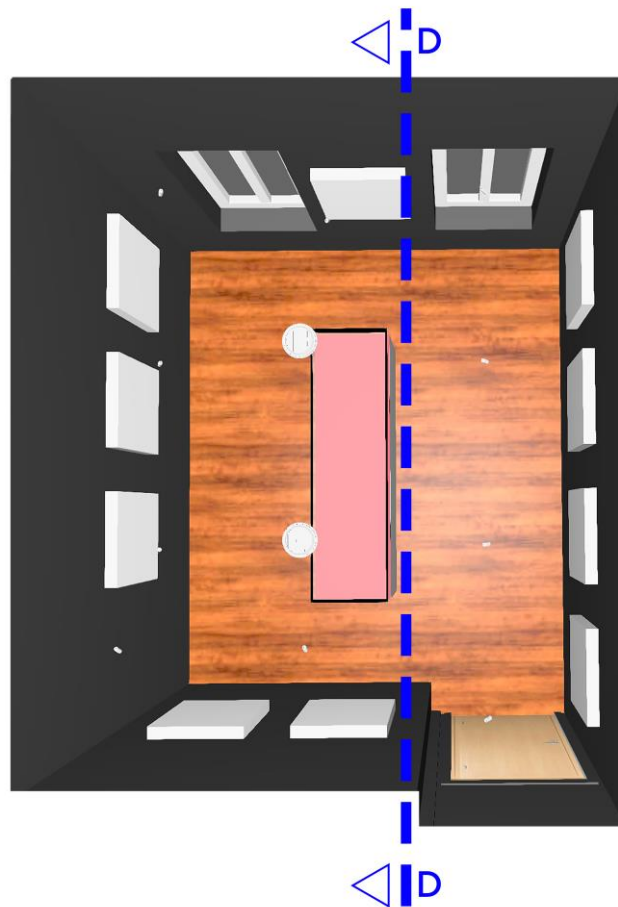


Figure 4.34. The perspective plan of Room 3



Figure 4.35. Proposed model of Room 3



Figure 4.36. Proposed model of Room 3

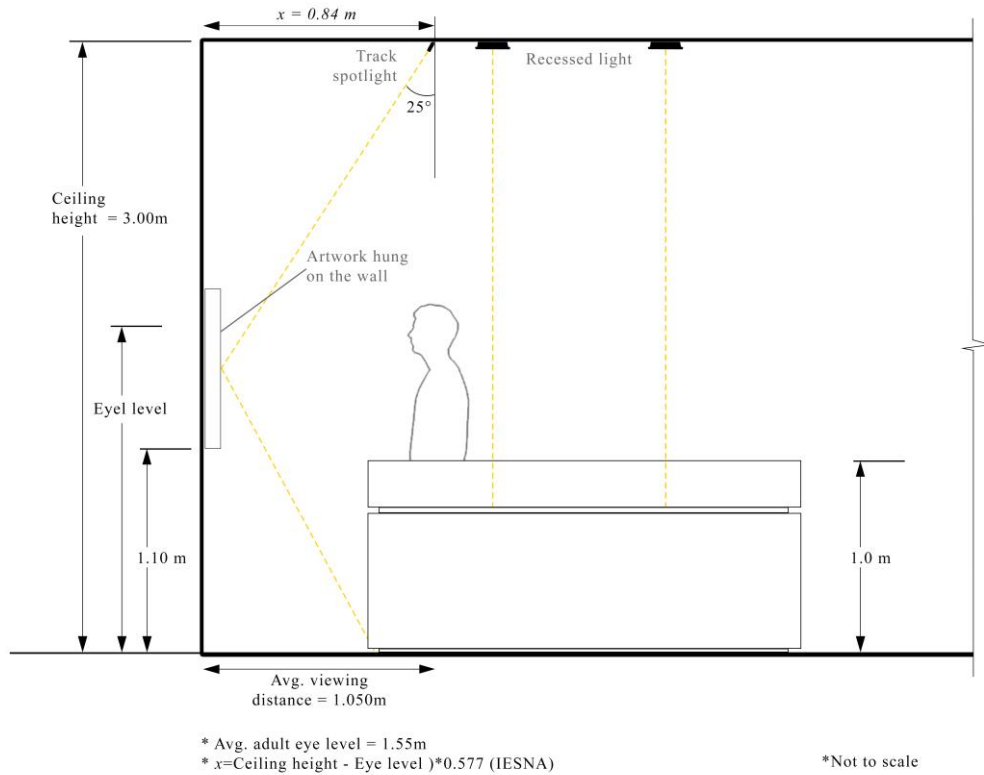


Figure 4.37. DD' Section – The mounted luminaire details in Room 3

The maximum illuminance exposed by each type of luminaire are in the range mentioned by IESNA in Table 3.3. The results of calculations are shown in Figure 4.38 and Figure 4.39. The maximum illuminance exposed by spotlight on moderately susceptible drawings and by recessed lights on the least susceptible artifacts is 185 lux (Figure 4.38) and 78 lux (Figure 4.39), respectively.

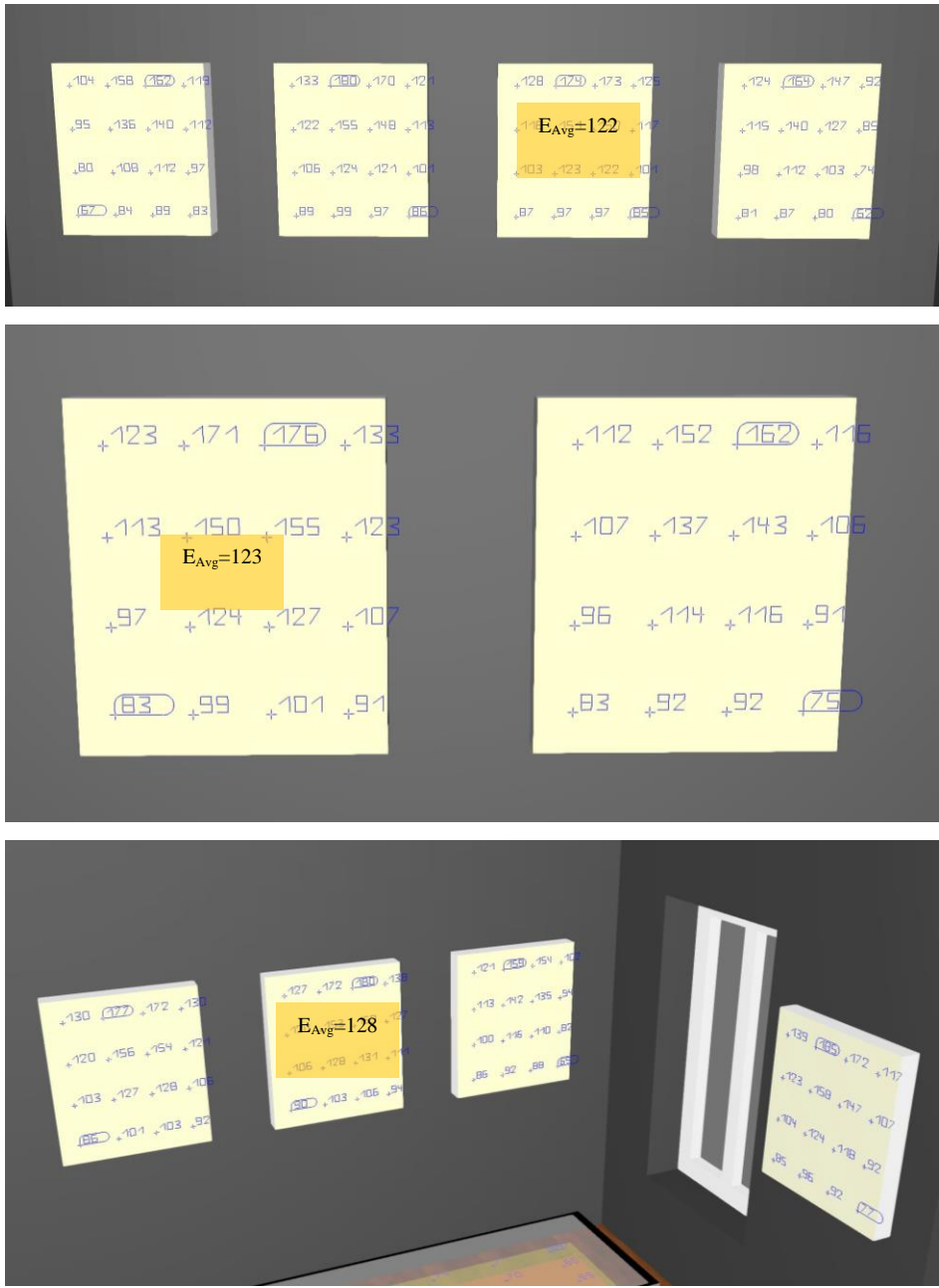


Figure 4.38. Light level calculation results (in lux) for moderately susceptible photographs in Room 3

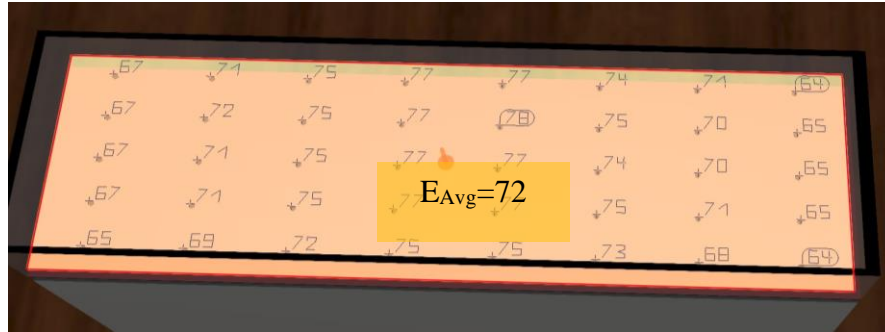


Figure 4.39. Light level calculation results (in lux) for least susceptible artifacts (small metal objects, natural stone roseries) in Room 3

d) Room 4

Regarding the mentioned analysis and critics, the following are considered design strategies in Room 4.

1. Due to its small dimensions, Room 4 is decided to be used as a digital LED screen exhibition room for displaying scanned photographs and drawings. This eliminates any risk of deterioration.
2. A contrast is created between the background and the LED screen. Dark grey wall color is used. This eliminates visual discomfort and creates a focus of attention.

The luminous brightness of LED screens is measured in luminous intensity per square meter,  $\text{cd/m}^2$  or nit(s). The higher the value, the brighter the display [30]. Adjusting the brightness of LED screen display at correct level is important because if the screen is not bright enough the images and videos will not be visible. Likewise, if the screen is brighter than the recommended range, then it will lead to visual discomfort.

A touch sensitive LED screen gallery on the table with luminous intensity of 800 nits, and an interconnected LED screen above with luminous intensity of 600 nits, are decided to be used (Figure 4.41). According to Adhaiwell (2023), the recommended range for most indoor LED screen displays is 500 to 1500 nits. The digital touch sensitive LED screen gallery allows visitors to drag, select, and zoom in the photographs, and the LED screen above displays the photographs that visitors selected. By this way, photographs do not get damaged by any kind of external light source.

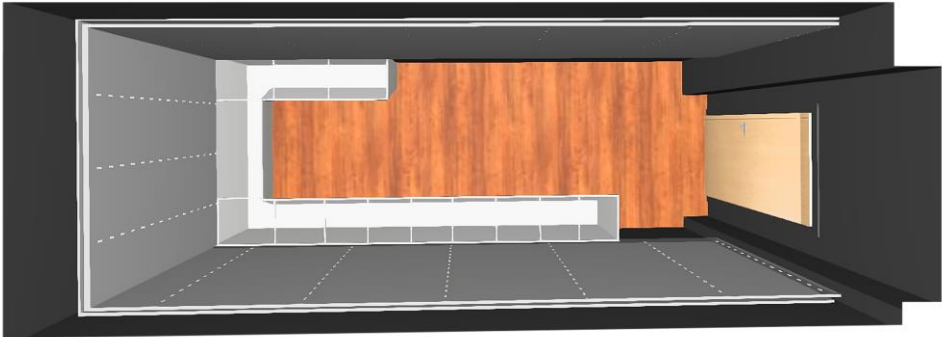


Figure 4.40. The perspective plan of Room 4



Figure 4.41. Proposed model of Room 4

### Luminaires used in Room 1, Room 2 and Room 3

Three different types of luminaires, which are track spotlight, recessed ceiling light, and LED linear spotlight, are used in Room 1, Room 2 and in Room 3. General properties and technical details of each luminaire is described in Table 4.2. Further details of luminaires can be accessed from the data sheet mentioned in the references. According to the susceptibility of objects displayed, the luminous flux of each type of luminaire is adjusted for each room. Being high quality products, mostly used in the market, and open accessibility of DIALux compatible 3D models of all three luminaires, are the main reasons of selecting them.




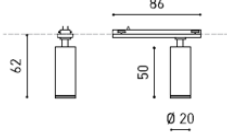
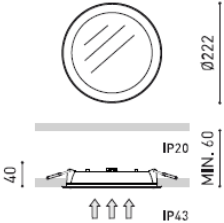
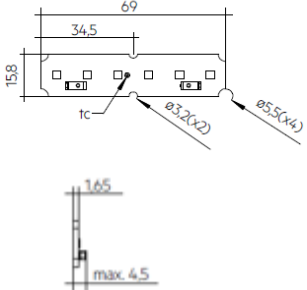
FIT 20 24V by ARKOS LIGHT is the used luminaire as track lights. MIX 1 3000K W by ARKOS LIGHT is the used luminaire as recessed ceiling light. LED linear tape light by TRIDONIC Lights, are used inside of display cabinets for illuminating highly susceptible books.

In Room 1 and in Room 2, 127 lumen of gross luminance flux and 2700 K of color temperature is used in track spotlight FIT 20 24V by ARKOS LIGHT for illuminating highly susceptible objects [31]. In Room 3, by adjusting the luminous power to illuminate moderately susceptible drawings on the wall, 350 lumen of gross luminance flux color temperature of 2700 K is used in track spotlight FIT 20 24V by ARKOS LIGHT [31].

1650 lumen of gross luminance flux and 3000 K of color temperature is used in recessed ceiling light MIX 1 3000K W by ARKOS LIGHT in each room, for illuminating least susceptible objects [32].

LED linear tape light by TRIDONIC Lights is used inside of display cabinets for illuminating highly susceptible books. By adjusting their luminous power, 5 LED lamps, each of 30 lumen and 2700 K color temperature, are located inside of each display cabinet [33].

Table 4.2. Properties and technical details of luminaires used

<b>LUMINAIRES USED</b>			
	<b>FIT 20 24V by Arkos Light [31]</b>	<b>MIX 1 3000K W by Arkos Light [32]</b>	<b>Tape LED by Tridonic Lights [33]</b>
			
<b>Dimensions</b>			
<b>Technical Data</b>			
Category	Tracklights	Ceiling Recessed	Linear tape light
Light source	LED	LED	LED
Gross luminous flux	127 lm / 150 lm	1,650 lm	325 lm
Efficacy	71 lm/W	157 lm/W	183 lm/W
Power	2,1 W	10,5 W	-
Color temperature	2700K	3000 K	2700 K
Color Rendering Index	CRI>90	CRI>90	CRI>80
Light efficiency	87%	83%	High efficiency
LED lifespan	L80B10 >50.000h	L80B10 >60.000h	72,000 h
Sealing	IP20	IP43	IP00

### 4.3. Evaluation

The evaluation is done according to 6 design strategies.

1. Creating a focus of attention to the displayed objects.
2. Minimizing the glare and reflection of light from surfaces.
3. The visibility of displayed objects.
4. Selecting luminaire types which emit light that is among the recommended light level range by IESNA, demonstrated in Table 3.3 and Table 3.4.
5. Categorizing artifacts within each room, according to their susceptibility to light.
6. Categorizing artifacts according to display techniques as well as their relatability to each other, for each room.

#### In existing model:

The wall color is off-white color, which distracts the focus of attention. The positions of used luminaires do not follow IESNA guidelines. This increases glare and reflection of light from surfaces especially display cabinets. Both the distance between the luminaire and the displayed object, and the luminous intensity of the luminaires do not follow IESNA guidelines (Figure 3.6 and Table 3.3). The distance to the artwork is smaller than the recommended distance, which leads to lux levels that are greater than the recommended maximum illuminance. The angle of mounted luminaire is also not considered. Instead of focusing the light beam at the center of the artwork, most luminaires are mounted in such a way that the light element illuminates the wall above the artwork. The majority of framed objects are hung at greater than 150 cm above the floor. This makes it hard to observe and read hung photographs, drawings, and other artworks. As shown in Table 4.1, the display technique in the existing model does not consider the different susceptibility levels of displayed objects. This disorder is also valid for the relatability of displayed objects within each other. While all these unconsidered factors cause artwork to get damaged sooner than their expected time, it also downscales visitors' experience as it causes glare and less attractive display rooms.

#### In proposed model:

A dark grey wall color is proposed that allows integration of artworks within the exhibition space. The distance between the luminaire and the displayed object is calculated referencing the

formula given by IESNA (Figure 3.6), and the angle of luminaire is adjusted accordingly. This minimizes the undesired glare. The center of framed hung photographs, drawings, and other artifacts, corresponds at eye level enabling the visibility. As for the luminous intensity, luminaires are chosen according to their luminous power. Lux measurements calculated by DIALux software (Table 4.3) show that calculations are within the range of maximum illuminance recommended by IESNA in Table 3.3. To add to that, each room is categorized according to the susceptibility to light as well as relatability to each other in terms of concept and theme, as seen in Table 4.3.

To sum up, the following are general factors achieved in the Abdürrahim Tuncak Atatürk House as a result of the analysis.

**1. Keeping visitors' focus of attention and visiting time at the maximum level as possible by:**

- Categorizing all displayed objects in each room according to their susceptibility to light and their related concept, which creates order and easy flow of traffic.
- Choosing different exhibition techniques for different kinds of exhibition objects.
- Creating a contrast between the background and the displayed object.

**2. Protecting artifacts and maximizing visual comfort by:**

- Arranging all light exposure levels of objects to be in the range of recommended light levels by IESNA.

**3. Eliminating over-illumination and undesired glare by:**

- Using various kinds of luminaires with different luminance power.

Similar to Table 4.1, Table 4.3 is also categorized with the same headings; 'Type of Displayed Material', 'Displayed Artifact', 'Recommended Maximum Illuminance', 'Used Luminaire(s)', 'Max. Illuminance exposed in proposal model', and 'Max. Illuminance exposed in existing model'. By this way, existing and proposed models can be compared reliably. The most important factor, which is the maximum illuminance exposed by the luminaire is controlled in proposed model by calculation in DIALux software. In Table 4.3, extra heading, 'Max. Illuminance exposed in existing model', is added so that the light levels of materials displayed in both existing and proposed model can be compared in the same table. When the

last 2 columns of Table 4.3, are compared, it can be read that light levels, which exceed the maximum recommended illuminance range in existing model, are decreased to acceptable ranges in proposed model. For example, as shown in Table 4.3, in Room 1 of the existing model, highly susceptible materials are exposed to 266 lux. This number is reduced to 68 lux in the proposed model. Similarly in Room 2 of the existing model, the light level that highly susceptible drawings and books are exposed to are 266 lux and 313 lux, respectively. These figures are reduced to light levels of 38 lux and 70 lux.

Table 4.3. Exhibition categories of proposed model

Room Number	Type of Displayed Material	Displayed Artifact	Recommended Max. Illuminance	Used Luminaire(s)	Max. Illuminance exposed in existing model	Max. Illuminance exposed in proposal model
<b>Room 1</b>	• Highly susceptible	• Cotton clothes, framed fabrics, hand drawings	• 50 lux	• Spotlight: FIT 20 24V	• 266 lux	• 68 lux
	• Moderately susceptible	• Luggage	• 200 lux	• Recessed Ceiling Light: MIX 1 3000 K	• 149 lux	• 146 lux
<b>Room 2</b>	• Highly susceptible	• Drawings	• 50 lux	• Spotlight: FIT 20 24V	• 266 lux	• 38 lux
	• Highly susceptible	• Books	• 50 lux	• LED Linear Tape Light	• 313 lux	• 70 lux
	• Least susceptible	• Typewriter	• Depends on the exhibition situation	• Recessed Ceiling Light: MIX 1 3000 K	• 145 lux	• 191 lux
<b>Room 3</b>	• Moderately susceptible	• Photographs	• 200 lux	• Spotlight: FIT 20 24V	• 149 lux	• 185 lux
	• Least susceptible	• Small metal objects, natural stone roseries	• Depends on the exhibition situation	• Recessed Ceiling Light: MIX 1 3000 K	• 200 lux	• 78 lux
<b>Room 4</b>	• Not susceptible	• Digital photographs	• None	• LED touch-screen • LED screen on wall	• None	• None

## 5. CONCLUSION AND RECOMMENDATIONS

The impact of artificial lighting and color on museums and exhibits was investigated. Aimed to enhance both visitor experience and displayed object protection, the correct selection of artificial lighting, color, and exhibition techniques will allow visitors to feel more engaged as well as increase the lifespan of artifacts. After analyzing the luminosity levels of luminaires, the wall paint color, the categorization of displayed objects, and general visibility of displayed artifacts in the existing model, a new model is proposed. As a result of processes of analysis, measurements, designing and test modelling, 6 outcomes are derived.

- Creating a focus of attention to the displayed artifact increases the visitors' museum experience.

Distractions are minimized, which also solves wayfinding problems. To make this, a contrast should be created between the background and the displayed figure. 'Background' does not necessarily mean the wall, but the floor material, display case color or even platform color as well. One way of achieving this is selecting a contrasting paint color. If the hung artifact on the wall is light colored, then dark colored wall paint is suggested, and vice versa.

- Minimizing glare and reflection of light from surfaces can increase visual comfort.

This is another important factor in room design because reduced visual comfort is also associated with reduced visiting time and unfavorable visitor experience. The angle between the luminaire and the mounted surface is the most crucial factor that glare relies on. The reflection factor and the type of surface material are also among the factors that affect the severity of glare. This issue gives extra importance to objects with reflective material. Especially, when an object material is glass or coated with material with high reflective factor, or when there is a glass layer between the observer and the displayed object, then glare becomes a crucial determinant. The angle should be arranged in such a way that the reflected light ray does not come to the eye.

- Creating an efficient visibility of displayed objects is significant.

The visibility of displayed objects is one of the main factors in exhibition room designs. The center of the displayed object should be at the same/similar height as eye level as possible. Otherwise, when observing the exhibited object, looking at too high or too low creates a visual

discomfort. The average adult eye level is 150 cm. When deciding the visibility of displayed objects, visitors with wheelchairs should also be among the considered issues.

- The exposed light level should not exceed the recommended ranges mentioned by IESNA.

The luminaire type and the luminosity level of the luminaire are the factors which affect the lighting level that the light fixture emits. Different types of materials have different maximum recommended lux level exposure. To protect the quality of material at the highest level as possible, the exposed light level should not exceed the recommended ranges mentioned by IESNA (Table 3.3 and Table 3.4). Before installing the light fixture, the maximum exposure of the luminaire to the exhibited objects should be measured and compared with recommended values.

- Categorization of displayed objects brings an order to the exhibition room.

This creates a theme or a concept allowing visitors to follow the exhibition in a more practical and attractive manner. Several types of categorizations can be applied to different museums. Categorization of objects by their susceptibility to light, conceptual categorization (selecting artifacts with related themes such as books and typewriters, or clothes and luggage) are some of them. Apart from creating an order, selecting a luminaire type to illuminate objects with similar susceptibility levels is practical.

- Using substantial kinds of display techniques allows visitors to have a unique visiting experience.

For example, exhibiting books on tilted display cases, or framed drawings on wall gives visitors a flexibility of observation.

The analysis, results and recommendations in this thesis study can be used as guidance in similar types of museums with similar factors that are open to improvement. However, there is still room for improvement. The effect of UV light on different kinds of materials – cotton, wood, leather, natural stone etc., and relating protection measurements, in various functional and larger spaces, the user experience, the cost of luminaires the effect of glare on various materials and visual comfort, can be worked on in future studies.

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