ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF ARTS AND SOCIAL SCIENCES

THE HUMAN CENTRIC LIGHTING CONCEPT: A PROPOSAL FOR AN OFFICE INTERIOR

M.A THESIS

Cennet Gökcen KÖSELİ

Department of Interior Design

International Master of Interior Architectural Design M.A. Programme

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Thesis Advisor: Prof. Dr. Alpin KÖKNEL YENER

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Cennet Gökcen KÖSELİ
(418151004)

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Tez Danışmanı: Prof. Dr. Alpin KÖKNEL YENER

ARALIK 2018

Cennet Gökcen Köseli, a M.A student of ITU Graduate School of Arts and Social Sciences student ID 418151004, successfully defended the thesis/dissertation entitled "THE HUMAN CENTRIC LIGHTING CONCEPT: A PROPOSAL FOR AN OFFICE INTERIOR", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :	**Prof. Dr. Alpin KÖKNEL YENER** Istanbul Technical University	.....
Jury Members :	**Assoc. Prof. Dr. Özge CORDAN** Istanbul Technical University	.....
	Prof. Dr. Banu MANAV Ayvansaray University	.....

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To my family,

FOREWORD

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Lighting Designer

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ABBREVIATIONS

ADHD	**:** Attention Deficit Hyperactivity Disorder
CCT	**:** Correlated Colour Temperature
CIBSE	**:** Chareted Institution of Building Services Engineers
CIE	**:** International Comission of Illumination
CRI	**:** Colour Rendering Index
DIN	**:** Deutsches Institut für Normung
EN	**:** European Normung
HCL	**:** Human Centric Lighting
IESNA	**:** Illuminating Engineering Society of North America
K	**:** Kelvin
lm	: Lumen
MK	**:** Mega Kelvin
NEI	**:** National Eye Institute
OCR/MCR	**:** Automatic Identification and Data Collection
PMMA	**:** Para-Methoxymethamphetamine
Ra	**:** Colour Rendering Index
SAD	**:** Seasonal Effective Disorder
UGR	**:** Unified Glare Rating
Uo	**:** Uniformity

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THE HUMAN CENTRIC LIGHTING CONCEPT: A PROPOSAL FOR AN OFFICE INTERIOR

SUMMARY

As people spend more time indoors, their contact with daylight decreases. For human beings, daylight is a critical need for their bodily processes, physical and psychological health. When designing interiors, it is essential to provide a good quality of life, healthy, motivational, and productive environments to human beings. The lighting is one of the crucial elements of interior design.

There are international standards for quality lighting to supply the vital needs to people. These regulations are regulated to provide the users with a good vision, quite correct perception, and adequately supply environmental information. However, the standards consider only the visual effects of light; there is also non-visual effects of light which have been not enough placed in them. Modern lighting concepts, therefore, take into account not only the visual but also the non-visual lighting effects and promote the well-being, mood, and health of the person. In the human body, there are kinds of biochemical process ongoing. The production of hormones and their effects on circadian rhythm are affected by both daylight and artificial light.

Therefore, there is a new lighting design concept; 'Human Centric Lighting (HCL)'. This design concept has been created in recent years to meet the basic light needs of people in the changing world. The HCL concept considers both visual and non-visual effects of light when designing a lighting concept for spaces. The new lighting design processes for interiors should be considered with these essential criteria, and take human at the centre of the design process.

In this thesis, first, the effects of lighting on human beings have been explained. The effects were investigated in two main headlines; visual effects of light and non-visual effects of light. The visual effects of light were evaluated vision, perception, and information (cognition) as they stated in the literature. The visual lighting characteristics have been shown. The non-visual effects of light on human beings, which are related to human bodily cycles and hormones, have been explained after visual effects. The visual and non-visual effects of lighting, the HCL concept has been given in details, and how significant in people's lives.

In the third section, interior spaces in offices have been investigated from literature and explained. The development of office interior design by the time and how it was affected by the developing technologies have been clarified. Then lighting design concepts, which have been used when designing an office luminaire concept, were explicated. They are quantitative-based, luminance-based, and perception-oriented lighting concepts. Through these concepts, it has been defined how today's lighting design approach has been achieved. Then there have been three examples, designed based on these three concepts. The project Microsoft Headquarters in Vienna, CMS Bureau Francis Lefebre in Paris, and Ströer News Publishing GmbH in Berlin have been shown. These projects have been designed with existing market products.

In the fourth section, there has been an implementation of lighting design to a design office. First, the design office and the existing lighting situation have been explained. Then the occupants and their activities have been defined. Then space has been divided into three areas depending on the activities, and in order to fulfil the needs of occupants and their activities during the day, there has been a lighting design proposal given. The lighting should be suitable any time of a day, any activities of users. So, there have been nine scenarios depends on the observations. In the project, three products from the market have been used as the references. Product A is a pendant downlight, product B is a table light as a task light, and product C is also a pendant downlight.

The required visual needs have been fulfilled with product A, B, and C. Moreover, there have been entirely five suggestions to these products in order to provide the HCL concept in the office. The existing products in the market have some of these features, but not all of them provide all HCL concept requirements in space. Therefore, by using with existing product and by adding new features to them, there has been new product proposals for future lighting product design processes were aimed.

In the conclusion section, the importance of the study has been explained. Then the project has been evaluated based on visual needs. Then the suggestions to the existing products have been given in order to provide HCL concept.

The aims of the thesis are pointing out the importance of lighting in spaces for human beings and explaining the HCL concept. The lighting design steps have been shown in project implementation. Moreover, there have been suggestions to the existing products and lighting designs.

İNSAN ODAKLI AYDINLATMA TASARIM KONSEPTİ: OFİS İÇ MEKANI İÇİN BİR ÖNERİ

ÖZET

Dünya ve insanlar, gelişen teknolojiler ve iletişim çağıyla birlikte hızla değişmektedir. Bu değişim, insanların hem özel hayatlarına, hem de iş hayatlarına yansımaktadır. İnsanların ihtiyaçları da her geçen gün farklılaşmaktadır. Geçmişten günümüze yaşanan bu süreç ile birlikte, insanın dış dünyada geçirdiği zaman azalmıştır. Özellikle çalışma hayatında yapılan işler ve bunların tanımları yeniden değerlendirilmektedir.

Kapalı mekanlarda çok fazla zaman geçiren insanlar, günışığından yeterince yararlanamamaktadır. Günışığının insan sağlığı üzerindeki etkileri ve faydaları gözardı edilmektedir. Yeterince günışığı alamayan insanlarda fiziksel ve psikolojik rahatsızlıklar meydana gelmektedir. Son yıllarda yapılan çalışmalar ile bu rahatsızlıkların önemi iyice ortaya çıkmıştır. Yapılan araştırmalar gösteriyor ki, yeterli günışığı alamayan insanlarda hastalıklar çoğalmaktadır. Özellikle psikolojik rahatsızlıklar nedeniyle oluşan depresyon ve iş temposuyla gelen stresle baş etme gün geçtikçe zorlaşmaktadır. Bu da insanların hem iş hayatlarına hem de özel hayatlarına olumsuz etki yapmaktadır.

Bu sebeple iç mekan tasarımlarında insan sağlığı göz önünde bulundurulmalıdır. Doğadan kopuşla birlikte uzaklaşılan günışığı, iç mekan aydınlatmalarının iç mekan tasarım elemanı olarak önemini daha da ortaya çıkarmaktadır. Mekanlar tasarlanırken, insanlara iyi bir yaşam kalitesi, sağlıklı, motive edici ve üretken ortamlar sağlamak şarttır. Bu kriterler sağlanırken iç tasarımın önemli unsurlarından biri aydınlatmadır. Gerekli koşullar yapay aydınlatma aygıtları ile sağlanmaya çalışılmaktadır. Bu çalışmada, özellikle insanların evlerinden sonra en çok vakit geçirdikleri iç mekanlar olan ofisler ve bunların aydınlatma tasarımları değerlendirilmiştir.

Bu tezde öncelikle aydınlatmanın insan üzerindeki etkileri açıklanmıştır. Etkiler iki ana başlıkta incelenmiştir; ışığın görsel etkileri ve görsel olmayan etkileri. Işığın görsel etkileri, literatürde belirtildiği gibi görme, algı ve bilgi (biliş) değerlendirilmiştir. Işığın görsel olmayan etkileri, insan vücut döngüleri ve hormonlarıyla ilişkilidir. Aydınlatmanın görsel ve görsel olmayan etkilerinden sonra, İnsan Odaklı Aydınlatma kavramı detaylı olarak verilmiştir ve insanların yaşamlarında ne kadar önemli olduğu açıklanmıştır.

İnsanlara daha kaliteli mekanlar tasarlarken aydınlatma, uluslararası standartlar ile değerlendirilmektedir. Bu standartlar, kullanıcılara iyi bir görüş, doğru bir algı ve çevre ile ilgili bilgileri yeterince sağlayabilecek aydınlatma tasarımı üzerine oluşturulmuştur. Bunları sağlayacak kriterler ışıklı çevre, parıltı dağılımı, görev alanı ve çevre alanı için yeterli aydınlık düzeyi, düzgünlük, doğrudan ve yansıyan kamaşma sınırlaması, yansımalar, modelleme, renk sıcaklığı, renksel geriverim, titreme ve stroboskopik etkilerden kaçınma, gün ışığının kalitesi ve ışığın değişkenliğidir. Görsel etkiler ışığın fiziksel özellikleriyle birlikte gelir. Ancak, standartlarda ışığın görsel etkileri dikkate alınırken, görsel olmayan etkilerine yeterince yer verilmemiştir. Bu

nedenle yapılan aydınlatma tasarımları insanların hayati ihtiyaçlarını tam anlamıyla karşılamamaktadır.

Son yıllarda bu konuda yapılan araştırmalar doğrultusunda yeni bir aydınlatma konsepti ortaya konmuştur ve adı İnsan Odaklı Aydınlatma (Human Centric Lighting-HCL) olarak geçmektedir. Bu modern aydınlatma konseptinde, ışığın sadece görsel değil, aynı zamanda görsel olmayan etkileri de dikkate alınır ve kişinin refahını, ruh halini ve sağlığını olumlu etkileyecek şekilde aydınlatma tasarımları yapılır. İç mekanlara yönelik yeni aydınlatma tasarım süreçleri bu temel kriterler ile düşünülmeli ve tasarım sürecinin merkezinde insan alınmalıdır.

İnsan vücudunda gözle görülmeyen fakat yaşamsal ihtiyaçları karşılayan hormonların üretimi ve vücudun sirkadiyen ritmi olarak adlandırılan biyokimyasal süreçler, ışığın görsel olmayan etkilerini ifade eder. Bunlar hem günışığından hem de yapay aydınlatmadan etkilenirler. Gün saatlerinde yeterli günışığı alınamayan mekanlarda, aydınlık düzeyi yapay aydınlatma ile düzenlenmektedir. Fakat yapay aydınlatma günışığının sağladığı performansı sağlayamaz. Bu nedenle günışığından daha az etkilidir. Bu durum gün boyunca yeterli günışığı alamayan insanlara ve biyolojik ritimlerine zarar verir ve sağlık sorunlarına yol açar. Teknik nedenlerden ve enerji tasarrufu ihtiyacından dolayı, görsel olmayan efektler için yapay aydınlatma, gün ışığını tam olarak simüle edemez. Ancak destek sağlayabilir. Bu şekilde günışığı benzeri yapay aydınlatma, melanopik etkili aydınlatma olarak adlandırılır. İnsan vücut ritminin düzenlenmesine yardımcı olur. Bu aydınlatma sistemleri günışığının gün içindeki durumuna göre otomatik olarak değişim gösterebilirler. Gün ışığından yararlanma, ışığın kalitesini artırır, daha iyi bir refah duygusu sağlar ve enerji girdisini optimize eder. Bunların yanında renk sıcaklığı da önemli bir rol oynar ve gün boyunca yüksek mavi içerikli değerini korumalıdır, bu doğal ışığa en yakın renk sıcaklığıdır. Görsel olmayan efektler için yapay aydınlatmanın tasarlanmasında bir diğer önemli nokta, doğru ışığı, doğru zamanda, mekanda oluşturmaktır. Örneğin, günışığı simüle eden yapay aydınlatma ile aydınlık düzeyi ve renk sıcaklığı, sabah erken saatlerde veya öğleden önce artar, akşam melanopik etki istenmeyen zamanda sıcak ışık renkleri ve düşük aydınlık düzeyi sağlanır. Bu da insan bedenini uykuya hazırlar. Bu melanopik etkili aydınlatmadır ve bu bölümde detaylı anlatılmaktadır.

Üçüncü bölümde, ofislerdeki iç mekanlar literatürden araştırılmıştır. Ofis iç mekan tasarımının geçmişten günümüze teknolojilerden nasıl etkilendiği ve nasıl geliştiği; bu süreçte aydınlatma tasarım konseptlerinin nasıl ilerlediği açıklanmıştır. Bu tasarım konseptleri sayısal (nicel) veri tabanlı, parıltı tabanlı ve algı odaklı aydınlatma kavramlarıdır. Daha sonra bugünün ofis aydınlatma tasarımı yapılırken kullanılan değerlendirme kriterlerine yer verilmiştir. Bu konseptler ışığında tasarlanan modern ofis aydınlatmalarından üç örnek gösterilmiştir. Bunlar Viyana'daki Microsoft Genel Merkezi, Paris'teki CMS Bureau Francis Lefebre ve Berlin'deki Ströer News Publishing GmbH projeleridir. Bu projeler piyasadaki mevcut aydınlatma armatürleri ile tasarlanmıştır.

Dördüncü bölümde seçilen bir tasarım ofisine aydınlatma tasarımı uygulaması yapılmıştır. İlk olarak, tasarım ofisi ve mevcut aydınlatma durumu açıklanmıştır. Daha sonra, kullanıcılar ve faaliyetleri tanımlanmıştır. Mekan faaliyetlere bağlı olarak üç bölüme ayrılmıştır. Gün içinde kullanıcıların ve faaliyetlerinin ihtiyaçlarını karşılamak için bir aydınlatma tasarım önerisi verilmiştir. Aydınlatma, günün herhangi bir saatinde, kullanıcıların herhangi bir aktivitesine uygun olarak planlanmıştır. Bu ihtiyaçlar doğrultusunda dokuz senaryo belirlenmiştir ve uygulanan aydınlatma

tasarımı dokuz senaryo için de DIALUX EVO programında hesaplanmıştır. Projede, piyasadan üç ürün referans olarak kullanılmıştır. Ürün A bir sarkıt aygıt, ürün B görev aydınlatması sağlayan masa aygıtı ve ürün C de bir sarkıt aygıttır.

Uluslararası standartlarda geçen gerekli görsel ihtiyaçlar A, B ve C ürünleri ile yerine getirilmiştir. Ayrıca, bu ürünlere ek olarak, mekanda İnsan Odaklı Aydınlatma konseptini uygulayabilmek için proje tasarımı sırasında belirlenen öneriler sunulmuştur. Piyasadaki mevcut ürünler bu özelliklerden bazılarına sahiptir, ancak 'İnsan Odaklı Aydınlatma' konseptinin gereksinimleri mekanda sağlamamaktadır. Yapılan önerilerle birlikte, bu yeni konseptin iç mekan tasarımlarında nasıl sağlanabileceği ifade edilmiştir.

Sonuç bölümünde çalışmanın önemi açıklanmıştır. Proje, ışığın görsel ve görsel olmayan etkilerine göre değerlendirilmiştir. 'İnsan Odaklı Aydınlatma' konseptinin sağlanması için mevcut ürünlere öneriler sunulmuştur. Tezin amacı, gelişen ve değişen dünyada, aydınlatma tasarım konseptlerindeki yeniliklerden bahsetmek ve İnsan Odaklı aydınlatmanın önemini vurgulamaktır. Bugün kullanılan uluslararası standartlarda, ışığın görsel etkilerine yönelik kriterler bulunmaktadır. Fakat bunlar yeterli değildir. Işığın görsel olmayan etkileri mekan aydınlatmaları tasarlanırken mutlaka göz önünde bulundurulmalıdır. 'İnsan Odaklı Aydınlatma' konsepti bu sebeple çok önemlidir. Bu çalışma ile piyasadaki mevcut ürünler kullanılarak, uluslararası standartlar ile tasarlanan projelerin insanların hem görsel hem görsel olmayan ihtiyaçlarını karşılamadığı gösterilmiştir. Proje, giriş kısmında verilen ve tüm araştırmalar sonucunda oluşturulmuş aydınlatma tasarım kriterlerine göre değerlendirilmiştir. Eksiklikler belirlenip, bunlardan gelen veriler ışığında gelecekteki aydınlatma tasarım projeleri için öneriler sunulmuştur.

1. INTRODUCTION

Light is one of the primary needs of people. It helps to see spaces and perceive the details. Moreover, lighting research which has been done in the last century proved the effect of light on the human organism. The light and its effect on health have been improved with these studies.

The people spend their time indoors because of the requirements of today's working conditions. They are going away from their nature, and what they need. This situation affects human body negatively in many cases. It can be said that the human being, who is distant from the outside world and nature, is also distant from the daylight and the benefits of daylight.

The light affects people from different aspects. These can be examined under two headings, visual and non-visual effects. The visual effects come with the physical characteristics of light and have been determined by International Standards which provide to the users a good vision, quite correct perception, and adequately supply environmental information. The vital criteria of standards are agreeable luminous environment, harmonious luminance distribution, adequate illuminance for the interior areas, task areas or activity areas, good uniformity, limitation of direct and reflected glare, including veiling reflections, correct directionality of lighting and agreeable modelling, appropriate colour rendering and colour appearance of the light, avoidance of flicker and stroboscopic effects, quality of daylight, and variability of light. In addition to these criteria, with developing technologies changing lighting situations, personal control, energy efficiency, daylight integration, light as an interior design element become new criteria. These criteria cannot be fulfilled by quantitative based, luminance based, and perception-oriented lighting design approaches.

There is also non-visual effects of light for people. The recent studies on modern lighting concepts, therefore, take into account not only the visual but also the non-visual lighting effects and promote the well-being, mood, and health of the person. In the human body, there are kinds of biochemical process happening. The production of

hormones and their effects on circadian rhythm are affected by both daylight and artificial light.

Even though the illumination level provided at a workplace by artificial lighting is quantitatively sufficient, absence of daylight during the day could be harmful to human beings and their biological rhythms and causes health problems. For technical reasons and because of the need to save energy, lighting for non-visual effects cannot simulate natural daylight precisely, but can provide effective support, which can be defined 'Melanopically Effective Lighting'. Melanopically effective lighting can either be additionally activated or automatically regulated to recover for changes in daylight rate. Benefiting from daylight enhances the quality of artificial light, makes for a greater sense of well-being and optimises energy input. Colour temperature also plays a crucial role: during the day, it should be close to that of natural light with high blue content. Another key element in designing artificial lighting for non-visual effects is the need to provide the right light at the right time. The greatest melanopic effect is achieved after a period of darkness, especially in the morning. Apart from supporting long-term diurnal synchronisation, melanopically effective light can also be used to activate. In this case, for example, illuminance and colour temperature are briefly raised at mid-day or early in the afternoon. In the evening, when activation is undesirable, warm light colours and lowered illuminance prepare the body for sleep (Licht.Wissen, 2010).

The new lighting design processes for interiors should be considered with these essential criteria, and take human at the center of the design process. The name of this concept is Human Centric Lighting (HCL). This design concept has been created in the last decade to meet the basic lighting needs of people in the changing world.

The HCL means that when designing the lighting in a place visual and non-visual requirements of human should be considered. With the right light, the designers can create appropriate spaces for people and ensure visual comfort, good visual performance, and safety. The light must provide sufficient values for daily rhythms of the human body, and for the hormones. In this way, the physical and psychological needs of people can be fulfilled. Although perception is a subject changing from person to person, with good lighting stable spaces can be created to minimise differences in views. When designing an HCL for space by putting a human at the center, the other parameters for lighting design the age status, seeing ability, task type, and etc. are

considered. The new technologies bring more criteria to this field. For instance, changing lighting situations, personal control, energy efficiency, daylight integration, light as interior design elements are new essential criteria for good lighting.

1.1 Introduction and Problem Definition

The development of technologies and communication tools, contemporary offices and the tasks which are done by the employees in these offices have changed recently. These alterations affected not only the purposes but also interior spaces and the interior elements in these spaces. One of the essential element in office interior is lighting design.

Visual and non-visual effects of light on human beings' physical and psychological needs in space, how a human perceives interior and the element of the interior in this space, and how human uses it are the important parameters for lighting design process. Human beings are always in the center of it. This is general 'Human Centric Lighting' concept's definition. For good lighting design, the human is placed in the center, then all the elements, related to human, like space, lights, etc., should be arranged around human. The aim of this study is researching the existing lighting concepts for offices, explaining the HCL concept and clarifying the importance of it for human beings, through the research defining the lighting design steps for HCL concept, applying these steps on an office project, pointing out the the deficiencies in existing products, and listing the suggestings for the future lighting products and concepts.

1.2 Content and Limits

The thesis contains five sections. The first section consists of the introduction of this thesis. On the second section, Human Centric Lighting (HCL) is explained. Before HCL concept, first, the visual and non-visual effects are given, because they are the basis for HCL concept.

In the third section, the relation between interior space and lighting concept design in offices are researched. The development process of office design from past to future was investigated. The types of offices are explained through the literature review. Then, lighting design is studied under three main subtitles: Quantitative-based, luminance-based, and perception-oriented (Ganslandt & Hofmann, 1992). The process

of lighting design in offices are defined. At the end of the third section, there are some contemporary office design examples with the lighting equipment have been shown.

Conclusions coming from the studies done in last years show that lighting is not only a quantity-based element but also there are critical factors for lighting design process, related to human's physical and psychological needs coming from the visual and non-visual effects of light. Because office spaces are the place where people spend most of their time in their lives after their homes, not only the visual effects but also the non-visual effects of light should be considered when designing an interior space lighting. However, the planning of lighting in an office interior is mostly based on the requirements of the International Standards. But HCL concept also should consider when designing a lighting system for an office interior. It is very important for human beings.

On the fourth section, through the information collected on the previous sections, the lighting of office space has been designed. The project field was observed with space details and user information. Then an HCL concept has been designed for the office.

1.3 Methodology

For the research, digital, visual and analog information was used. The literature has been analyzed through lighting design standards, lighting magazines, papers, journals, printed and digital books, previous thesis studies written about related topics and web pages related to lighting design.

For the project on section four, an office interior located in Çukurcuma was observed personally and designed a lighting concept for the working area, which is also used for several purposes. The office was observed in the class 'IMT 509E Interior Architectural Project III' which was in 2016-2017 autumn semester. The observations, the existing lighting situations, and the photos have been collected in this semester. The information from this course has been reviewed for the case study and presented in project section in this study. The lighting data have been collected from the companies in the market, and the office lighting concept has been planned in Dialux EVO programme. The results are taken from a lighting calculation programme.

The evaluation of lighting design aspects and Human Centric Concept, there has been formed a lighting design way and shown in Figure 1.1. As it is stated in the figure, first

space and space's details should be defined in three steps which are user profiles, purposes/tasks, and space features. After a well-defined space, it is easier to define lighting needs. The lighting needs contain visual and non-visual needs based on user and their tasks, interior needs based on space. After defining space and lighting needs then lighting design could be implemented properly and evaluated correctly. The lighting design can be assessed using the following steps: Appropriate lighting levels, harmonious distribution of brightness, limited glare, avoiding glare by reflection, effective light colour, maintenance illumination, good colour rendering, changing lighting situations, personal control of lighting, energy efficiency, daylight integration, melanopic efficiency. The diagram below includes all the approaches around quantitative, luminance, perception-oriented, and Human Centric Lighting concept based. The evaluation of the project has been done by using this chart.

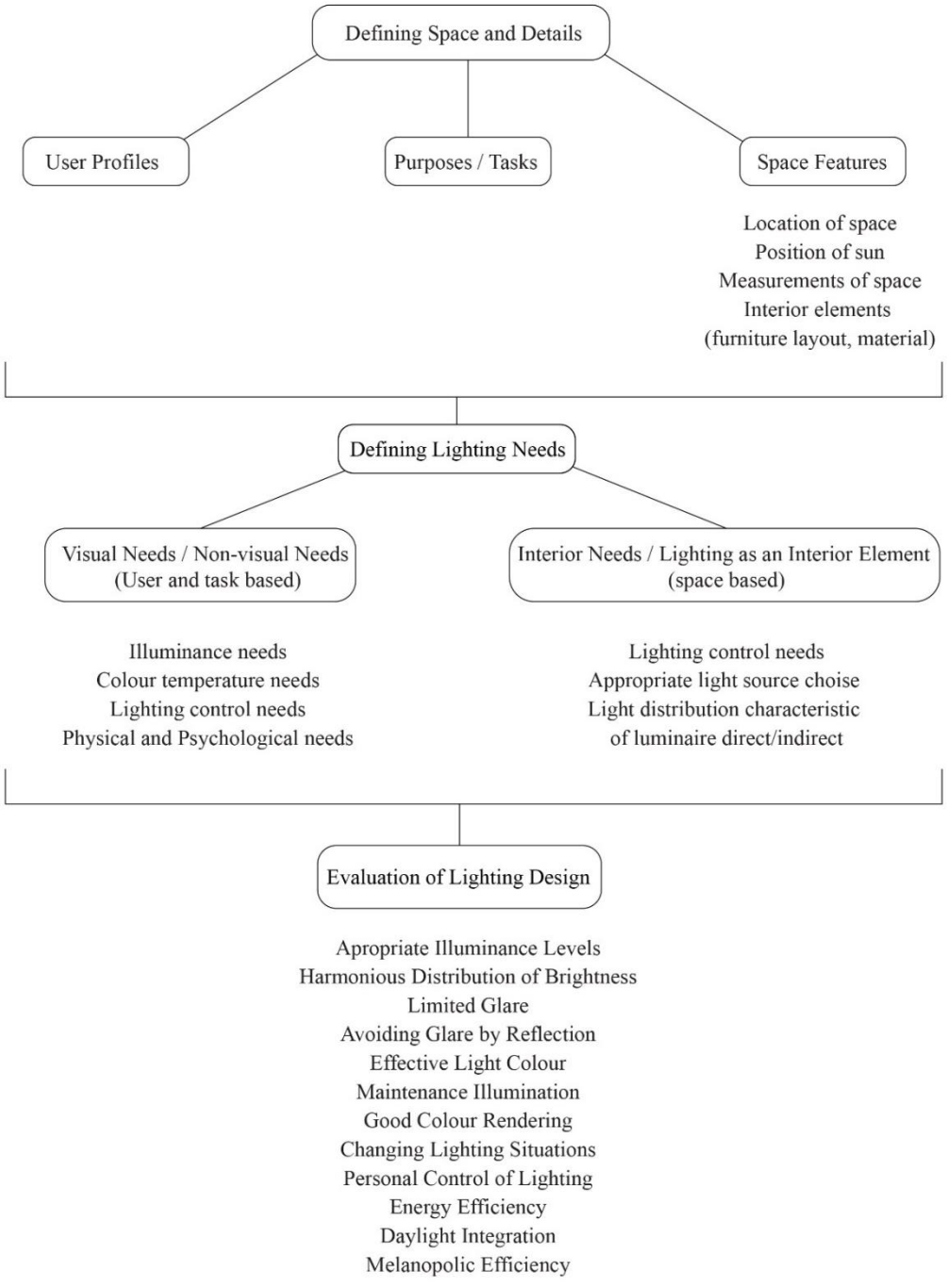


Figure 1.1: The lighting design criteria chart for interiors (Köseli, 2018).

2. HUMAN CENTRIC LIGHTING

The light means the life. Under the influence of the sun, the first living beings are started to exist 3 billion years ago. 200,000 years ago, the humans were born. Until the invention of the first artificial light source, which is fire, the people had only daylight. In the last150 years, human beings have been using the electric light. The research projects from all around the world have proved the effect of light on the human organism. When the daylight is not enough, the artificial lighting with dynamic light can give the people's bodies the decisive effect today. Thus, the topic of light and health takes on a whole new dimension: the dynamic light will change the daily lives at the desk, in industry, at school, and at home – for a better quality of life. Today, it is clear that light serves not only visual needs but also has emotional and biological effects on humans. Modern lighting concepts, therefore, take into account not only the visual but also the non-visual lighting effects and promote the well-being, mood, and health of the person. The people are at the center of the lighting concept. This concept is the basis for Human Centric Lighting (Licht.Wissen, 2018)

Human Centric Lighting matches the interplay of light, climate, and space to correspond to the individual needs of people in particular surroundings. The aim of Human Centric Lighting is to significantly improve the lighting situation for greater well-being and performance capability, as well as achieving optimum synchronization with the outdoor environment. Human Centric Lighting (HCL) extends the concept of biologically effective lighting to holistic planning and includes the visual, emotional and biological effects of light. HCL supports long-term health, well-being, and performance of humans (Licht. Wissen, 2018).

In this section, first, the effects of lighting on human beings are explained. The effects are given in two parts: visual effects, and non-visual effects. The visual effects are related to providing correct vision, perception, and information. The process of vision and perception, and how they ensure the right information around the environment are stated. After visual effects, the lighting characteristic, which is related to the lighting features, and lighting terminology, lighting design needs, and process are shown.

Secondly, the non-visual effects on human beings are clarified. The non-visual effects are the effects on human beings in a biological way. How the light affects human body in the way of melatonin suppression, cortisol concentration, sleep-wake-cycle, sleep quality, immune response, pain perception, appetite, mood, alertness, stress perception, attention, and well-being are explained. After the effects of lighting, the significance of the HCL on people's lives is stated.

2.1 The Effects of Lighting on Human Beings

The ability to see is a significant evolution for humans. The vision enables people to position themselves in space, allows to move by purpose, controls the inner clock, makes them to feel of emotions and communication through gestures and to orient themselves with signs and writing (Licht.Wissen, 2010).

The eyes are body's highly developed sensory organs, enabling the sense of sight. The different segments of the eye, which can be seen in Figure 2.1, create a vision that is translated into an image by the brain. The light first enters the cornea, transparent, dome-shaped surface that covers the front of the eye, which bends - or refracts- this incoming light. The iris, the coloured part of the eye, regulates the size of the pupil, the opening that controls the amount of light that enters the eye. Behind the pupil is the lens, an explicit part of the eye that further focuses light, or an image, onto the retina. The retina is a thin, delicate, photosensitive tissue that contains the individual "photoreceptor" cells that convert light into electrical signals (NEI, 2018). These photoreceptor cells for daytime vision are particularly concentrated in the fovea, the small depression at the centre of the retina responsible for sharpness of vision (Figure 2.1). Rods and cones are responsible for vision, functioning as receptors for the visual system. The cones in the eyes make it possible to see the colours when the sufficient light is provided. Without sufficient lightning, it is not possible for the human eye to perceive the spaces and objects with colours. The electrical signals are processed further and then travel from the retina of the eye to the brain through the optic nerve, a bundle of about one million nerve fibres. In addition to all this, in 2002, scientists also discovered special ganglion cells in the retina that do not have a visual function. These cells contain melanopsin which affects the daily cycle of the human body (Licht.Wissen, 2010).

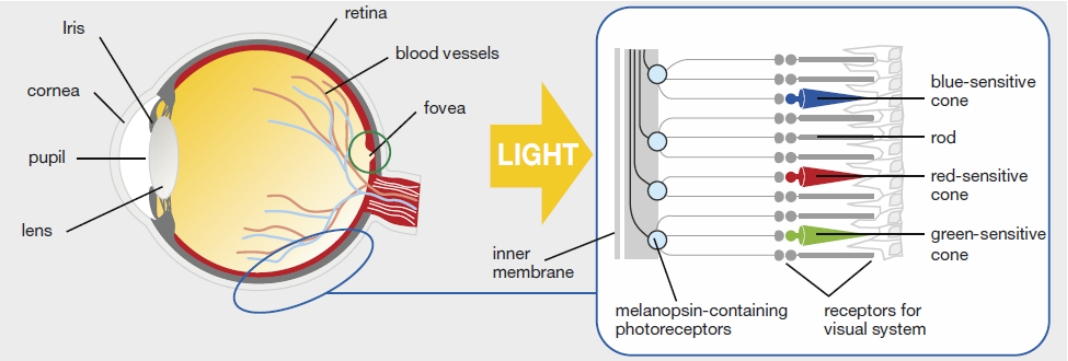


Figure 2.1 : The parts of the eye (Licht.Wissen, 2010).

The perception of light in the human body as stated in Figure 2.2. With the green path, the light is perceived for the visual effects. With the blue path, the light is comprehended for the non-visual effects. The visual effects mostly managed by the brain. However, for the biological effects, the light perception get the way retinohypothalamic tract through to the spinal cord and superior cervical ganglion.

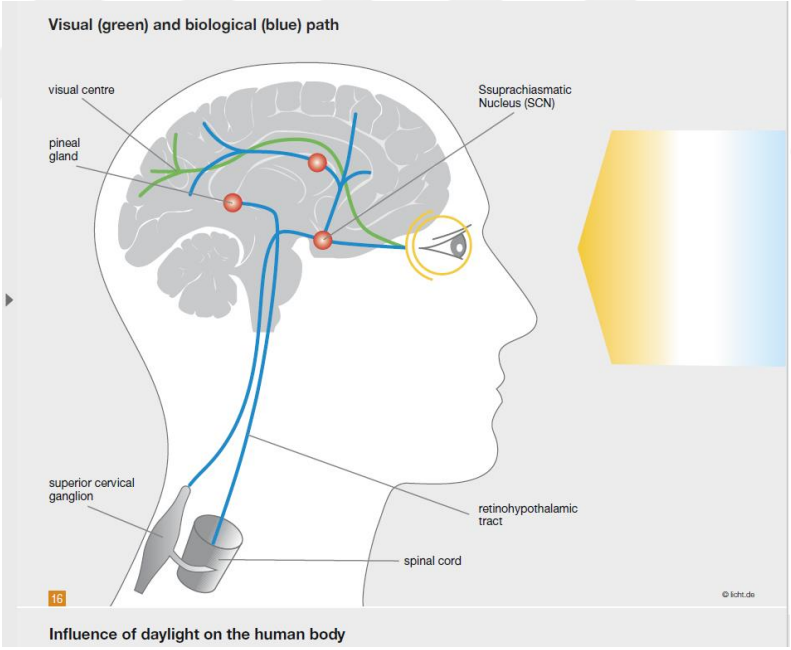


Figure 2.2 : Perception of light (Licht.Wissen, 2010).

As it is shown in Figure 2.3, there are many parameters for effects of the light on human beings. People have physiological and psychological needs. Physiological needs contain sleep, health, and freedom from pain. Psychological needs include protection, demarcation, individuality, and security. The light has vital importance on the physiology and the psychology. The visual effects of light, which are vision,

perception, and information(cognition), are related to the human's physiology. The non-visual effects on the human body are well-being, mood elevation, greater productive capacity, alertness, and responsiveness. These are associated with the human's psychology.

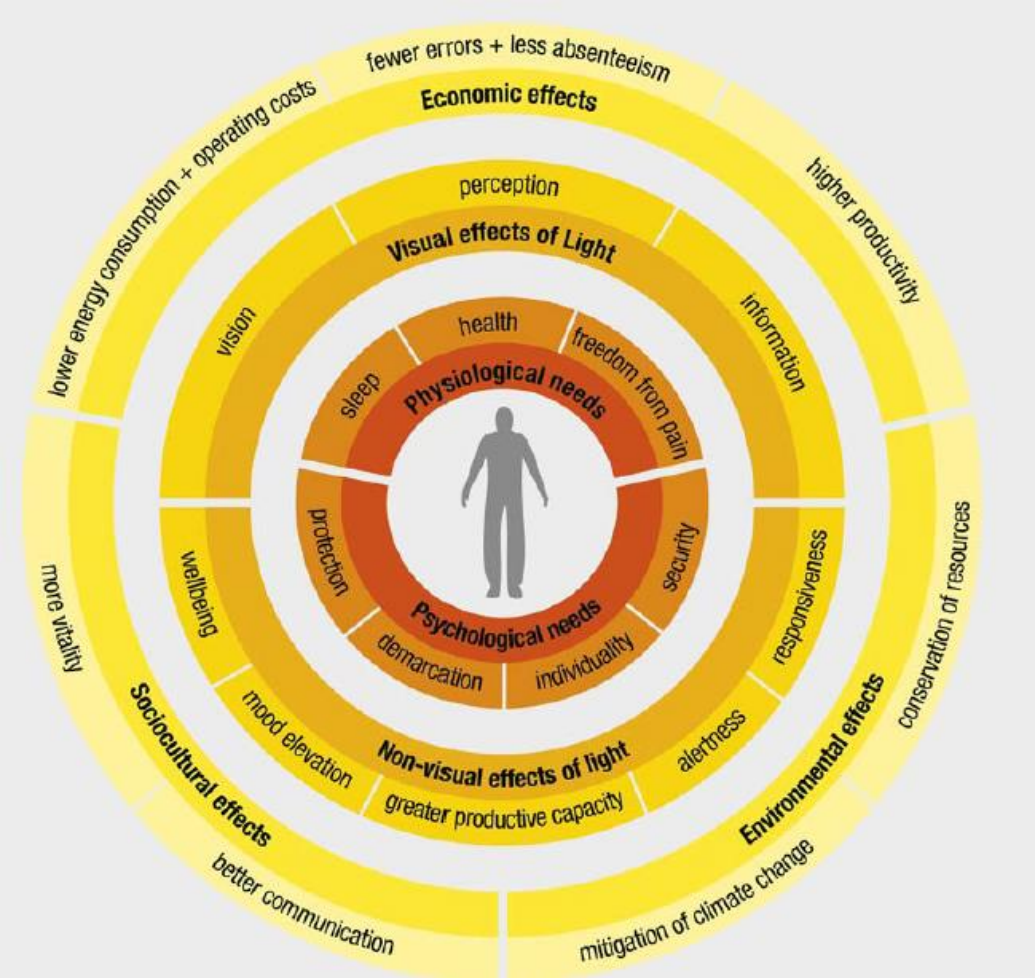


Figure 2.3 : The Model of the effects of light on human beings (Licht.Wissen, 2010).

The visual and non-visual effects of light concern more extensive areas which are economical, socio-cultural and environmental. The light effects which is focused on human beings enlarge these effects and become more relevant to the world. The visual effects bound up with economic effects, which are lower energy consumption and operating costs, fewer errors and less absenteeism, and higher productivity. The non-visual effects influence, the sociocultural through more vitality and better

communication, and also affect environmental through more mitigation of climate change and conversation of resources.

2.1.1 Visual effects of light on human beings

The light provides to enable people to see so that all lighting could be evaluated in terms how well it enables people to see. The lighting determines visual details by light and contrast, and with that, it enables all the details perceıved correct. These are the basis of many lighting recommendations and standards. The judgements of observation of environment are based on appearance, and it can be influenced by subtle aspects of lighting in spaces. The appearance of the object is changed by which light is reflected, refracted, dispersed and scattered. Lighting is both the medium that makes things visible and a visible medium. At one level it reveals the identifying attributes that enable us to recognize the objects that surround us, and at another level, it creates patterns of colour, and light and shade, which add other dimensions to the visual scene. The primary aim of lighting design is to control the luminous environment in order to affect the perceived space (Cuttle, 2003).

2.1.1.1 Vision, perception, and information (cognition)

The process of visual perception starts with the luminous environment. The luminous environment generates the retinal image. The retinal image is the stimulus for the process of vision, which provides information to enable the visual perception. Then the environment is perceived by the human. This process is stated in the chart in Figure 2.4 (Cuttle, 2003).

The luminous environment is the physical environment enlightened by the light. The human eye is an optical system and focuses an inverted image onto the retina. This image is continually varying with the movements of the head and the scanning movements of the eyes (Cuttle, 2003). According to Cuttle (2003), ‘’ the distribution of luminance and colour that comprises the retinal image is modified by light losses that occur in the optical media of the eye, and these losses are not constant as they increase significantly with age.’’(p. 4). The visual process aims to supply continuously changing information flow to the visual cortex of the brain. The retinal image induces photoreceptors set in the retina, leading to a series of minute electrical impulses to flow

along the optic nerve pathways to the brain. The first step for this process happens within the retina. Moreover, then the retinal image is interpreted in the brain (Cuttle, 2003).

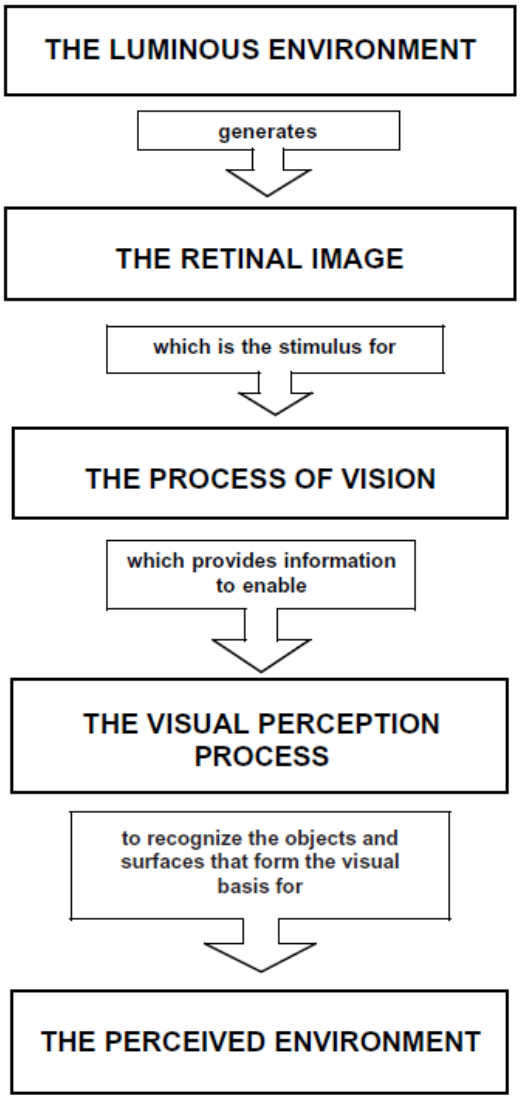


Figure 2.4 : A basic model of visual perception (Cuttle, 2003).

The perception of the environment has many kinds of sources, not only the vision. The vision generally is the primary source of sensory information, but the perception could be affected by the inputs of the other senses like auditory, olfactory, and tactile and the information gathered from these senses. The perceived environment is a form within the brain and works as a model for the physical environment. This form orientates the people through space, guides them, and helps to make them operational decisions. However, the perceived environment always changes by person to person. For

instance, one person finds a space pleasant, and another does not. So that, it could be stated that the forms within the brain are formed differently for each (Cuttle, 2003).

Cuttle (2003) stated that 'the outcome of these observations is quite profound. To think of lighting solely as the medium by which objects and surfaces are made visible is to ignore creative opportunities for influencing users' perceptions'(p.19).

2.1.1.2 Lighting characteristics and lighting design

Most of the lighting design scenarios are only focused on to provide enough light to enable vision to perform the tasks. However, it has been always ignored that how people perceive the space and how they react in the space. On this section, first of all, the visible characteristics of light are explained, then the necessary lighting values for the interior designs are given.

Light is the small section of electromagnetic radiation that is visible to the eyes of people. If "white" daylight is directed through a prism, its spectral colours appear. These have different wavelengths (Licht.Wissen, 2016). It has been shown in Figure 2.5.

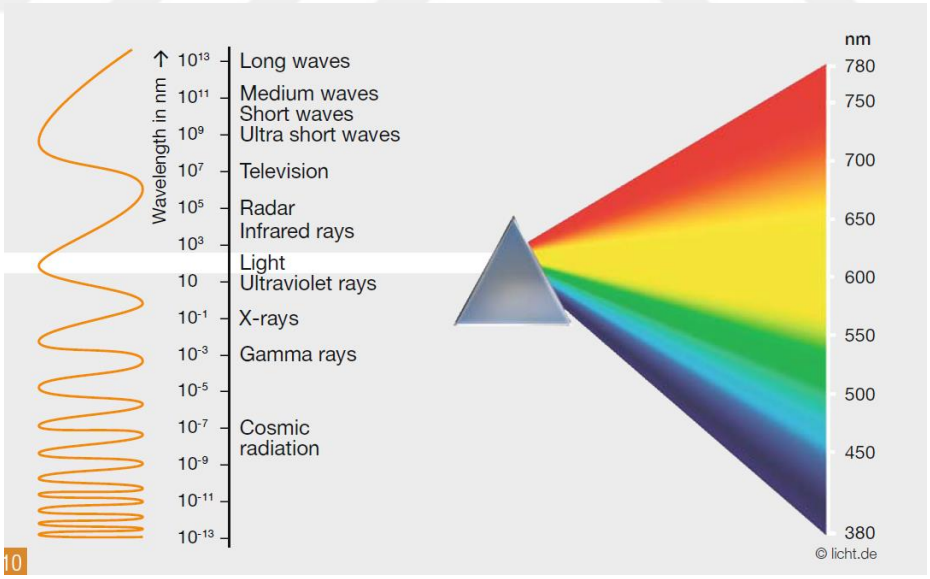


Figure 2.5 : Light and the other wavelengths (Licht.Wissen, 2016).

Independent from the light sources, the light affects the perception of the environment. According to Cuttle (2003) 'A designer can be expected to look for more than lighting that makes everything visible. Much design effort may have been expended on selecting materials and specifying colours and textures, and it is important that these

qualities were accurately revealed'(p.8). The visual constancy is a process, which the people perceive the objects maintain more or less stable attributes despite changes in the retinal images. An understanding of how the people develop perceptions of their environments and the role that perceived attributes play in enabling them to come to terms with surroundings is crucial to understanding the roles that lighting can play in influencing people's perceptions of their environments (Cuttle, 2003).

The investigations on artificial lighting design field are very recent, in comparison to daylight. In the last century or two, scientists are more focused on the scientific applications of the artificial light. Only in the last century, with the fast improvement of efficient light sources, lighting design has obtained the tools that allow artificial lighting to be produced with sufficient illuminance levels. However the development on this new discipline, by the purpose of defining the objectives and methods behind this new discipline, of deciding on the criteria by which the artificial light that is now available is to be applied (Ganslandt & Hofmann, 1992).

The photometry science and illumination engineering have put together the technology that defines and quantifies lighting. Luminous flux is radiant flux evaluated according to the CIE (International Commission on Illumination) Relative Photopic Response, sometimes referred to as the V(λ) function, where V is the relative human sensation of brightness according to the wavelength of radiant flux λ (lambda). It refers to the light-adapted visual response, which usually applies to architectural lighting (Cuttle, 2003). It has been shown in Figure 2.6.

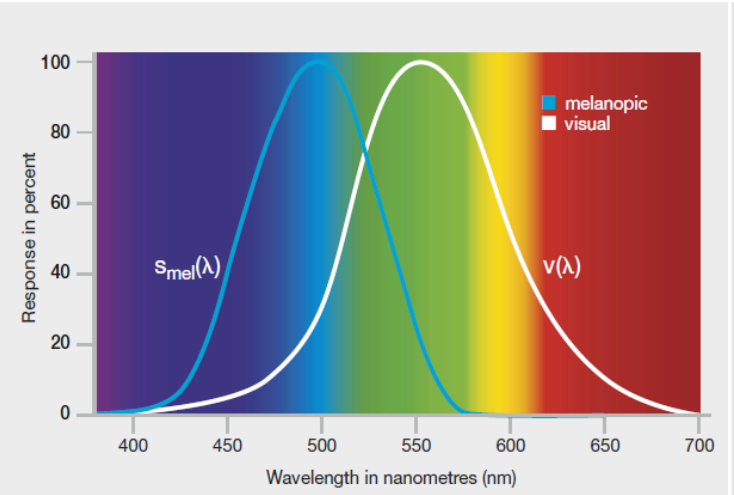


Figure 2.6 : The CIE relative photopic response [*V*(λ) function] (Licht.Wissen, 2010).

The luminous flux describes the quantity of light spread by a light source. The luminous efficacy of a lamp is the measure of the lamp's performance in converting electrical power into luminous flux and is measured in lumens per watt. Illuminance E is the density of luminous flux incident on a surface. One lux equals one lumen per square meter. Luminance is the measure of the stimulus that produces the sensation of brightness (Cuttle, 2003). Luminance is the only primary lighting parameter that is perceived by the eye (Zumtobel, 2018).

In order to perform visual tasks in illuminated areas, there should not be any vast differences in brightness so that uniformity should not fall below (Zumtobel, 2018). Glare is the sensation produced by bright areas within the visual field, such as lit surfaces, parts of the luminaires, windows and roof lights. Glare shall be limited to avoid errors, fatigue, and accidents. Glare can be experienced either as discomfort glare or as disability glare. In interior (work) places disability glare is not usually a significant problem if discomfort glare limits are met. The rating of disturbance glare caused directly from the luminaires of an indoor lighting assembly shall be determined using the CIE Unified Glare Rating (UGR) tabular method (EN12464-1, 2011).

It is necessary to evaluate lighting designs regarding meeting expectations and to make this evaluation appropriately. When examining the international literature, the objectives of sustainable lighting design have been to increase the performance of lighting systems from the initial design stages, to reduce lighting energy consumption and to minimize the environmental impact of the lighting elements used. For this reason, it is essential to evaluate the performance of lighting design in order to determine the performance of these lighting schemes (Yılmaz & Yener, 2013).

As the traditional quality lighting criteria according to DIN EN 12464-1, light quality can be evaluated with sufficient illumination level, harmonious brightness distribution, glare limitation, avoidance of reflections, good modeling, correct colour temperature, proper colour rendering. In addition to these criteria, with developing technologies, there are many new features could be said like changing lighting situations, personal control, energy efficiency, daylight integration, light as an interior design element. These criteria have been shown in Figure 2.7 as the diagram.

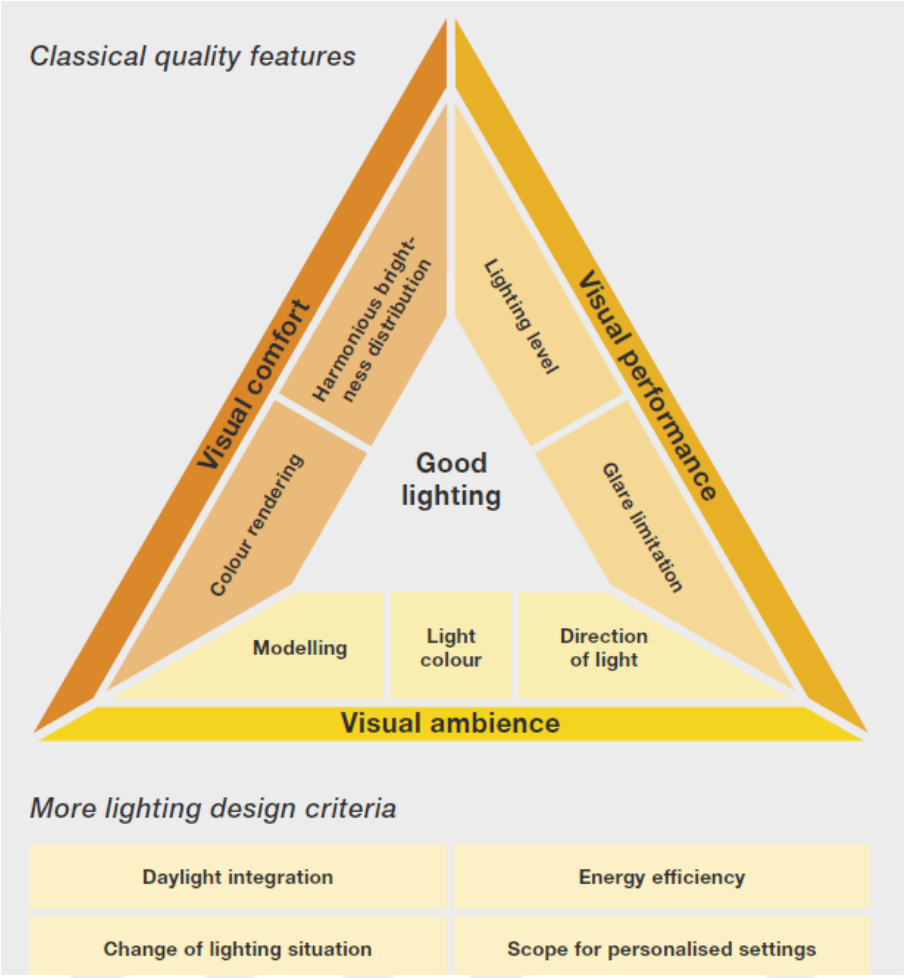


Figure 2.7 : Lighting criteria according to DIN EN 12464-1 (Licht.Wissen, 2010).

For good lighting implementation, it is essential that as well as the required illuminances, additional qualitative and quantitative needs are satisfied (EN12464-1, 2011).

Lighting standards have been defined by the satisfaction of three basic human needs (EN12464-1, 2011):

- visual comfort, where people have a feeling of well-being; indirectly this also contributes to a higher productivity level and a higher quality of work;
- visual performance, where the workers can perform their visual tasks, even under difficult circumstances and during more extended periods;
- safety.

Main parameters determining the luminous environment concerning artificial light and daylight are (EN12464-1, 2011):

- luminance distribution;
- illuminance;
- the directionality of light, lighting in the interior space;
- variability of light (levels and colour of light);
- colour rendering and colour appearance of the light;
- glare;
- flicker.

The luminance distribution in the visual field controls the adaptation level of the eyes, which affects task visibility. According to EN 12464-1 (2011) a well-balanced adaptation luminance is needed to increase:

- visual acuity (sharpness of vision);
- contrast sensitivity (discrimination of small relative luminance differences);
- the efficiency of the visual functions (such as accommodation, convergence, pupillary contraction, eye movements, etc.).
- The luminance distribution in the visual field also affects visual comfort. The following should be avoided for the reasons given:
- too high luminance which can give rise to glare;
- too high luminance contrasts which will cause fatigue because of constant re-adaptation of the eyes;
- too low luminance and too low luminance contrasts which result in a dull and non-stimulating working environment.

As it has been shown in Table 2.1, there are many different kinds of lighting needs for each kind of tasks. When designing a place, first it should be considered that what is the importance of this place and what kind of tasks are acted in there. If space is used for different purposes, for providing the necessary illuminance for spacing, the area could be divided into parts. In public spaces such as streets, the minimum level of

illuminance is 30 lux, less than 30 lux there will be not enough vision for the users. For limited to movement and common vision without the perception of detail, the illuminance should be minimum 50 lux to provide simple orientation. In order to limited perception of detail, 100 lux should be ensured for the people. To perform some visual tasks which need high contrast and large size minimum of 300 lux are recommended for the spaces. To perform visual tasks which are high contrast and small size or low contrast and large size, 500 lux is the value that should be, and include colour requirements. More detailed tasks which are low contrast and small size, need more than 1000 lux illumination, also with light temperature requirements.

Table 2.1 : The scales of illumination and visual tasks (Cuttle, 2003).

Characteristic visual tasks (CIBSE 1994)	*Illuminance (lux)*	*Illuminance category (IESNA 2000)*
	30	Public spaces
Confined to movement and casual seeing without the perception of detail.	*50*	B Simple orientation for short visits
Movement and casual seeing with the only limited perception of detail.	*100*	C Working spaces where simple visual tasks are performed
Involving some risk to people, equipment or product.	*150*	
Requiring some perception of detail.	*200*	
Moderately easy: i.e., large detail, high contrast.	*300*	D Performance of visual tasks of high contrast and large size
Moderately difficult: i.e., moderate size, may be of low contrast. Colour judgement may be required.	*500*	E Performance of visual tasks of high contrast and small size, or low contrast and large size
Difficult: details to be seen are small and of low contrast. Colour judgements may be important.	*750*	
Very difficult: very small details which may be of very low contrast. Accurate colour judgements required.	*1000*	F Performance of visual tasks of low contrast and small size
Extremely difficult: details are extremely small and of low contrast. Optical aids may be of advantage.	*2000*	
Exceptionally difficult: details to be seen are exceptionally small and of low contrast. Optical aids will be of advantage.	3000	G Performance of visual tasks near threshold

For creating a well-balanced luminance distribution, the luminance of all surfaces shall be taken into consideration and will be determined by the reflectance and the illuminance on the surfaces. To avoid gloom and to raise adaptation levels and comfort of people in buildings, it is highly desirable to have bright interior surfaces particularly the walls and ceiling.

Recommended reflectance for the major interior diffusely reflecting surfaces by EN12464-1 (2011) are:

- ceiling: 0,7 to 0,9;
- walls: 0,5 to 0,8;
- floor: 0,2 to 0,4.

According to EN 12665, to give the perceptual difference to the space recommended illuminance steps are (EN12464-1, 2011):

20 - 30 - 50 - 75 - 100 - 150 - 200 - 300 - 500 - 750 - 1000 - 1500 - 2000 - 3000 - 5000

The glare of all luminaires that are in the room regularly can be evaluated with the UGR method, as determined in the standard EN 12464-1 "Lighting of indoor workplaces." However LED luminaires with very bright light points, which can be perceived individually, are crucial. The UGR method takes account the brightness of walls and ceilings as well as all luminaires in the system that contribute to the sensation of glare. The result is a UGR index.

According to EN 12464-1 (2011), the colour qualities of a near-white lamp or transmitted daylight are characterized by two attributes:

- the colour appearance of the light;
- its colour rendering capabilities, which affect the colour appearance of objects and persons.

These two attributes shall be considered separately. The colour appearance of a lamp refers to the apparent colour (chromaticity) of the light emitted. The scale for illumination is named by correlated colour temperature (CCT) or in low colour temperature. There is also an alternative scale for colour temperature. It is called mega Kelvin (MK^{-1}), and to transfer a CCT into MK^{-1} divide the kelvins by one million and take the reciprocal. However, mostly CCT is used for as a scale for illumination. In Figure 2.8, the colour appearance of ambient illumination, and the comparison of CCT with the MK^{-1} has been shown.

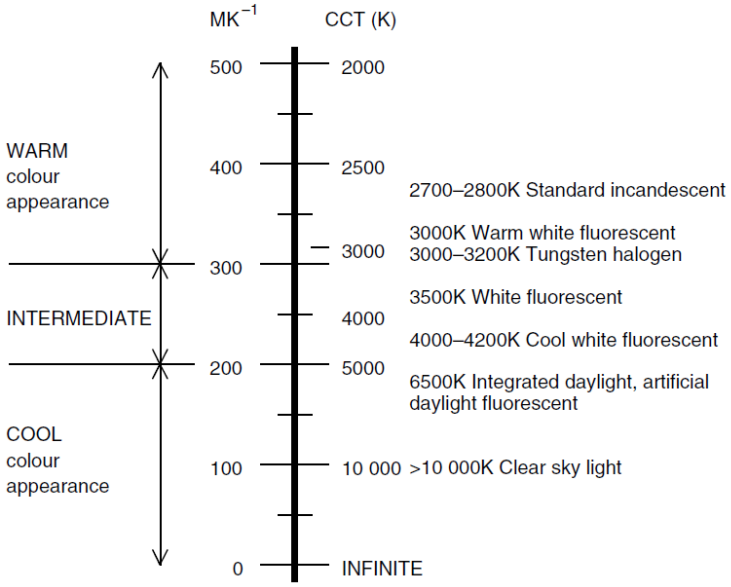


Figure 2.8 : The colour appearance of ambient illumination (Cuttle, 2003).

It is quantified by its correlated colour temperature (CCT). Colour appearance of daylight varies throughout the day. The choice of colour appearance is a matter of psychology, aesthetics and what is considered to be natural. The choice will depend on illuminance level, colours of the room and furniture, surrounding climate and the application. In warm climates generally, a cooler colour temperature appearance is preferred, whereas in cold climates a warmer colour temperature appearance is preferred (p.17). The lamp colour groups have been shown in Table 2.2. 3300K and below is counted as warm white, between 3300K and 5300K is accepted as intermediate white, and above 5300K is always known as cool white (EN12464-1, 2011).

Table 2.2 : Lamp colour apperaence group (EN12464-1, 2011).

Colour appearance	Correlated colour temperature TCP
warm	below 3 300 K
intermediate	3 300 to 5 300 K
cool	above 5 300 K

For visual performance and the feeling of comfort and well-being colours in the environment, of objects and human skin, shall be rendered naturally, correctly and in a way that makes people look attractive and healthy. The standards have been given by EN 12464-1 (2011), to provide an objective indication of the colour rendering

properties of a light source the general colour rendering index Ra is used. The maximum value of Ra is 100 (p.17).

A well-illuminated place should also have well-illuminated surfaces on walls, and ceiling enhances with the room environment. According to EN 12464-1 standard, 30-50 lux on the ceiling (in offices, classrooms, and hospitals), and minimum 50-70 lux on walls (in offices, classrooms, and hospitals) are the necessary illuminance levels.

Lighting quality is not the only reason for good visual performance. When designing the lighting in a space, the people should also be considered. The seeing ability, age, and task type are the other relevant criteria of the lighting design process. For example, with the higher ages, people's lighting requirements change. The seeing abilities of people are also very important as an example lighting needs rise with age. (Beld & Bommel, 2004). In Figure 2.9, it has been shown that the increase of the age how to affect the light requirements.

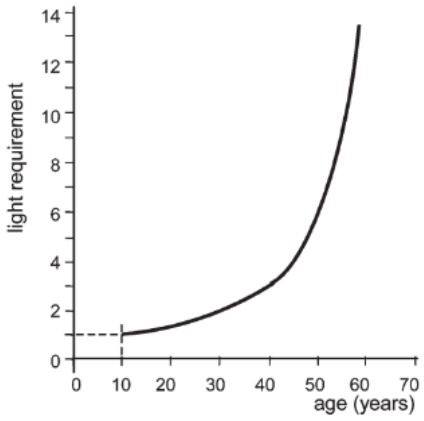


Figure 2.9 : The relation between age and lighting (Fortuin, 1951).

The criteria for quality lighting are listed as sufficient illumination level, harmonious brightness distribution, glare limitation, avoidance of reflections, good modeling, correct colour temperature, appropriate colour rendering; in addition to these criteria, with developing technologies, changing lighting situations, personal control, energy efficiency, daylight integration, light as an interior design element become new criteria.

In short, when designing the lighting in a place, there are regulations for the visual needs of human. These regulations are essential to provide the users with a good vision, quite correct perception, and adequately supply environmental information. With the right light, the designers create appropriate spaces for people and ensure visual

comfort, good visual performance, and safety. Although perception is a subject changing from person to person, with good lighting stable spaces can be created to minimise differences in views. The age status, seeing ability, and task type are the other parameters for lighting design. The new technologies bring more criteria to this field. For instance, changing lighting situations, personal control, energy efficiency, daylight integration, light as interior design elements are new essential steps for good lighting.

2.1.2 Non-visual effects of light on human beings

The people no longer spend time outdoors. Because of this reason, the necessary light for the human body should be provided by other sources. The people need light not only for vision and perception but also for biological functions of their body. In addition to the daylight, biologically effective artificial light source help to stabilise the human day/night rhythm. This rhythm is also called an internal clock and operate the hormonal system. According to Falkenberg (2016), "with the quality lighting (improved lighting with a basic control system), life quality could be improved" (s.49).

Although light has a critical role in adjusting human health and wellbeing with the circadian rhythm and hormones, the lighting was typically planned to provide only the visual needs. There was less attention to understand how light affects the non-visual systems on human-beings (Figueiro & Rea, 2014). Until recent years the non-visual effects of light have been ignored or were paid less attention compared to visual needs. Küller (2002) noted that all types of light within the visual range, both natural and artificial, have some influence on the biological clock, the bright light is more effective than dim light, and white light or daylight being more effective than coloured light. In indoor spaces, not only the light sources but also ceiling, walls, and floor, will contribute to increasing the effect. Although some non-visual effects of light have been known to science for a century or more, it is only recently that this knowledge has been brought to the eyes of the lighting community (p. 90).

The nonvisual-effects of body functions, stated in Figure 2.10, melatonin suppression, cortisol concentration, sleep-wake-cycle, sleep quality, immune response, pain perception, appetite, mood, alertness, stress perception, attention, and well-being are organised by light. The model represents the human body.

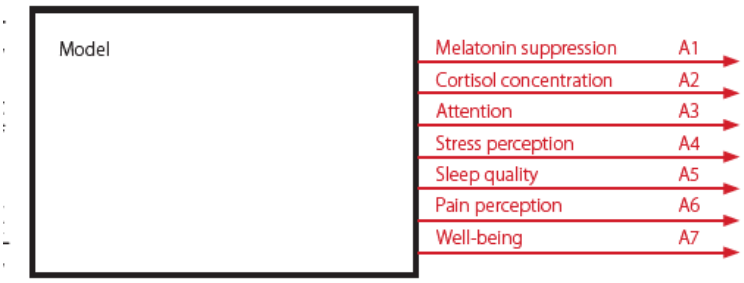


Figure 2.10 : Non-visual effects examples (Völker, 2016).

Controlled by the brain, the same program runs in the human body every day. The internal clock controls sleep and waking phases, but also heart rate, blood pressure, and mood. Each cell and organ has its rhythm, which must be regularly synchronised with the outside world. The human being is oriented primarily to the brightness of the day and the darkness of the night (Veitch, 2005).

People and their bodily functions follow daily and seasonal rhythms. From the cell to the organs, each unit controls its temporal program. Breathing and heartbeat, waking and sleeping: All biochemically controlled functions have their individual high and low points during the day. Just before waking up, body temperature rises, blood pressure and pulse rate increase. About an hour later, the body produces stimulating hormones (Beld & Bommel, 2004). The human performance during the day has been shown in Figure 2.11.

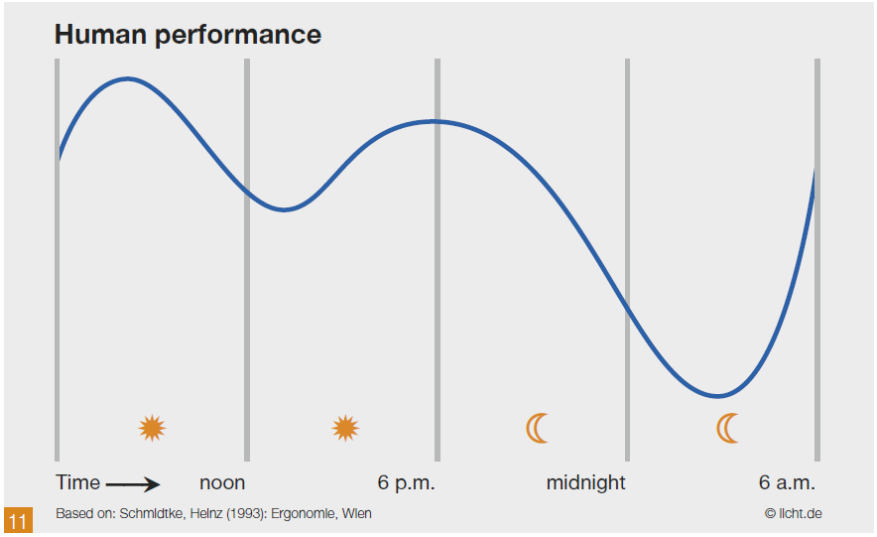


Figure 2.11 : Human performance curve over the day: body and mind are fittest around 10 a.m. and hit a low at 3 a.m. (Schmidtke, 1993).

Between 12 a.m. and 2 p.m., the stomach produces the most acid. which digests the lunch. The stomach consumes so much energy that the rest of the body fatigues. However, even without eating anything, people have a power loss at noon. In the early afternoon, body and mind start to be active again. The feeling of pain is at this time the lowest point. Sensitive patients should take their dentist appointment at around 3 p.m., not in the morning. The people who do sports between 4 p.m. and 5 p.m. o'clock, are particularly effective. This time is ideal for muscle building and fitness training. Between 6 p.m. and 8 p.m., the body is on its most efficient time for a glass of beer. This efficiency is when liver performance and alcohol tolerance is high. When it gets dark, the person gets tired. At 3 o'clock in the morning, his organism reaches the absolute low. Incidentally, the statistic records show that this is the time for most natural deaths (Licht.Wissen, 2010).

Most of the people don't have the same rhythm of the day and night. Some of them have the rhythm of 23 hours, some of them 26 hours. This difference comes from our genetic codes. Even without daylight the people have still sleeping and waking phases. There are two types of people: larks and owls. Larks are forced by their internal clock to wake up early in contrast to owls (Licht.Wissen, 2010).

The seasons of the year affect people's biologic rhythms. The colder seasons are mostly tended to be less fit for human beings and they have difficulties concentrating. Because of the less daylight, the people feel more depressed (Staedt & Riemann, 2006).

The age is also another reason for different biologic rhythm. Because of the work stress, people's sleeping habits could be affected. A study, which is done by Prof. Dr Jurgen Staedt and Prof. Dr Dieter Riemann at 2006 in Stuttgart, has shown that people have very different sleeping habits depending on age and external cues in Figure 2.12 shown (Veitch, 2005).

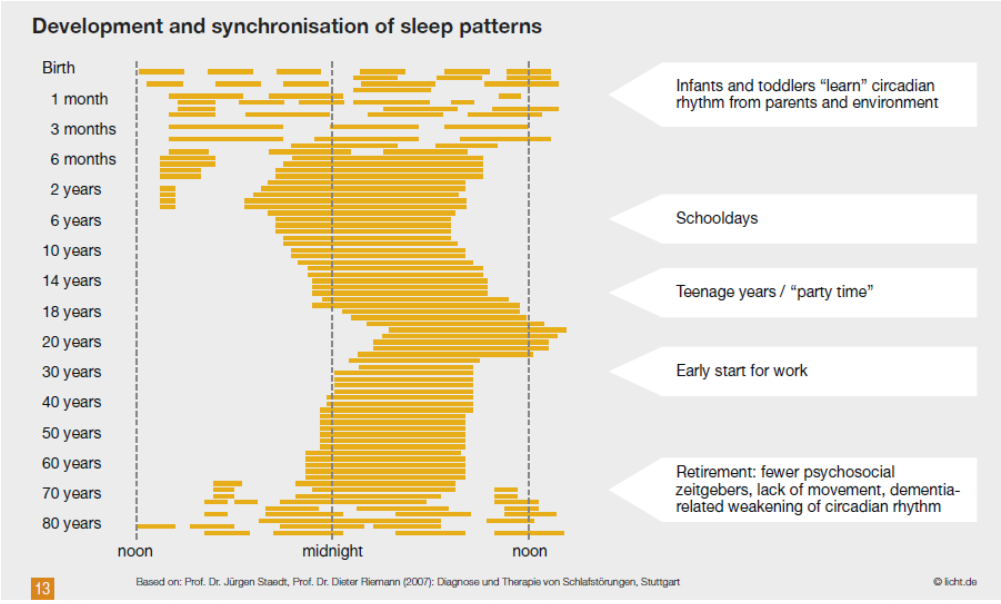


Figure 2.12 : From birth to old age: sleep patterns are shaped and synchronised by external cues known as 'zeitgeber.' (Staedt & Riemann, 2006).

Even age, environmental factors, seasons, daily habits, way of life and work all respond to day and night. The human bodies adjust their internal clock due to these reasons. However, the main timer is always daylight.

The third receptors in the human brain can perceive the daylight of brain and provide this regulation. For a long time, it was unclear how humans absorb these light stimuli. In 2002, however, scientists identified a third retinal light receptor in addition to the known cones (for colour vision) and rods (for twilight vision). These individual ganglion cells are sensitive to light, but not for the sake of vision. They only register the brightness in the environment and regulate biological processes in the body when light hits - such as the pupil reflex or the inner clocks. Only about one to three percent of ganglion cells are non-visual photoreceptors. In this cell type, researchers discovered the photosensitive protein melanopsin - a colour pigment that is responsible for allowing frogs to adapt their skin colour to the environment. Although the melanopsin-containing ganglion cells are distributed over the entire retina, they are particularly sensitive in the lower and nasal areas of the retina. In experiments, light-insensitive cells from mice changed to light-sensitive after being inoculated with human melanopsin. The blue light spectrum is most effective suppression on melanopsin. In humans, scientists initially indirectly detected the new photoreceptor: they irradiated subjects with monochromatic light of different wavelengths at night for one and a half hours and observed the concentration of melatonin known as the sleep

hormone in their blood. A comparison of the levels of exposure to different colours of light showed that blue light with a wavelength of about 480 nanometers suppressed the production of melatonin at night (Beld & Bommel, 2004).

The human body is like a big corporate company. There are many kinds of biochemical process ongoing. The hormones manage all these processes. The circadian rhythms of the human body especially are regulated by melatonin and cortisol hormones. They influence the body in inverse cycles (Licht.Wissen, 2010). The light and dark reactions of human body effect all hormone system. The level of cortisol and melatonin hormones changes throughout the day and the levels are shown in Figure 2.13 as graphically. They operate in a continuous loop. Some steps of this cycle are essential for the body. The process which starts with the third receptors in the brain has been shown. Seratonin, melatonin, and cortisol are mainly critical elements of this ongoing process. Cortisol and melatonin are working inverse cycles. As it has been stated in the chart; when cortisol reaches the highest level around 9 a.m., melatonin is in the lowest. After 6 p.m., melatonin starts to increase and peak up at around 3 a.m.

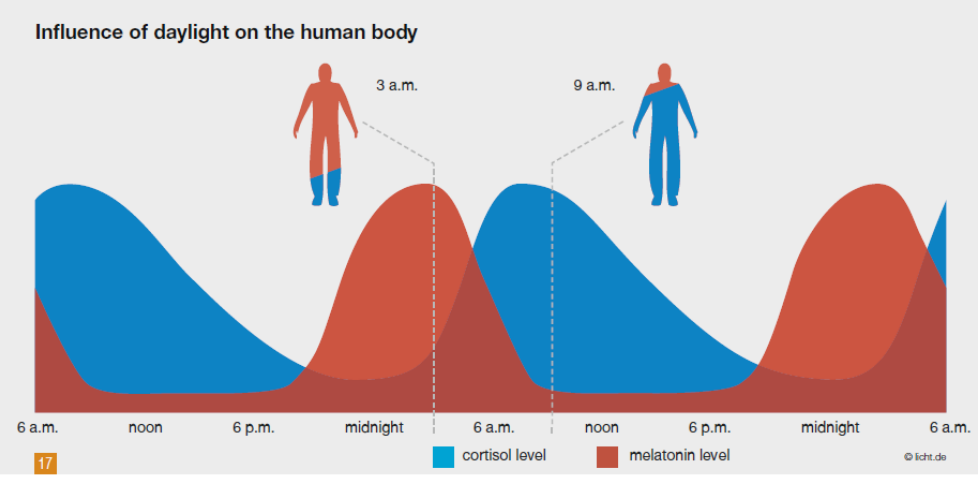


Figure 2.13 : The cortisol and melatonin hormone levels during the day (Licht.Wissen, 2010).

Seratonin, which is influential on people's psychological process, also plays an integral part in this biochemical transaction (Veitch, 2005).

Melatonin is a hormone that slows down the functions of the human body and prepares them to sleep. It also helps regulate body temperature, blood pressure, and hormone levels. In this process, the human body produces growth hormone and helps to repair the cells during the night (Veitch, 2005). Transfer of the effect of melatonin

suppression is very crucial on non-visual effects like attention, stress perception, sleep quality, and well-being.

Cortisol is a stress hormone like nature's built-in alarm system. Regularly, it starts to produce around 3 a.m., reduce the melatonin level and prepare the human body for day-time. During this phase, the body makes sure that enough serotonin is secreted by hypophysis (Veitch, 2005).

Serotonin keeps the level of motivation and mood up during the day. If the level of cortisol hormone is not enough at daytime, serotonin assists in reaching necessary fulfilments (Veitch, 2005).

Non-visual effects, depending on different photometric conditions, are: brightness, spectral distribution, spatial distribution, time of day, and static vs dynamic lighting, with covariates, which are age, chronotype, stress type, individuality, genetics, health status, and job situation (Völker, 2016). All these photometric features and covariates also affect the cycles in the human body.

In light of all this information, it could be said that light is the primary external for synchronising human's internal clock. The daylight sets the human's bodily processes during the day, their hormones, wake-sleep rhythms. It has visual and non-visual effects on people. These effects influence the people's physical and psychological health. If the daylight is not sufficient in interiors, the artificial light should provide similar effects on human beings. The artificial lighting with daylight helps the human body by stabilising circadian rhythms at indoors.

2.2 Human Centric Lighting Concept

The light not only provides visual needs but also has phycological and biological effects on human beings. Therefore the users always should be in the focus point when designing a lighting concept. These form the basis of Human Centric Lighting; in low HCL (Licht.Wissen, 2018).

Human Centric Lighting (HCL) stands for a lighting concept that provides to the users intended light at all times, which is appropriate for their respective living or working situations. HCL concepts provide the right light for any time of the day or year. HCL concepts have to anchor in the project at an early step and form the basis for holistic, interdisciplinary planning. The daylight, if architecturally possible, is included. The

lighting system is installed and operated according to the lighting design. The users receive information about The HCL concept so that they can recognise the benefits of the lighting (Licht.Wissen, 2018).

If there is not enough daylight provided in a space, artificial lighting helps to synchronise the human body with the environment. This light is named melanopic effective light or biologically effective light (Licht.Wissen, 2010). The visual and non-visual effects have been explained in the previous section. It is evident that the light has a very significant feature on the human bodily process. The HCL concept aims to provide melanopic effective lighting for a human. The darkness, brightness, and dynamism of daylight should be created in interiors as artificial lighting. The artificial light which acts like daylight is suggested only in the daytime. Because at night, in the evening, and in the early morning hours, daylight-like lighting is not effective. This light protects the human body from any disordering of biological processes. Daylight-like lighting with non-visual effect is advisable only during the day (blue curve) which is shown in Figure 2.14. At night, in the evening and in the early morning hours, light with only little biological effect is correct. This avoids any disruption of biological processes in the body such as the rise in melatonin level(orange) in the evening.

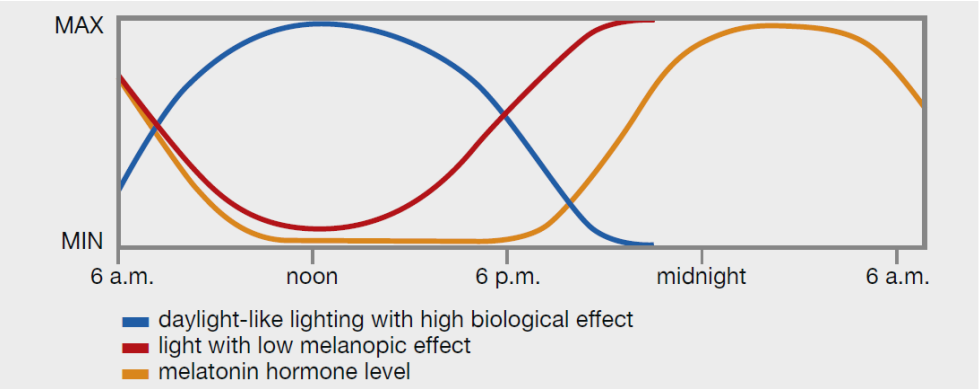


Figure 2.14: The circadian lighting (Licht.Wissen, 2018).

Light has a different effect during the day than during the night - this should be the light concept and provide a corresponding variability, which is a prerequisite for good lighting so that the requirements for good visual quality are met. Also, light creates spaces. If there is no daylight, an artificial lighting situation arises with its own identity. This art lighting situation should not alienate the existing perception of space. Finally, light acts biologically, whereas during the day more activating effects are expected while in the evening they are preferably avoided in order to stabilise the

circadian rhythm. The lighting should, therefore, be a dynamic change between different lighting scenarios, from morning through the day to evening and night, allow (Licht.Wissen, 2018).

The main aim is to produce a healthy environment, which contains energy efficiency, low cost, less maintenance and quality of light. Daylight is significant for interiors and should be well integrated with artificial lighting (Manav, 2018). In many cases, the approach of a bright and daylight-like daytime lighting and a warm white, in the brightness reduced light level in the evening is followed. When closely examined, the HCL concept is much more demanding and goes well beyond the mere adaptation of illuminance and colour temperature: The effect of lighting is considered holistically. The targeted and professional use of light for therapeutic purposes goes beyond the HCL concept and is not part of this guideline. Ultimately, light according to the HCL concept should serve the users, and fulfill their expectation in the long run. Light is multifaceted and always - visually, emotionally and biologically. Human Centric Lighting (HCL) supports in a targeted and long-term manner the health, well-being, and performance of human beings through holistic planning and implementation of the visual, emotional and in particular the biological effects of light (Licht.Wissen, 2018). There are three crucial effects for HCL concepts: Visual, emotional and biological. These have been shown in Figure 2.15. HCL concepts must be considered already in the planning, startup, and operation (Licht.Wissen, 2018).

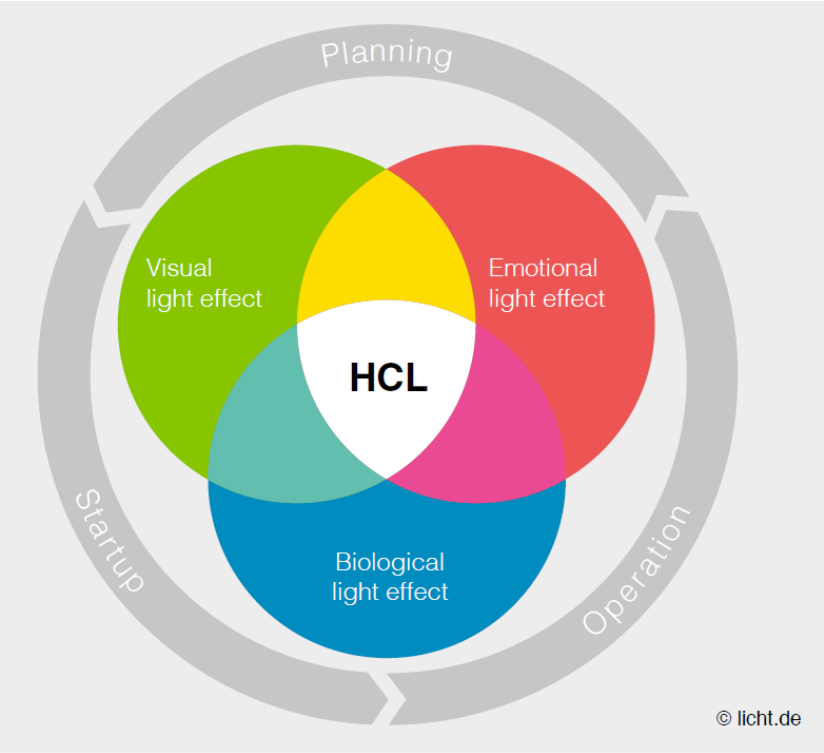


Figure 2.15: The illustration shows the three effects that are crucial for HCL concepts (Licht.Wissen, 2018).

In order to implement a lighting energy efficient and to ensure the long-term effect on people and health, well-being and performance, an integrated, holistic lighting and spatial planning as well as the proper installation and commissioning should be ensured. The use and the effect of light must be included in the planning process right from the start. It is essential to coordinate all trades, products and materials well. Only a long-term, according to the planning specifications, operated and functioning lighting system meets the needs of people (Licht.Wissen, 2018).

2.2.1 Visual light effect

Good visibility makes working easier. For this purpose, minimum criteria are defined in normative and legal regulations in order to enable the fulfilment of the visual tasks in different activities in the work areas. The standards, like DIN EN 12464-1 "Lighting of workplaces", offer designers minimum values for the design of a lighting system. Optimal visual conditions should always be the goal of planning and operation. Individual features, such as higher light requirements in the elderly must be tailor-

made and planned appropriately (Licht.Wissen, 2018). It has been explained with details in the previous chapter.

2.2.2 Emotional light effect

The HCL targets to achieve a positive effect on people, which is based on their expectations and their understands and uses. They take full account of the effects of light (Licht.Wissen, 2018).

In recent years the Human Centric Lighting concept is further explored. But before named it HCL, there has been many researches about the emotional effects of lighting. There is a research done by Manav and Küçükdoğu at Istanbul Technical University about the effect of illumination level and colour temperature on performance. The results from this research are that: in a work environment, only changing the light level does not improve the viewing conditions and does not affect the performance entirely. However, changing the colour temperature influences performance within the framework of acceptance. Control of the lighting system is a preference for users. The difference in the level of light affects personal impressions. In the work environment, making a difference between the illumination levels in various spaces will create a difference in luminance and perception, and visual monotony will be prevented. The parameters that provide physical comfort for offices were stated in the standards. However, as it is aimed to provide visual comfort in lighting design, it is necessary to investigate psychological comfort conditions and to create more efficient working environments (Manav & Küçükdoğu, 2006).

The alertness and cognitive performance are the main non-visual effects of HCL. The alertness means that active attention by high sensory awareness. It increases concentration, vigilance, accident error prevention. The cognitive performance, means mental performance, that includes working memory, producing and comprehending language, learning, reasoning, problem-solving, complex reaction, decision making. With cognitive performance, people can improve their memory, learning creativity and motivation (Kearney, 2015).

Architectural, formal, aesthetic and perceptual psychology criteria and expectations have to be considered to support the well-being of people in their social environment. These criteria follow the rules and interdisciplinary principles that arise from good

practice. They can hardly be expressed in numbers and not be found in standards and regulations. Attention to an attractive expected compliant design of the room with light and its formal elements can be assumed that more acceptance, satisfaction and well-being (Licht.Wissen, 2018).

2.2.3 Biological light effect

The non-visual effects of Human Centric Lighting on emotions are basically on mood, energise and relax. The mood describes positive and negative disposition that is influenced by personality traits, sleep, social context and behaviour. It is useful for depression and anxiety. The energise brings the body and mind into a state of general wakefulness and readiness for activities. With energise, the level of activation raises and provides vitality. The relaxation is about low tension and low emotional pressure while feeling at ease. It reduces the level of activation and stress (Kearney, 2015).

Biological effects must be considered and planned with great care. They act on the circadian rhythm and can stabilise the need to support on the one hand for daytime performance and on the other hand for a good night's sleep. In the short term, they can increase the attention and alertness. Adverse biological effects by false light at the appropriate time can be prevented by good HCL concept (Licht.Wissen, 2018).

The non-visual biological effects of HCL are mostly about biological cycles of the human body. There is the 24-hour rhythm of rest and activity. The biological clock of an individual controls it. These cycles are essential for optimised functioning during daytime and a good and recovering sleep at night. Thus it supports robust health. The adequately completed cycles prevent from disease/disorder, also treatment and alleviation for many diseases (dementia, SAD, ADHD, schizophrenia, sleep disturbances) (Kearney, 2015).

The other important element for HCL concept is long-term or sustainable lighting. Long-term means that the visual, emotional and biological effects have a lasting and positive effect on humans. They cover short-term effects also, for example, to encourage alertness, provided that they have no long-term negative effects such as on sleeping behaviour. And "long-term" refers to the aim of ensuring or improving long-term operation of the lighting system in accordance with the instructions of the designer (Licht.Wissen, 2018).

Architectural lighting is not just for vision anymore. The users are increasingly requesting and expecting lighting systems and applications that can support human health and well-being—and lighting professionals must be prepared to respond to those expectations.

A basic idea of HCL is to provide the right light for any time of the day. The effect of lighting must be considered holistically. In particular, a distinction is made between the illumination during the day and at night. The prerequisite is that the lighting meets all requirements for good visual quality, as well as enables a dynamic change between different lighting scenarios throughout the day.

For the majority of applications, the recommendation is correct and "colder" daylight-white light during the day as well as a less and "warmer" light at night. This applies to light in the workplace, in training centres, care facilities and other areas of life, with the result that the correct use of light in the private sector should be taken into account. Biological light effects extend beyond the period of light exposure. Unrestricted use of daylight white lighting at night is, therefore, to be avoided.

3. LIGHTING CONCEPT DESIGN IN OFFICE INTERIORS

From past to future, the technological and communicational developments are growing fastly. This growth affects the office system, people, works, and task types. Also, the office environments are influenced by this change. People were spending more time in their homes in the last century. However, nowadays, most of the time in human life passes in the offices. So the office design is critical to consider and provide to the people good environments for their physical and psychological needs for being productive and motivational.

In the modern world with developing technologies, human needs are changing every part of their lives. These changes bring a variety of spaces. In this section, it is explained that the history of office interior spaces.

3.1 Interior Design in Offices

Over the last four decades of the twentieth century, the design of office buildings in Europe expanded through the changing trends in business management. In the 1960s, the office has been seen as a communications system, with the floorplan opening up to facilitate the free flow of information across the open plan. In the 1970s, increasing labour power in Europe and the consequent articulation of users' interests saw the development of the office as a place of social engagement. Issues of privacy, acoustic control, individual office rooms, and healthy and personally responsive environments became increasingly important. In Europe, therefore, floorplates became increasingly narrow and complex, whilst in North America, the reverse happened, as office buildings became deeper and simpler, more generic, with less individual control of the environment (CABE, 2005).

The improvement of technologies and business affected the office interior design, carried away from homes and provide them to be a type of space in itself. Especially the communication technology is overpowering in the working environment during the last century. Therefore the office products, furniture, and interior are influenced by these progressions. The modern office interior changed by the effects of developing

computer and communication technology. The office systems have also benefited from the advantages provided by computer technologies. At the end of the 19th century, the office products consisted of paper and pen types. The people had different behaviours and activities in the offices. Consequently, the office interior had other needs and features. The changes of office products also affected and advanced the office's organisations (Başar, 2008).

The workplace was revolutionised in the 1980s as the computer moved from the basement to the desktop. At the same time, new network technologies facilitated the increasing globalisation of particular industries, especially financial and professional services, with a corresponding demand for consistent worldwide guidelines to regularise patterns of space use. European and Asia Pacific financial centres in particular imported North American design practices. The distributed intelligence of the ubiquitous desktop personal computer required improved facilities management, and lead to the emergence of the so-called 'intelligent building'. This can be defined as a building with integrated management and information communication technologies systems providing a robust infrastructure for information technology – and therefore more responsive to changing user demands (CABE, 2005).

The application of new methods, techniques, products and processes resulting in technological improvements has significantly increased office productivity. Again in office activities; the use of computers and modern communication tools have lifted many routine tasks and made office operations faster, more efficient and more organised. Competition, communication and influence have become important in the process of globalisation in our time. Offices are also part of this process. Both manufacturing and, in the service sector, the primary locations where the various economic activities are initiated, sustained and terminated. At the time of the business revolution, all of the business functions (management, production, marketing, financing, personnel and accounting) must be integrated with active office activities (Başar, 2008).

3.1.1 Development of office interior design

Office activities have been around since the beginning of history. Tengilimoğlu and Tutar have stated; the first office work "records" is written on clay tablets and continued in later periods by exploring the papyrus and then recording the papers

(Başar, 2008). Also according to Tengilimoğlu and Tutar, the first office work, the taxes, the dates of birth and death, and the land were simple things, and the real office work in the modern sense began with the "industrial revolution". As a result of faster and more complex information needs, the development of typewriters, calculators and photocopiers has increased the importance of office work (Başar, 2008).

The features, characters, and working methods for every user are different in varied environments. With these differences, the design elements for office interior can be defined. Office interior design has been thought of like the flexibility that can be adapted to the innovations while providing ideas and ideas on how best to experience office life for users (Altınok, 2011).

In the past, office activities are far from what they are today. Office, a dynamic environment in which the continually changing, renewed and intense flow of information is front-line, under the influence of technology. It has become a flexible system based on information technology, away from the spaces consisting of the working surfaces and auxiliary storage elements used to meet user needs. This ensures uninterrupted progress of work between four walls. The work done in the locality is; has become more information work than manual work in the classical sense (Altınok, 2011). In light of this information, first, the development of office technologies should be considered. At Table 3.1, the technological development and changes have been stated by periodical.

Table 3.1 : Significant inventions and office technologies (Altınöz, 2008).

Period	Significant Inventions and Office Technologies
before 1950	Developments such as telephone inventions (1870), production of typewriters (1873), inventions of electronic calculators (1946) and inventions of transistors (1948) were seen. These tools are considered as elements of the information system and constitute the bases of office automation because they are directly related to the processing, transmission and duplication of information.
1950-1959	Electric typewriters, paper records, mechanical calculators, digital phones, electronic typewriters and electronic calculators have been invented. Electronic typewriters have increased writing speed and ease of use. These tools make it possible to use multiple letter characters in the same text and in a practical way. Parallel to this development, it appeared that the installation machines appeared. Also in the same year, the phone started to be used widely.

Table 3.1 (continued): Significant Inventions and Office Technologies (Altınöz, 2008).

Period	Significant Inventions and Office Technologies
1960-1969	First commercial computers began to be seen on the right market at the end of the 1950s. Photocopying and facsimile machines have been invented. These inventions play an important role in simplifying office operations.
1970-1979	Word processors, OCR / MCR (automatic identification and data collection) systems, developments in electronic printers and communication systems. The computers started to spread. In this period, management information systems are beginning to gain importance. The availability of these new and useful tools only by a specific group of experts has led to the creation of a class of experts in organisations.
1980-1989	Improved computers, optical storage, local networks, regional networks, copying devices and operating systems have begun to be used in office activities. The solution of the problem of recording and transmitting the generated information is that the rapidly developing computers have been realised to a great extent. However, the slowness of the circulation rate of information produced and recorded in this process has emerged as a problem.
1990-1999	Significant improvements are made especially in communication technology. In this period, systems such as visual information systems (visual automation), electronic mail and internet have been developed, and the importance of computer in office processes has increased considerably. The number of office operations carried out in the computer environment has increased in this period, but the processing has become more comfortable. The Internet, one of today's information technologies, has added innovations to existing information sharing tools and has brought the possibility of sharing corporate information with customers, citizens, partners through the Intranet, Extranet and corporate information portals.
2000-…	Integrated automation systems such as Enterprise Information Portal, Document Management System, Workflow Management and Fax Automation have been introduced to the work life to help organisations build reliable and modular information chains. Companies such as Microsoft, Sun and Oracle have taken their office systems to the most advanced level with new technologies. The use of the Internet has become widespread, and almost all organisations have found the opportunity of e-commerce on the internet, and a major revolution has occurred with mobile technologies.

The appliances which were used in the offices have changed by years. These changes affect the activities and work types so that the office plans. Before the 1950s the office works were mostly based on processing, transmission and duplication of information.

Big office rooms or even separate spaces as offices were not needed. After the invention of commercial computers around 1960-1969, the office operation systems were simplified and the needs of companies today, in the real sense of office space, have increased.

The changes in the office technology systems and the fact that the prices of these systems are becoming more and more convenient day by day make these systems more widespread in both public and private institutions and organisations. In this context, it is possible to make automation systems in offices faster, more comfortable and more convenient to use in office activities, making it possible to keep the documents and information in the right way and to reuse them when required, and to increase the individual performance by contributing to the motivation of the employees (Altınöz, 2008). The development of modern offices with developing technologies has been shown in Figure 3.1. In the 1960s with existing office systems bench seating is designed for the working places. After the 1970s, the growing economy brought more employment, more office places, and more people. These systems, which can fit too much work in small areas, have been replaced by cubic offices after the 1980s. However, after 2000, the computer systems have become smaller and more spaces became available in the offices.

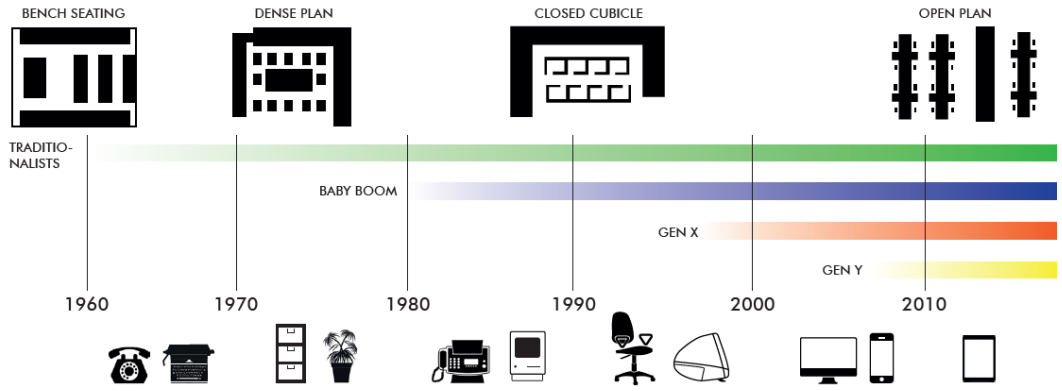


Figure 3.1: The effect of developing technologies with the generations on the office organisations (Url-1, 2018).

The economic recession in the late 1980s and early 1990s, the deterioration of real estate partnerships in Europe and America, and the need for corporate organisations to restructure to survive; office work system, office design and developments related to

offices. Unspecified, speculative office buildings were not built; together with high-cost, user-specific office buildings that are designed and designed accordingly (Başar, 2008).

In today's world, the offices should provide a suitable environment for each person's need. That brings the need for a variety of office rooms. Since people are spending many hours in working spaces, office interior design should be flexible that can be adapted to the next innovations while providing ideas on how best to experience office life for users. The different types of work create many kinds of office spaces. These types of office places will be explained in the following section.

3.1.2 Main office types from past to future

In this section, the office types and the lighting design for these spaces have been explained in detail. The traditional office types coming from past include single cell offices, double cell offices, two and more users cell offices. After traditional office types, there are open offices which are the first example of today's most used office type. The progression of open offices has also formed free-standing, group standing, and mixed standing offices.

3.1.2.1 Traditional offices

- **Single cell offices**

Single cell offices are usually planned for managers. Natural lighting, quietness and personal working space (such as the personal best arrangement of environmental conditions) provide better workplace conditions. However, the use of space by one person today is only in exceptional circumstances (Begeç, 2005).

Direct/indirect light distribution is the right solution for one-person offices and task areas. Pendant or free-standing luminaires directly at the workplace fulfill the requirements. At work zones near windows, it is important to ensure an optimal interplay of daylight, artificial light and lighting atmosphere. Luminaires are often implemented parallel to the window wall to supplement daylight incidence.

- **Double cell offices**

Two-person cell offices consist of two work tables arranged side by side or side by side in a row. Traditional office is the most used room type. In these offices, the psychological pressure of two people working in the same place all the time may be the issue. While the single-row placement of the tables in the space affects the square space and leaves enough room for the closet, the side-by-side workspace provides for more extensive and more varying depth of space (Begeç, 2005).

The lighting design for double cell offices is similar to single cell office interiors. The difference is to provide the required illumination for both two people on task areas. The suggested luminaires are similar.

- **Two and more users cell offices**

In this type of office setup, which is not different from the two-person office, the length of the space is increased by the increase in the number of people. The alignment of three or more people in a single row can create some problems (Begeç, 2005).

Traditional offices are organised for a specific structurally planned organisation. Natural ventilation, lighting must be provided for traditional office placement. Artificial lighting in traditional offices should be from the side and the window side (Begeç, 2005).

A pendant luminaire with indirect components provides uniform lighting in the one-person office and makes the room environment bright. The aim is to ensure the direct light onto the work surface without causing glare. Also with table luminaires, the illumination levels for more intensive tasks can be supported (Licht.Wissen, 2012).

3.1.2.2 Open offices

In open office spaces, there is no strong separator among users, furniture are placed on a level where solid geometry dominates at specified intervals. This level is either completely open between the employee, or it is divided with the help of low sections, cabinets or flowers to strengthen the sense of space. In some cases, working groups are created in a few open office layouts on the office floor, and dividers can be used to separate these groups (Begeç, 2005).

Open office landscapes allow flexible room layouts and areas needed for the formation of work groups and teams. Good lighting design structures the space available and uses different lighting systems to make a visual distinction between areas (Licht.Wissen, 2012).

The arrangement of working areas in open offices, libraries, storage units, and dividing panels are arranged about each other; but are arranged independently of the working surfaces in the arrangement of the working area. The hardware elements are used in the arrangement of the open office space are based on the principle of geometric spatial (triangle, hexagon, etc.) arrangements (Begeç, 2005).

For the general lighting, a combination of direct and indirect light is recommended. A balanced distribution of light and shade makes for an agreeable visual ambience and supports communication. It is also rated positively by employees − especially if it can be additionally regulated to meet personal requirements. Luminaires with asymmetric light distribution (wallwashers) cast light onto walls, which then bounce it back into the room. Large luminous ceilings are also in vogue. Both solutions offer an optimal basis for biologically effective lighting (Licht.Wissen, 2012).

In open offices, where internal communication relationships are essential and influential, large spaces should be preferred in order to provide an uninterrupted flow of work. Open offices are very advantageous regarding workflow and communication. The flexibility of the space allows any change to be made quickly and cheaply. These systems can be rearranged in the exchange of work types. Also, units and other panels also allow for new arrangements based on workflow and communication (Aluçlu, 2000).

Where ceilings are low, the illuminance required can be provided by direct luminaires with all-round glare shielding; alternatively, free-standing luminaires with direct/indirect light distribution can be used. Adjustable spots or downlights with asymmetric light distribution can be used to set accents. They direct the eye to pictures and surfaces and structure the room. Lighting control systems facilitate swift lighting replacement operations and introduce dynamism into office life (Licht.Wissen, 2012).

3.1.2.3. Freestanding offices

As it stated by Gürer (1997), the freestanding office is a system developed by the Schnelle brothers in Quickborn, Germany, in 1960. "Quickborn", a business management specialist, a planning and management consultancy firm, has developed a new planning concept that changes the traditional office layout at the end of studies on office furnishings, organisation, communication, document flow studies and filing systems (Begeç, 2005).

According to Gottschalk (1967), the basic principles that constitute the concept of free-standing office have not been set forth by architectural designers. These principles, which bring a new perception and approach to office planning, are based on business organisation theories and are known in Germany as 'Planungs und Organisation Kybernetik' (Planning and Organization Cybernetics). The Quickborner team researches the business organisation in offices and approaches office planning from a 'cybernetic' perspective. This technique, which is used by Norbert Wiener, is used for the analysis of thinking and communication processes parallel to computers (Begeç, 2005).

The principles that make up the sense of free-standing office come to the fore of 68 items that are not related to each other. Some of these principles are (Begeç, 2005):

- The number of people working in the office should be at least one hundred. Separator items should not be used until the ceiling.
- Senior managers may need more space in the workplace than other staff, but they need to share the same venue with the staff.
- By developing a centralised archiving system, paper and other equipment that does not require immediate use during operation should be minimized.
- Noise generating equipment should be considered in a separate place from the working area.
- Employees should not be placed in a mutual position, but a visual link should be established within a working group. For visual privacy, moving panels and plants should be used.
- The carpet should be laid for an aesthetic appearance and noise control.

With these principles, it can be said that there is a vast difference between the concept of free office and that of a traditional office. In the study groups, rather than a rigid geometric settlement pattern, the residential structure determined according to workplace relations and flow is seen. Differences are provided by plants and flat panels (Begeç, 2005).

The lighting for these offices is to provide uniform illumination using luminaires arranged according to a set grid, where character and glare limitation can be influenced by the choice of luminaires and whether they are direct, indirect or direct-indirect fixtures. For freestanding offices which are clearly subdivided into individual areas (working area, circulation zone, social area, conference area) it is possible to develop an area based concept, lighting each area in accordance with the task that takes place there. By switching different combinations of luminaires the lighting can be adjusted to suit the use of the space, e.g. by combining luminaires for fluorescent lamps and halogen lamps. It is also possible to provide daylight-related switching of luminaires located near windows (Ganslandt & Hofmann, 1992).

3.1.2.4. Group standing offices

Gürer (1997) noted that by removing the intermediate walls of the traditional office and incorporating the corridor into the hall, the resulting office space is called the "group standing office". In such offices, a floor has at least 2-3 sections for 5-10 people. The daylight penetration determines the depth of the space. The core is passed directly to the working space. A medium-sized space is sufficient for this type of plan, as there is secure communication between the departments and departments and group work is done (Begeç, 2005).

The lighting design is similar to open offices. Also, desk or free-standing luminaires give users access to additional lighting if required. This makes work easier on the eyes and guards against early fatigue. Desk luminaires are also suitable where the desk allows the user to switch from a seated to a standing position (Licht.Wissen, 2012).

3.1.2.5. Mixed standing offices

Traditional, open and group office space types are used together in one building, on the same floor or different floors. In the projecting process, conversion to other types

takes place over time, although one of these three types is based on one. Distribution of office space usage patterns in this system; single rooms for executives, group offices for groups, large open spaces for other uses. The working space can be medium or large. The divisor units are reduced, several groups are arranged in the same place. Because of functional and behavioural reasons, individual closed sections were also needed (Begeç, 2005).

For the office working areas, the lighting design is similar to the other office types. For the communication areas, direct/indirect lighting solutions allow suitable light with high visual comfort for conversations and reading. For reading, the preference is generally for a mainly direct lighting component beside the seat; for conversations, indirect lighting makes for an agreeable atmosphere and casts faces in a kinder light. Free standing luminaires permit flexible lighting and furnishing arrangements. Formally coordinated design concepts can be flexibly adapted for different tasks by a lighting control system (Licht.Wissen, 2012).

Today, the companies, regardless of the size, are no longer using the traditional office interior designs. Due to technological improvements, new methods, techniques and processes enhance office efficiency and productivity. The use of computers and modern communication equipment, many tasks that are done by the workers are changing or vanishing. The tasks ofthe people are different and more specialised. In our time of globalisation, competition, communication, and influence are becoming more critical, and the offices are also taking part in this process.

From past to future, the offices have changed rapidly. Beside the working spaces, there are many other parts in offices created in contemporary office design. The employees depend on the task type have different needs in the offices. Sometimes they need to work in a quiet place, other times need a group working space, in which more than two people can fit. Based on these needs there are team space, cubicle personal working space, study booth, work lounge, touch down, team room, different meeting rooms for different purposes, filling space, storage space, print and copy area, mail area, pantry area, break area, game rooms, waiting areas, circulation space, locker area, smoking area, library.

3.2 Lighting Design in Offices

Lighting design for offices has focused mostly on the workers in these offices. Their lighting needs depend on their tasks, adequate light for visual performance, minimal glare, quality colour rendering and energy saving are the main basis for the lighting design (Figueiro & Rea, 2014).

The scientific research results of recent years consistently show that light not only serves for vision but also has a significant influence on the health, well-being and vitality of people. Modern lighting concepts, therefore, take into account the emotional and especially the non-visual effects of light, in addition to the demands for a high quality of light for good vision already described in numerous standards, rules and recommendations. The wake-sleep rhythm of humans is based on the 24-hour course of the day (more circadian course). Circadian effective lighting supports people in active times and periods of rest, stabilises the day-night rhythm in the long term, provides better sleep and more energy during the day, activates immediately and promotes motivation and performance. The active time for people is mostly daytime, and they spend this period mostly in their workplaces. So the lighting in offices has significant importance in humans' lives.

In this chapter, the lighting design approaches for office interior from past to today have been described in detail. The scientific application of artificial lighting has been only needed in the last century. In the last one hundred years, with the rapid development of efficient light sources, the lighting design has acquired the elements that allow artificial lighting to be produced with sufficient illuminance levels. This development is accompanied, however, by the task of defining the objectives and methods behind this new discipline, of deciding on the criteria by which the artificial light that is now available is to be applied. Ganslandt and Hofmann (1992) defined the lighting design concepts in three approaches. Through all the information there have been three lighting design approaches created with the needs. These are quantitative-based, luminance-based, and perception-oriented based lighting design concepts (Ganslandt & Hofmann, 1992). These lighting concepts, which were used by architects and designers, are not sufficient by themselves.

3.2.1 Quantitative-based lighting design in offices

The first and to date most effective concept has given rise to a set of standards or criteria for the lighting of workplaces. While decisions with regard to lighting in the private sector can be limited to the choice of suitably attractive luminaires, there is a clear interest in the field of the lighting of workplaces to develop effective and efficient forms of lighting. The main concern is which illuminance levels and types of lighting will ensure optimum visual performance, high productivity and safety at operating costs which are affordable (Ganslandt & Hofmann, 1992). The main point is that the illumination levels and lighting types provide optimum visual performance, high efficiency and cost-effective security at operating costs (Küller, 2002).

In the concept of quantitative lighting design, the first significant criterion is illuminance, followed by uniformity, luminous colour, shadow quality and the degree of glare limitation, developed at a relatively early stage. By taking these criteria as a basis, standards have been compiled containing minimum levels of illumination in the work area for a variety of activities and minimum requirements for other quality criteria (Küller, 2002).

This design concept, which only serves to ensure safety and a sound working economy, and ignores any other requirements regarding users may have of their visual environment, which cause problems at the workplace. Outside the working environment, the user would necessarily find such lighting deficient; the lighting solution will endure clearly lower to the feasible possibilities (Ganslandt & Hofmann, 1992).

3.2.2 Luminance-based lighting design in offices

The most important basis for this method is not only come up with sufficient illumination for visual tasks but also allowed to design the optical effect of the entire space at the same time. In order to plan the visual effect of an environment, the central reference amount must be changed (Ganslandt & Hofmann, 1992).

According to Ganslandt and Hofmann (1992), instead of illuminance, which describes only the technical performance of lighting installation, a dimension that stands up from the correlation of light and lit environment, thereby forming the basis for human perception. Changing the quantity to luminance means that brightness and contrast

ratios can be set for the entire perceived space, between visual task and background, between individual objects or between objects and their surroundings. This change of criteria does not make much difference to the lighting of visual tasks at the workplace, the effect of distinct contrast ratios on visual performance are known and have been taken into consideration according to the degree of difficulty defined for the certain visual tasks. This does not apply for the lighting effect in the whole space.

Designing the workplace with the concept of luminance level approach is not entirely different from quantitative lighting design by standards. However, it is based on widening analysis to the whole space. In one space, there are different tasks which need different illuminance levels. Ganslandt and Hofmann (1992) noted that it is now eventual to diversify between the various visual tasks performed in a space, to define room zones where the lighting is adjusted to the specific activities carried out in these areas. This shows that among the various visual tasks done in an area, it is now possible to define the room areas for which the illumination is set according to certain activities performed in these areas. At this stage, it is possible to set standards and recommendations for quantitative lighting design when planning illumination for individual visual tasks (Ganslandt & Hofmann, 1992).

There are limitations in luminance-based lighting design. The luminance levels are not only directed towards the lighting for visual tasks but towards the luminance levels between the visual tasks and their respective surroundings, the harmony of all luminances within one area. The aim of the luminance based design makes an equivalence between the efficient illuminance and the perception of the user. Perception is provided with illuminance and reflection of the illuminance from objects and surfaces together. The retina only gives the basic seeings with the illuminance. The rest of the process of seeing is completed in the brain. The perception always helps to perceive three-dimensional forms and materials around the world (Ganslandt & Hofmann, 1992).

3.2.3 Perception-oriented lighting design in offices

The quantitative process together with the luminance based process is still not enough to achieve the essential requirements in lighting design. Because both of them ignore human psychology, even when they satisfy the human physiological needs in the process (Ganslandt & Hofmann, 1992).

When only two main factors are associated, the structural information provided by a visual medium and the needs of a given person in a given situation develop the so-called pattern of a field's significance. Only then it is possible to analyse the order of importance of individual domains and functions. Based on this model of significance, it is possible to plan the enlightenment as the third variable factor in the visual process and design accordingly. The need for orientation is radically changing depending on the nature of the environment.

It was stated by Ganslandt and Hofmann (1992), perception-oriented lighting design, which is directed at the human being and his needs, can no longer be directed in primarily quantitative terms relating to illuminance and the distribution of luminance. To achieve lighting that is suitable for a given situation it is necessary to develop a set of qualitative criteria, an entire vocabulary of terms, which can describe the requirements a lighting installation has to meet and form the effects of the light with which these requirements can be fulfilled (p. 115).

3.2.4 Today's lighting design approach

Today the office lighting design are planned through the information of the international standards (EN 12464-1). But these standards only focus on human's physiological needs. The psychological effects of light are also as significant as the physiological ones. The present studies indicate this importance. These concepts can be applied to spaces with 'Human Centric Lighting' , achieving proper lighting design to provide psychological and physiological health to users at the same time.

The international standards have been given in the previous section in detail. In addition to them, there have been important criteria, which are used while designing lighting for offices. It is stated in Licht Wissen (2011), edited according to EN 12464-1 standards, that; defining the task area and the immediate surrounding area gives the designer the freedom to create a lighting design based on the visual requirements for a particular activity within a given space. It is important to understand that some visual tasks may extend over large areas. The designer is thus required to document the size and location of the task area(s). If the size and/or location of the task area are not known, DIN EN 12464-1 stipulates that either the whole room (or room zone) should be assumed to be the task area or the whole room should be uniformly illuminated at a level defined by the designer.

The primary Em (illumination), UGR (unified glare rating), Uo (uniformity) and Ra (colour rendering index) value in order to EN12464-1 for offices have been given in Table 3.2. The task area has been defined as the area like in Figure 3.2, in which the visual task is carried out. It needs to be at least 0.5 m wide from the wall. The visual performance required for the visual task is determined by the visually relevant elements (size of objects, background contrast, the luminance of objects and presentation time) of the activity performed. The main task reference surface for offices can be horizontal. The immediate surrounding area has been defined as a band surrounding the task area within the field of vision (Figure 3.2).

Table 3.2 : The necessary illumination (Em), uniformity (Uo), and unified glare rating (UGR) and colour rendering index(Ra) values in offices (EN12464-1, 2011).

Type of area, task or activity	Em , lx	UGR	Uo	Ra
Filling, copying, etc.	300	19	0,40	80
Writing, typing, reading, data processing	500	19	0,60	80
Technical drawing	750	16	0,70	80
CAD work stations	500	19	0,60	80
Conference and meeting rooms	500	19	0,60	80
Reception desk	300	22	0,60	80
Archieves	200	25	0,40	80

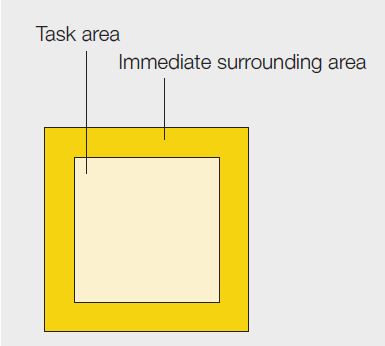


Figure 3.2: Task area and immediate surrounding area according to EN 12464-1 (Licht.Wissen, 2011).

A well-designed light in the offices can be sufficient for human's performance. The lighting quality is active on human's visual performance with the seeing ability. The atmosphere and impression of workplaces can be increased (Clements-Croome, 1997).

The artificial light supported with the daylight is a very significant element for a good quality office environment. The position of the office building must be evaluated according to daylight. However, daylight is also not enough to provide the necessary conditions for the efficient office lighting design. Imitating the daylight's dynamism regarding light colour and light intensity for artificial lighting in an office has a powerful influence on the mood and motivation of the office workers (Beld & Bommel, 2004).

When the task area is known, the lighting installation needs to be modified to achieve the appropriate illuminance levels required. The requirements of the workstation area, surrounding area, background area, and circulation area in the offices have been shown in Figure 3.3. The minimum maintained illuminance of the workstation area should be 500 lux, for the surrounding area 300 lux, and background 100 lux.

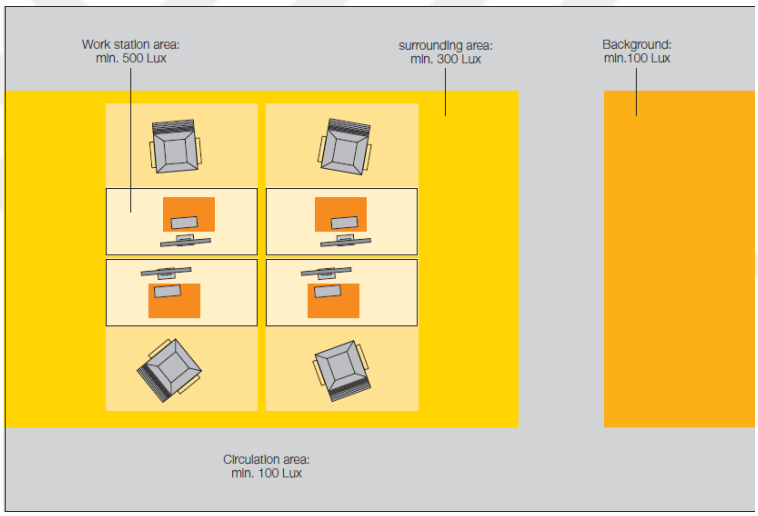


Figure 3.3: Typical plan of workstation area, surrounding area, circulation zone and the adjoining background area in a huge room (Licht.Wissen, 2011).

The illumination level is one of the important criteria, but there are also limits in spaces. In Figure 3.4 it is shown that the visual performance increase with the illumination level.

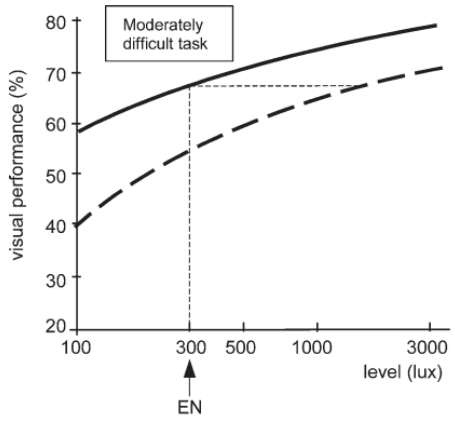


Figure 3.4 : CIE standards relation between visual performance and illumination level (Beld & Bommel, 2004).

3.3 Contemporary Office Design Examples

In a rapidly changing and evolving world, there is only one thing somehow not changing: Working to earn money. In the previous times, the working tasks are not the same with the tasks today. From the past to the present with the change of business structures, jobs are requiring less physical power, and office works and documentation processes increase. Digital innovations are one of the crucial factors that define the industry. Consequently, the office forms and buildings are changed.

The contemporary office jobs consist of writing, typing, reading, data processing, filing, copying, drawing, etc. The environment of the offices is shaped according to these works. The motivation of the employees and their physical and psychological health are essential for the companies. Because in the modern world, the people are spending half of their waking hours in their working environments. It means that the offices are like a second home for employees. Providing comfortable and home-like areas for people and creating functional areas suitable for every kind of task should be a critical point of the companies.

For designing a good office, it is critical to know how the people work and what they want in order to create the ideal constellation of physical, social, and virtual environments for them. There are many bases for the implementation of a well-designed office. The flexibility, energising, based on personal needs, the inclusion of the users, functionality, motivational, experienced-based, more with less, sustainable, eco-friendly, collaborative, etc. are the most significant elements. These key factors

should be solved not only by the interior design but also with the lighting design. Especially lighting is essential for a human's physical and psychological health. The artificial light and daylight should be in harmony together.

The users' performance and perception are affected mainly by the lighting design. For good visual performance in offices; not only physical conditions of a person like age, seeing ability and task type but also environmental conditions like daylight, artificial light, daylight and artificial light dynamism, light intensity and colour are crucial components. The good lighting installation contributes to working performance, human' physical and psychological conditions.

In this chapter, there are three office examples from Europe and their lighting design concepts. The first example is Microsoft Headquarters in Vienna, the second example is located in Paris, and the company name is CMS Bureau Francis Lefebre. The third example is Ströer SE & Co. KgaA. The Ströer News Publishing GmbH is located in Berlin.

3.3.1 Microsoft Headquarters, Vienna

The information about Microsoft is stated in Table 3.3. The interior space and lighting concept are designed by INNOCAD Architektur ZT GmbH in Graz.

Table 3.3 : The Microsoft Headquarters project information (XAL GmbH, 2018).

Completion year	Location	Architecture office	Lighting Design
2011	Vienna,Austria	INNOCAD Architektur GmbH	XAL GmbH

Microsoft has conducted several studies on how their employees work and what they want for creating the ideal working environments for them. The result is the Workplace Advantage Concept, which analyses the employee structure of every branch office by five categories, from the resident, and uses this information to create a custom-tailored interior programme. An average of 10% greater employee satisfaction, a 12% increase in productivity and efficiency, improved CO2 footprints, and many similar benefits were expected – and some can even already be measured. The complete renovation of the 4,500-square-metre head-quarters in Vienna took this concept to heart and even went one step further: The "sealed-off" employee floors

were opened up and arranged transparently. An architectural lifeline traverses the entire building in the shape of reachable, multi-functional furniture, ensuring a spatial bracket around all of the floors and facilitating a variety of working sets. The most significant possible flexibility was provided in the closed meeting rooms. Every employee can select their ideal environment for their needs and mood (XAL GmbH, 2018).

All circulation areas such as corridors and foyers were designed to be intentionally dynamic. The striped vinyl floor material and a slide that allows secure entrance from the second to the first floor both symbolise motion. The accompanying green walls in all of the floors have both an atmospheric and positive effect on the climate of the space. The lighting concept works with a few light sources as possible. Neutral, uniform lighting in the form of linear light elements in the “lifeline” creates an atmospheric mutter. The different sets of the meeting rooms are also strengthened by direct and indirect lighting with pendant, floor-standing, and table luminaires, and even LED walls and light curtains (XAL GmbH, 2018).

Mainly there are three types of lighting equipment used. For the circulation areas and foyer linear recessed mounted with dimmable LED used like in Figure 3.5. For a different kind of meeting rooms and offices, direct lighting feature in Figure 3.6 with suspended details was planned. At the entrance, the suspended lighting in Figure 3.7 is used. For floor LED recessed mounted spotlights were planed as it stated in Figure 3.8. Also for other meeting rooms and office spaces suspended and surface mounted are planned like in Figure 3.9. The lighting devices are all dimmable. Thus, depends on the daylight position and intensity, the lights can be dimmable. At this moment it provides the necessary illuminance during the day and helps to save energy. The colour temperature 4000K, which is cool light colour and also optionally with tunable-white diodes (3000-6000 K), provides excellent colour for the working areas in daytime. The micro-prismatic cover, PMMA diffuser include diffuser film for homogeneous illumination and reduced luminance, makes the vision more comfortable for working and meeting spaces. The colour rendering index is in good value (CRI $\geq$ 80), suitable for the offices (XAL GmbH, 2018).

Figure 3.5: The view from foyer area (XAL GmbH, 2018).

Figure 3.6: The view from meeting room (XAL GmbH, 2018).

Figure 3.7: The view from information desk area (XAL GmbH, 2018).

Figure 3.8: The view from circulation area (XAL GmbH, 2018).

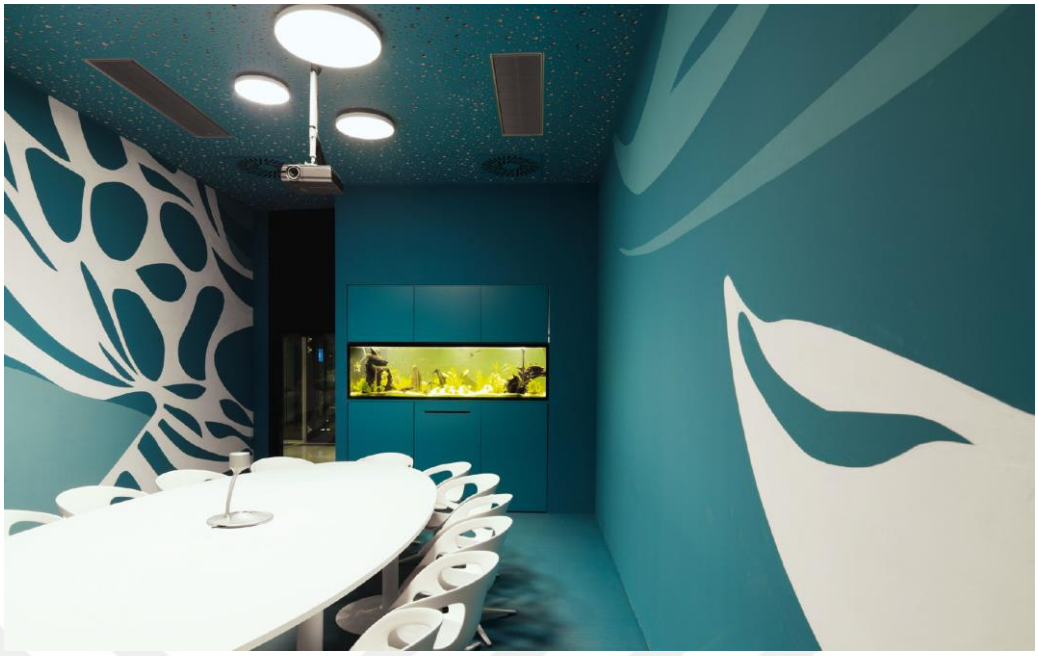


Figure 3.9: The view from conference room (XAL GmbH, 2018).

3.3.2 Cms Bureau Francis Lefebre, Paris

The Cms Bureau Francis Lefebre is located in Paris, and the information has been shown in Table 3.4. The architecture office was commissioned to design the ground floor reception areas and the seventh floor of the new office of CMS Francis Lefebvre, a multinational business law firm.

Table 3.4 : The CMS Bureau Francis Lefebre project information (XAL GmbH, 2018).

Completion year	Location	Architecture office	Lighting Design
2017	Paris, France	Lobjoy-Bouvier-Boisseau	XAL GmbH

The aim was to improve communication flows and give these zones a unique, custom appearance that reflects the firm's development and singularity. The project reinterprets the formal vocabulary usually used in hotel architecture. The primary design challenge was to create relationships between spaces. Ludovic Lobjoy achieved this by using strong contrasts in colours and materials and by skillful lighting design. The recessed mounted lighting in circulation areas was planned. They are used to give a clear structure to the rooms like in Figure 3.10, most notably the conference rooms, without dividing them. Selected highlighting of individual architectural elements and

the lighting design for the “bands of wood” are also an important design strategy, which gives the rooms as a whole a comfortable feel like in Figure 3.11 (XAL GmbH, 2018).

The lighting devices are all dimmable like in the Microsoft project. Thus, depends on the daylight position and intensity, the lights can be dimmable. At this moment it provides the necessary illuminance during the day and helps to save energy. The colour temperature 4000K, which is cool white and also optionally with tunable-white diodes (3000-6000 K), provides appropriate colour for the working areas in daytime. The micro-prismatic cover, PMMA diffuser include diffuser film for homogeneous illumination and reduced luminance, makes the vision more comfortable for working and meeting spaces. The colour rendering index is in good value (CRI $\geq$ 80), suitable for the offices. The foyer and the circulation areas were designed with recessed linear LED lighting for the feeling of continuity as it has been shown in Figure 3.12 (XAL GmbH, 2018).

Figure 3.10: The view from lounge area (XAL GmbH, 2018).

Figure 3.11: The view from foyer (XAL GmbH, 2018).

Figure 3.12: The circulation area and conference room (XAL GmbH, 2018).

3.3.3 Ströer News Publishing GmbH, Berlin

Ströer SE & Co. KGaA is a digital multi-channel media company offering customers complete solutions along the entire marketing and sales value chain. The information about the project has been stated in Table 3.5.

Table 3.5 : The Ströer News Publishing project information (Nimbus Group GmbH, 2018)

Completion year	Location	Architecture office	Lighting Design
2011	Berlin, Germany	Designfunktion Bonn GmbH	Nimbus GmbH

At the location of Ströer News Publishing GmbH in Berlin, the focus in designing the office space was on the development of conference areas and retreats for employees. Design function from Bonn designed the interior design. The rooms serve as a newsroom. From here, content for editorial content is delivered throughout Germany to Ströer media, desktop and mobile. The products, which are pendant LED lights, planed in open office have acoustic and lighting feature together, and make the idea of the cloud in the space shown in Figure 3.13, which stands behind digitally produced information, tangible on the surface. The various conference rooms and retreats are designed on the basis of different themes and have been furnished with great attention to detail: apart from a ski lodge like in Figure 3.14, a sports studio in Figure 3.15 and a tree house in Figure 3.16, for example, a cinema and table tennis room were staged spatially in Figure 3.17. Moreover, also for the lounge or pause rooms, portable lighting with dimmable LED is used. The result is a modern, contemporary and well-usable office space. In the single working rooms in Figure 3.18, the table lamps are planned for single usage and providing personal control. The luminaires which used for offices and conference rooms are suitable for the workplace, light emission 100% direct beam, wide distribution, dimmable, and the colour temperature is 4000K (Nimbus Group GmbH, 2018).

Figure 3.13: The view from open office area (Nimbus Group GmbH, 2018).

Figure 3.14: The conference room (Nimbus Group GmbH, 2018).

Figure 3.15: The sports room (Nimbus Group GmbH, 2018).

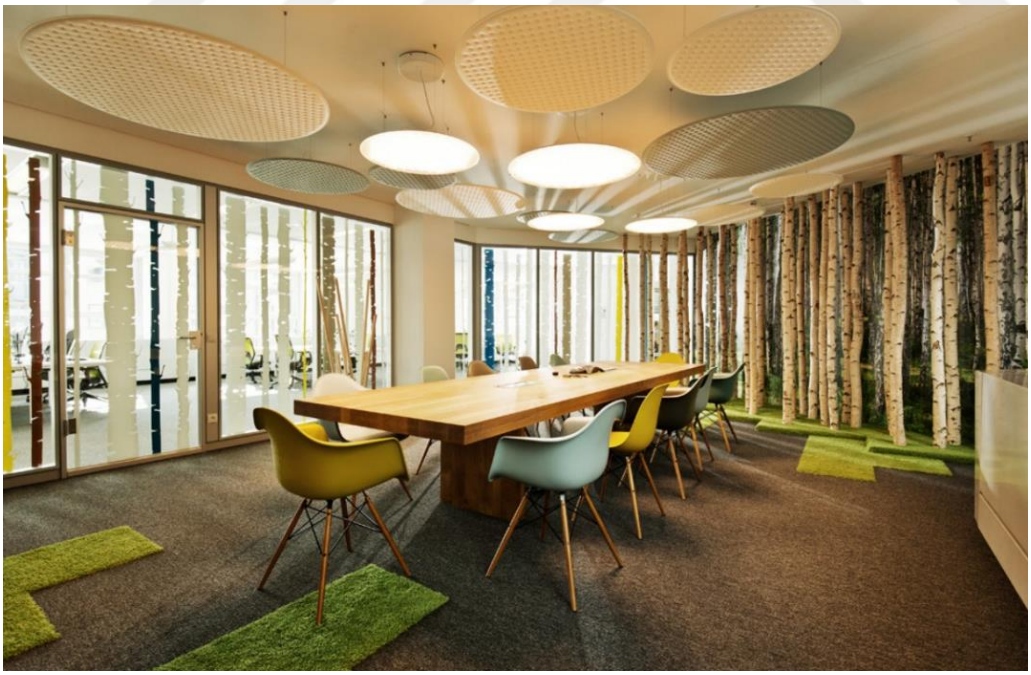


Figure 3.16: The second conference room (Nimbus Group GmbH, 2018).

Figure 3.17: The view from lounge areas (Nimbus Group GmbH, 2018).

Figure 3.18: The single working rooms (Nimbus Group GmbH, 2018).

4. A PROPOSAL FOR AN OFFICE INTERIOR

In this section, an implementation of Human Centric Lighting concept in a design office has been intended. First, the office has been observed, and the description of space, information on activities and occupants have been explained. The details of existing interior design and lighting system have been defined with their limitations. Then the design concept has been implemented to space with the required lighting needs. The needs were divided into groups depending on users' activities and their time schedule. At the end, in addition to the evaluated lighting design concept, there have been given the suggestions to ensure Human Centric Lighting in space.

4.1 Description of the Design Office, Information on Activities, and Occupants

The office was observed in the class 'IMT 509E Interior Architectural Project III' which was in 2016-2017 fall semester. The observations, the existing lighting situations, and the photos have been collected in this semester. The information from this course has been reviewed for the case study and presented in project section in this study.

The project area is located in Çukurcuma, Çukurcuma Caddesi No:41 in İstanbul Turkey, and founded by two product designers Mert and Melda. They are freelance designers and the owner of the design office. Mert is 30 years old and male user. Melda is also 30 years old and female. They are the primary users of the office. There is also a secondary user in the office. A friend of Mert Sezer also uses the office when he needs a workspace. So it could be assumed that there are three users in the office. Mehmet and Melda invite their clients and their friends to the office so often. The office takes place at a central location. The location of office has been given in Figure 4.1. The easiest transportation to the office is from Taksim Square by walking. The first way is through Cihangir, and the second option for walking is through Taksim Street than after Galatasaray Highschool by following the left street.

Figure 4.1: The location of the office (Url-2, Google Maps, 2018).

Around the office, there are apartments, design stores, cafes, and museums. The street is very narrow. The buildings are so close to each other. On the south-west side of the street, there is a construction site. Between the construction site and the project area, there is another narrow street going up with stairs. Along the street, there are low height stairs. The views from the street have been given in Figure 4.2 with the map. The office is on the entrance floor of a building, which is not older than five years. It has been renewed, but the exact renewal date couldn't be obtained. In front of the office, an antique furniture store is located. On the south-west side of the building, a museum is located. On the north-east side of the building, at the end of the street, there are many cafes. Even if it is a small street; there are many people passing through during the day.

The project field is on the corner of the street, and the main facade is faced to north-west side. The office does not get sufficient daylight because of the dense surrounding, and it is also located at the ground floor of the building. The office has two large windows on the front side which give the feeling of the showroom. Because of this reason lots of people who are using the street, look into the office frequently.

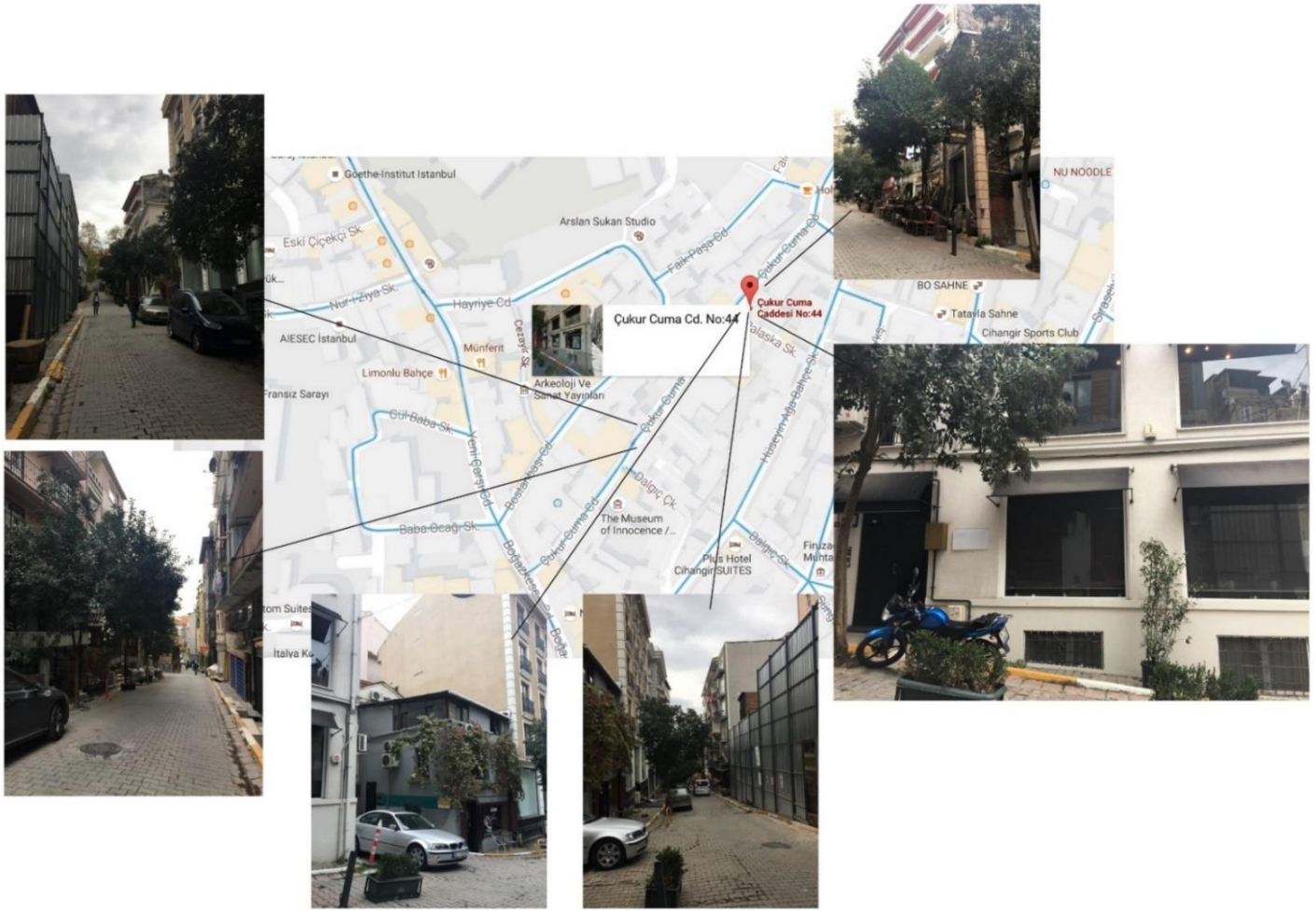


Figure 4.2: The views of the street (Köseli, 2016).

The office is 46.50 square meter (m²), includes one big office on the north-west side of the apartment, one small office on the south-east side of the building, one kitchen, 1 WC, and one small entrance hall. The sizes of the rooms are as follows: front office is 19.4 m², the back office is 13 m², the kitchen is 8.9 m², and the WC is 5.3 m². The plan has been given in Figure 4.3. The lighting design proposals are given only for the front office.

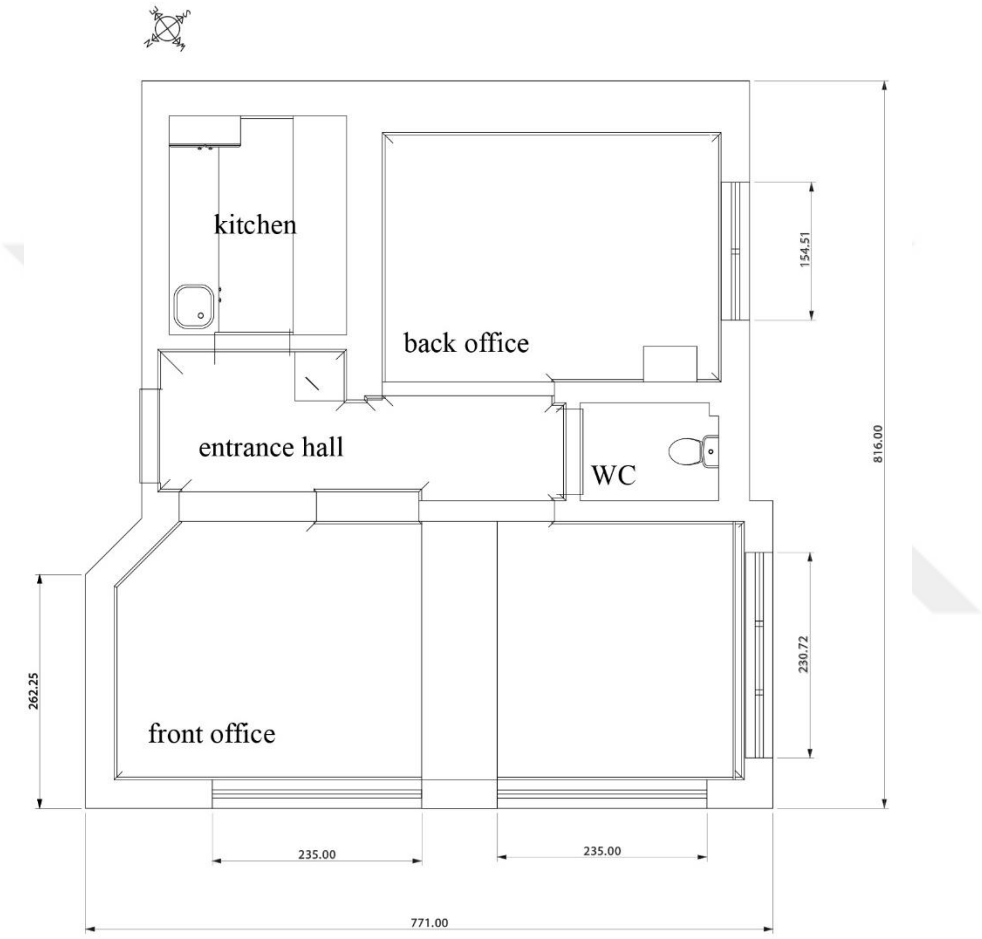


Figure 4.3: The plan of the office (Köseli, 2016).

In 2016 summer, the office has been founded by Mert and Melda. However, the interior design was not ready at that moment. The interior situation of space has been shown in Figure 4.4. The existing floor is wood parquet. The walls are grey, making the entire space darker. When entering into the apartment, first there is a small entrance hall, stated in Figure 4.5. The room height is 2.7 meter. Depends on the user groups and activities; the office was divided into three spaces which are shown in Figure 4.6.

Figure 4.4: The front office (Köseli, 2016).

Figure 4.5: The entrance hall (Köseli, 2016).

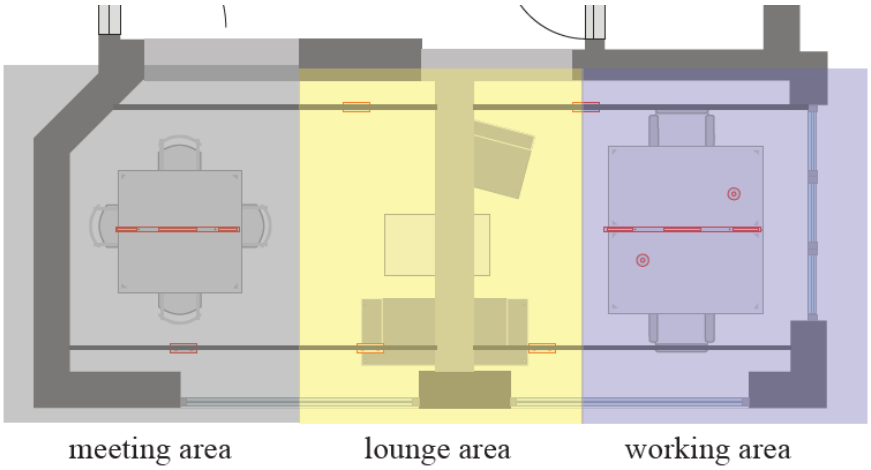


Figure 4.6: The divided space in 3 groups: meeting area, lounge /relaxing area, a working area (Köseli, 2018).

There are four different user groups in the office. The groups, occupants, their activities, and time periods have been shown in Table 4.1. The user groups and the time of use have been given in Table 4.2.

Table 4.1 : The groups, occupants, their activities, and time periods (Köseli, 2016).

Group	Occupants	Activites	Times	Information
A	Primary users Mert and Melda	Working, Intensive Working, Meeting	Morning, Afternoon, Evening	30 years old, freelance product designer
B	Secondary user A friend of them	Working, Intensive Working,	Afternoon, Evening	30 years old, freelance product designer
C	Clients	Meeting	Morning, Afternoon	30-35 years old, different gender groups
D	Friends	Relaxing	Evening	30-35 years old, different gender groups and professions

Table 4.2 : The occupants and time zones of use (Köseli, 2016).

	Meeting	Lounge	Working
Time of use	Morning, Afternoon	Morning, Afternoon, Evening	Morning, Afternoon, Evening
Occupants	A C	A, B, D	A, B

Group A use the office daytime and also night time. Group B come to office afternoon for working and also evening time for casual activities. Group C use the office during the day. Group D use the office mostly in the evening for relaxing and hanging around with Group A. All user groups use the front office and everytime of the day.

Because of the position of the building, daylight is not enough anytime during the day. With the grey walls, it becomes darker. In order to evaluate the daylight availability in the front office, two areas were determined when the daylight is measured. The first one is the window side areas, which include 1 meter near the window. The second one is inside room, which starts 1 meter away from the windows and ends in the entrance hall. For every area, three points 0.75 m height on the horizontal plane were determined. The measurement points are given in Figure 4.7.

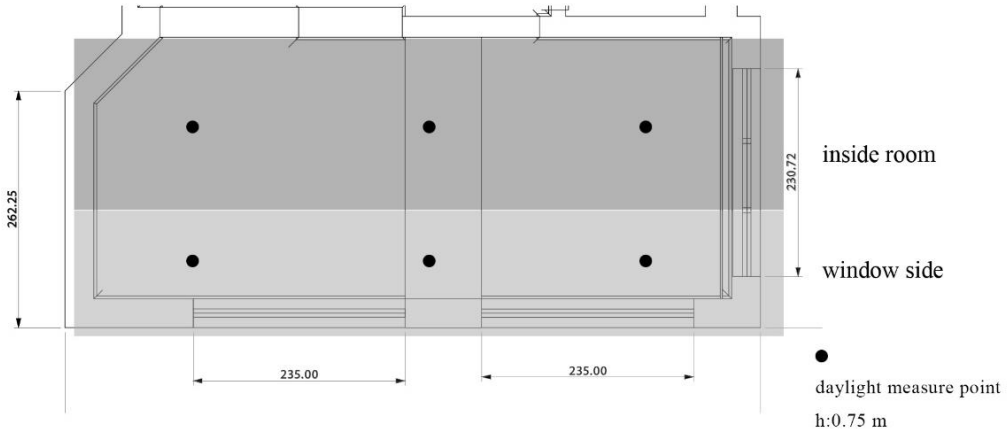


Figure 4.7: The defined spaces in the room (Köseli, 2016).

During November 2016, two times (morning-afternoon) in a day on every week, the daylight illumination without artificial light were measured with the phone application 'Galactica Luxmeter' at the given points. The average of the daylight values has been stated in Table 4.3. The illumination levels were measured once a week in November,

at the same periods of the days. Every 20 Minutes for one hour, the illumination levels were measured and the averages were taken. So that Table 4.3 is formed. The table shows that inside the office especially in winter times daylight is not sufficient for the required illumination level of the office working activities, which are already explained in section 3. The required illumination for the task areas (computer works) on the table is minimum 500 lux, for the surrounding areas in the office is minimum 300 lux, and for the intensive works (naked eye works) on the table is minimum 750 lux. These values have been explained in previous section and EN standards were given.

Table 4.3 : The measured illumination levels in the front office during November (Köseli, 2016).

November	Morning time (9:00-10:00)		Afternoon (14:00-15:00)	
	window side	room inside	window side	room inside
1st week	237 lux	152 lux	196 lux	116 lux
2nd week	226 lux	149 lux	187 lux	113 lux
3rd week	227 lux	151 lux	189 lux	117 lux
4th week	224 lux	147 lux	179 lux	113 lux

It is important for users to offer a daylight-like solution. Because of the building position, the office doesn’t have enough lighting and is mostly darker during the day. This reason affects the users' performance, moods, physical and psychological conditions, as it is explained in previous sections. The existing solution for the users at that moment is the usage of the table lamps for more brighter working areas.

In the front office, there have been two working tables for the users. Space has been used as a photographer office before. So there are moveable spots as artificial lighting equipment in the front office that are pointed at the working desk 1 2 which have been shown in Figure 4.8 and Figure 4.9. The spots are surface mounted have a moving mechanism, as in Figure 4.10.

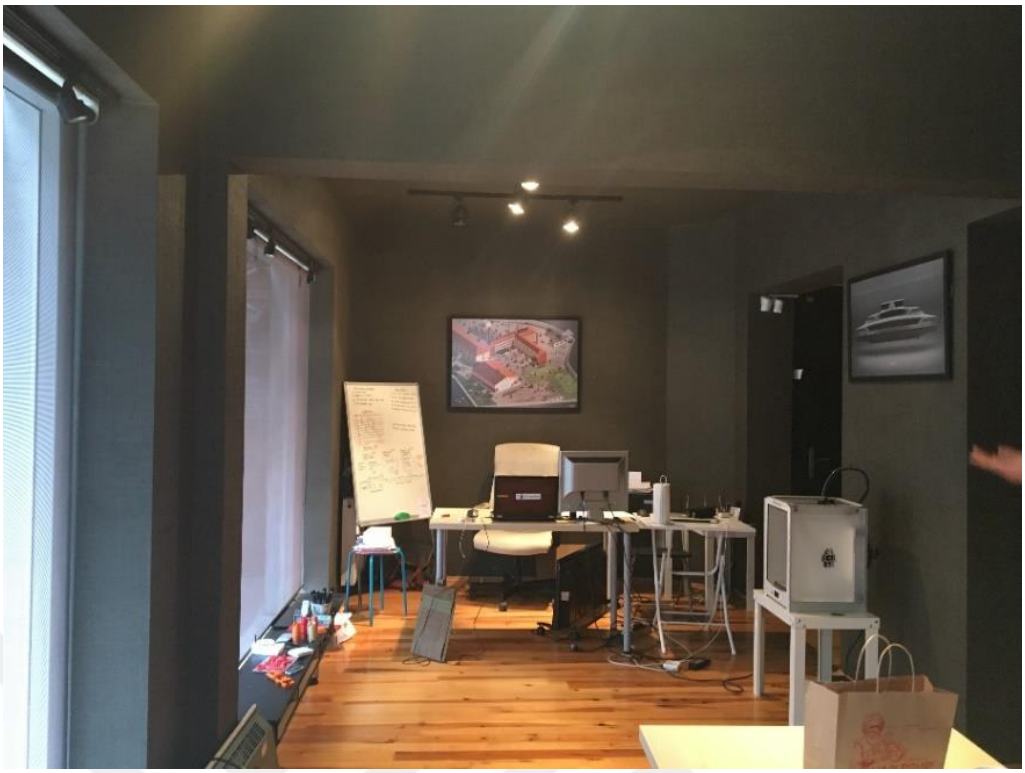


Figure 4.8: The working desk 1 (Köseli, 2016).

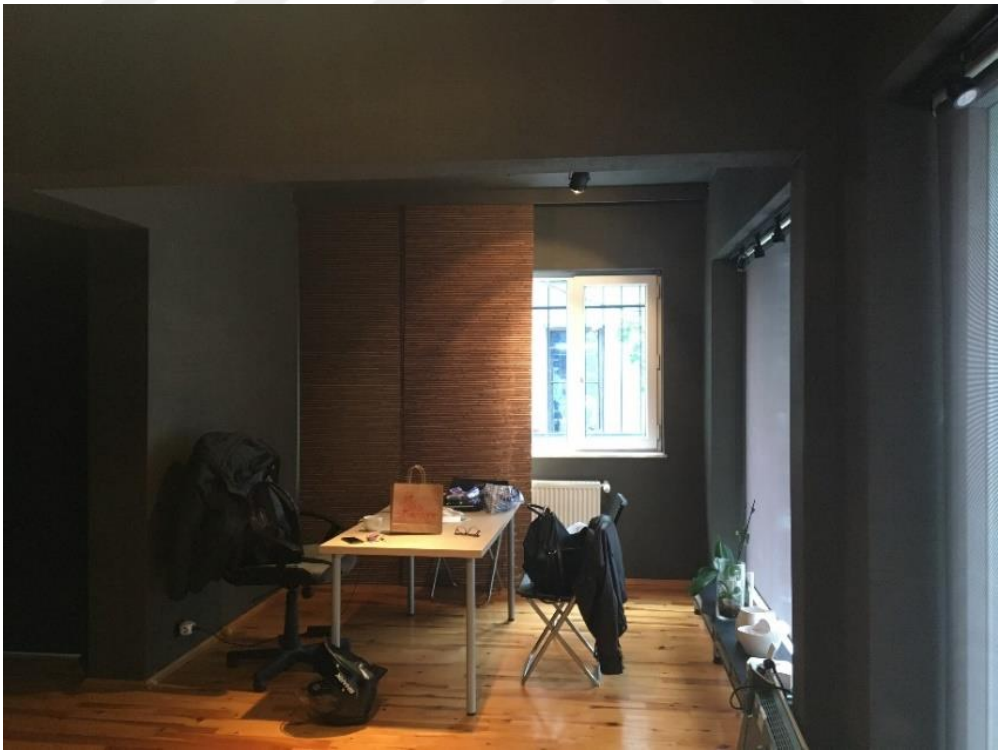


Figure 4.9: The working desk 2 (Köseli, 2016).

Figure 4.10: The surface mounted spots (Köseli, 2016).

The existing lighting design does not provide a good working area for the users. There is not sufficient lighting for different kind of tasks and times. Daylight is insufficient to illuminate the entire space, so a suitable lighting design should be carried out to ensure the necessary level of illumination and biological rhythm. The problems of the area listed below:

- Dark grey walls make space darker at daytime. For interior surfaces suggestions should be given in accordance with Section 2.1.1.1 by EN12464-1.
- Different interior scenarios need to be ensured for the space using the furniture and lighting. There should be another working area for the third user and a meeting area for clients. The office is used by different kind of occupants, different daytime, and for different activities. Users need a flexible interior design. In the office area, the sufficient illumination level should be provided for every activity, which is working, meeting, and relaxing. The light should be arranged for every occasion.
- The illumination is not sufficient for computer works, and naked eye works. The required illumination for the task areas (computer works) on the table is minimum 500 lux, for the surrounding areas in the office is minimum 300 lux, and for the intensive works (naked eye works) on the table is minimum 750 lux based on EN12464-1. The sufficient lighting for all kind of activities should be

provided in this space. The activities are working (computer works and naked eye works), meeting, and casual activities (relaxing, drinking, casual meetings). The room should be flexible for all the activities. The place could be assumed as a small open office or cell office for more than one user in contemporary office design.

- The significant elements for the lighting design in this office are maintaining the illumination, avoiding glare from reflection, limiting the direct glare, distributing the brightness incoherently, choosing the effective colour temperature, ensuring good colour rendering suitable for working areas. The place has not enough daylight, therefore for better working quality and mood, when using the lighting as an interior element in the space HCL concept is applied.

It is necessary to design new artificial lighting that provides visual comfort and should be designed by the HCL concept because it cannot benefit from daylight.

4.2 Implementation of The Project

The office has been used for different kind of activities, and occupants. These have been explained in the previous section. Through the observations, an HCL design concept has been suggested for the office, and the implementation of the project has been designed in Dialux Evo programme.

As it was explained in the previous section, because of the building location and non-suitable lighting system, the illumination of the interior was not sufficient. So, in this section, there is given a new lighting solution, which is suitable for the standards which are given by EN12464-1 for the offices. The necessary Em, UGRL, Uo, and Ra values, which have been shown in the 3rd section should be ensured for working and meeting areas. Moreover, also for relaxing times, a good mood lighting with indirect lighting is suggested.

There are nine types of scenarios, which are based on the users' needs, schedule and task areas.

1- Morning office works in the working area,

2- Afternoon office works in the working area,

3- Evening office works in the working area,

4- Morning intensive office works in the working area,

5- Afternoon intensive office works in the working area,

6- Morning meeting in the meeting area,

7- Afternoon meeting in the meeting area,

8- General lighting in the daytime in the whole office

9- The evening is relaxing in the lounge area.

The nine types of scenarios have been planned to provide essential illuminance for spacing and control the light conditions in any occasion for all the users. The daylight contribution is not taken into account. The scenarios, the schedule and the areas have been shown in Figure 4.11.

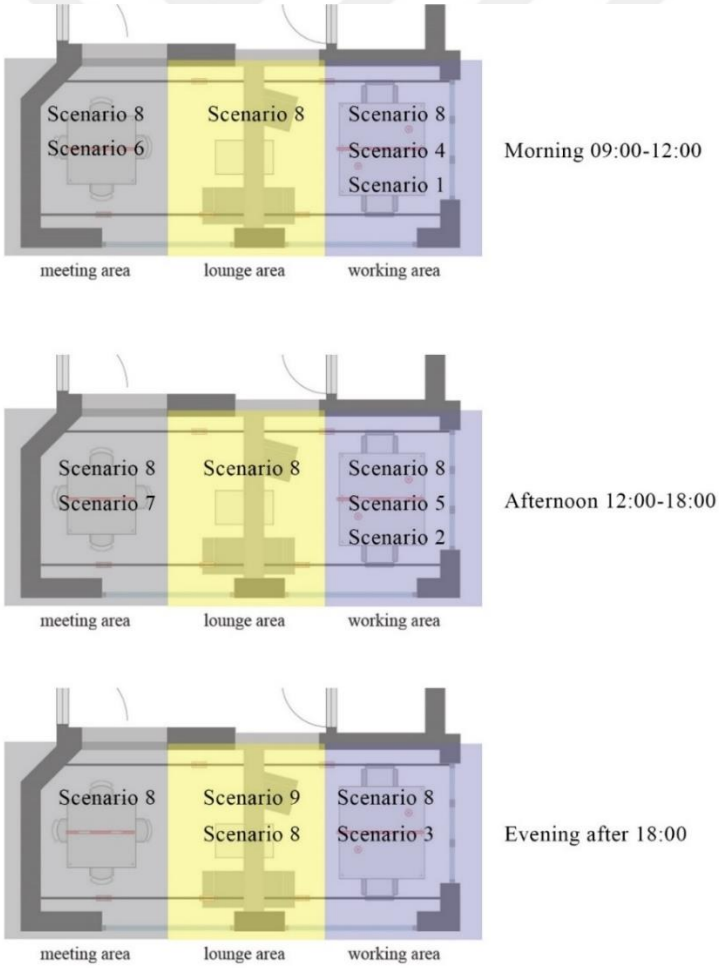


Figure 4.11: The scenarios, the schedule and the areas (Köseli, 2016).

As it is explained in Section 2 in HCL concept, for the daytime tasks and activities, daylight-like lighting with high biological effect is highly recommended for the users' visual and non-visual needs. The lighting design is an essential element to create an appropriate environment, in this space as an interior element. The required illuminance levels and colour temperatures depend on the daytime for these spaces are shown in Table 4.4.

Table 4.4 : The necessary illumination levels according to EN 12464-1, and colour temperatures for the office related to the suggested scenarios (Köseli, 2018).

Time of day	Office works (working area)	Intensive works (working area)	Meeting (meeting area)	Relaxing, casual meetings (lounge area)
Morning 09:00-12:00	*Scenario 1* Cool white (6000K) Task area 500 lux Uo:0.60, immediate surrounding area 300 lux Uo:0.40	*Scenario 4* Cool white (6000K) 750 lux Uo:0.70, immediate surrounding area 300 lux Uo:0.40	*Scenario 6* Cool white (6000K) 500 lux Uo:0.60, immediate surrounding area 300 lux Uo:0.40	*Scenario 8* Cool white (6000K), Mid-cool white(3000K-4000K), Warmer white (2700K) 200 lux Uo:0.40
Afternoon 12:00-18:00	*Scenario 2* Mid-cool white (3000K-4000K) 500 lux Uo:0.60, immediate surrounding area 300 lux Uo:0.40	*Scenario 5* Mid-cool white (3000K-4000K) 750 lux Uo:0.70, immediate surrounding area 300 lux Uo:0.40	*Scenario 7* Mid-cool white (3000K-4000K) 500 lux Uo:0.60, immediate surrounding area 300 lux Uo:0.40	*Scenario 8* Cool white, Mid-cool white (3000K-4000K), Warmer white (2700K) 200 lux Uo:0.40
Evening * 18:00- …	*Scenario 3* 500 lux	-	-	*Scenario 9* Warmer white (2700K) 200 lux

*For the evenings the biologically effective lighting is not recommended for working and meeting areas so that there are no colour temperature recommendations.

The colour temperature of the artificial lighting starts with absolute illuminance level and cool white in the morning. The cool white colour temperature (6000K) creates highly productive space for the users. It is close to the daylight temperature (6000K-10000K).

UGR level of the lighting fixtures is UGR≤19, suitable for the offices. The Uo levels could be 0.40, 0.60, 0.70 depends on the task type.

Moreover, instead of a dark grey wall colour, white wall colour was planned for better illumination in space. The existing wooden floor was considered. The calculations have been done with the suggested reflection factors for walls and ceiling by EN12464-1. The reflection factors are for ceiling 70.0%, for walls 50.0%, for floor 38.6% (wooden floor), and the maintenance factor is 0.80.

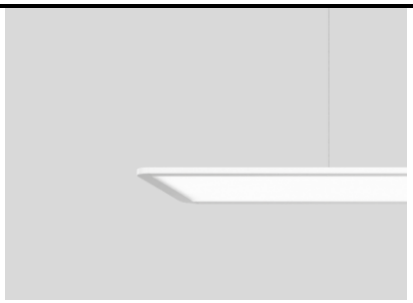
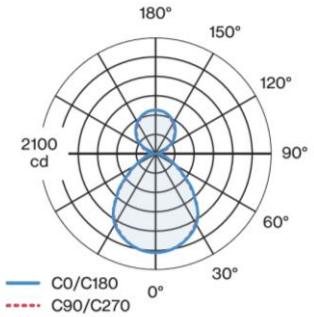
4.2.1 Office working scenarios

The office works' scenarios are done in the working area in morning, afternoon, and evening. The first, second, and third scenarios have been evaluated for the same area with the same lighting product, but with adjustable colour temperature suggestion.

The scenarios for the office tasks are in the morning before 12:00, afternoon 12:00-18:00, and after 18:00. There must be provided cool-white, mid-cool white and warm white during the day which are suitable for human biological body processes, as explained in Section 2, for circadian rhythm. The cool light affects the production suppression of the melanopsin hormone with high blue contain in the morning and makes the users more awake. Afternoon the daylight becomes less cooler white so that the daylight-light lighting ensured mid-cool light for the proper working areas. The melatonin needs less suppression of production in the evening the bodily processes are getting slower in this time, and the body prepares itself to sleep. For this time the melanopic useful light is not suggested. The human body needs more warm white colour temperature with less light for more relaxing.

For working space, the pendant downlight (Product A) was selected and the characteristics have been shown in Table 4.5. In the working area, one pendant downlight has been used.

Table 4.5 : The Product A features (Köseli, 2018).

Product Picture A	
The company and name of product	XAL GmbH / Task S 1180 mm
Lighting type	Pendant, LED module, dimmable
Lighting direction	Direct/indirect
Material	Aluminum profile, 1180 mm length, powder-coated, microprismatic lens.
Power	50W
Luminous flux	6034 lm
CCT value	4000K neutral white
CRI value	CRI≥80
Beam angle	

For the working task area, the product A's ground clearance is 2.20 meter. The length of the lighting is 1.180 meter. The luminaire layout plan has been shown in Figure 4.12.

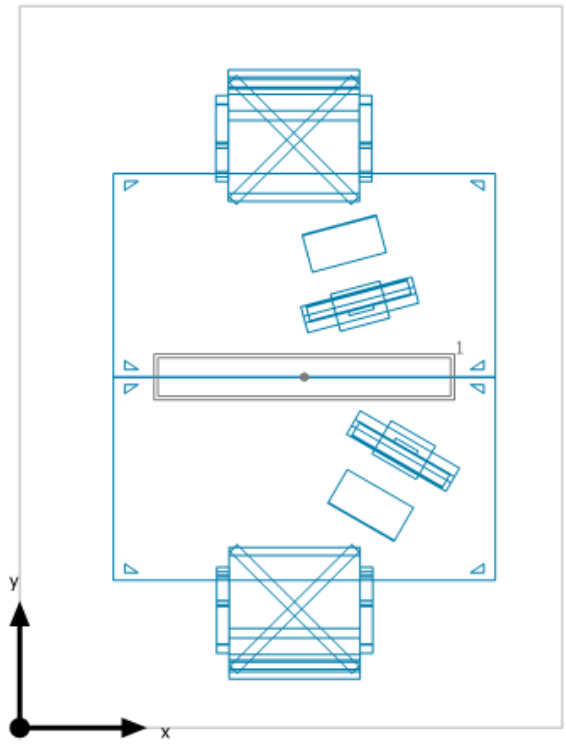


Figure 4.12: The luminaire layout plan for the working area (Köseli, 2018).

The results, with 0.80-meter height and 0.30 wall zone calculation surface, have been given in Table 4.6. The necessary illumination (Em), uniformity (Uo), and unified glare rating (UGR) levels, which are in standards, have been fulfilled. The isolines for this are have been shown in Appendix A.

Table 4.6 : The illumination (Em), uniformity (Uo), and unified glare rating (UGR) levels for working area (Köseli, 2018).

	Task areas (working surfaces on the table)	Surrounding area
Em	541 lux	482 lux
Uo	0.60	0.52
UGR (only working surface)	13.7	-

The product has a direct and indirect lighting feature. The direct light illuminated the task areas on the desks, the indirect light illuminated the ceiling, with reflections light is distributed all around the room. Therefore the immediate surrounding area has over 500 lux. The standard for these areas is minimum 300 lux.

The task areas have the required illumination levels, which are over the minimum level of 500 lux, and sufficient for the computer works.

The scenarios 1, 2, and 3 have been placed in the working area. The illumination and colour temperature changing suggestions during a day have been shown in Figure 4.13. The melanopic effective lighting is not suggested after 18:00.

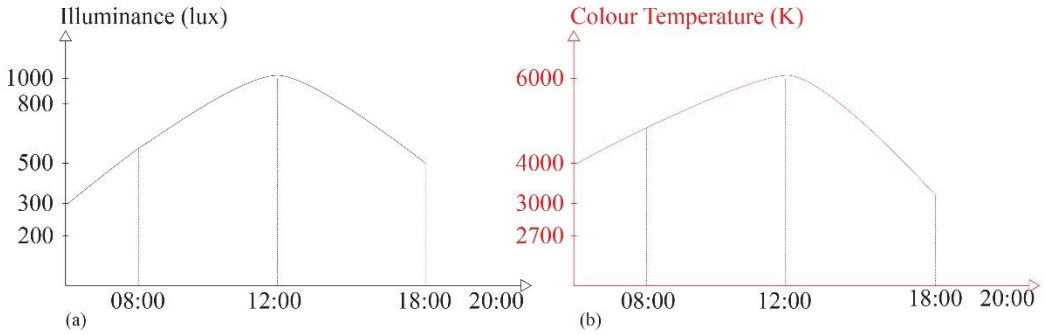


Figure 4.13: The illumination(a) and colour temperature(b) suggestions during a day for the working area (Köseli, 2018).

In Figure 4.14, three different correlated colour temperature (CCT) levels are given. The colour temperature for morning time of the day is planned as cool white 6000K in Figure 4.14(a), for afternoon mid-cool white 3000K-4000K in Figure 4.14(b), and for evening time warm white 2700K in Figure 4.14(c). However, for evenings the biologically effective lighting is not recommended for working and meeting areas, the colour temperature has been suggested as warm white which is not blocking the production of the melanopsin level. The first picture is for morning time, the second one is for the afternoon, and the third one is for evening time. The illuminance and the blue content of the light are steadily raised through up to mid-day and then gradually lowered again through to evening.

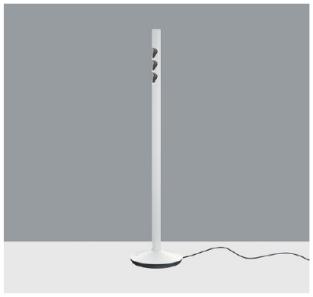
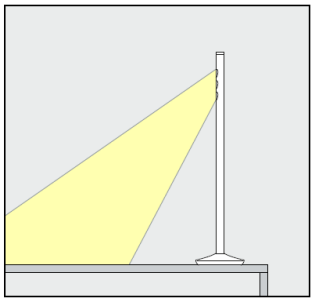
Figure 4.14: The results for the working area with cool white light (a), mid-cool white light (b), and warm white light (c) temperatures (Köseli, 2018).

4.2.2 Intensive office working scenarios

The illumination levels are the same for the all intensive office works' scenarios during the day. Therefore in this section, all the scenarios, fourth and fifth which are morning, and afternoon, have been evaluated for the same area with the same lighting product, but with adjustable colour temperature suggestion.

For intensive working, the necessary illumination level is minimum 750 lux. Because of this reason, local lighting (Product B) was planned for the task areas as a task light and has been shown in Table 4.7. The working areas have been calculated with one pendant lighting and two task lighting (Product B) for each task areas together.

Table 4.7 : Product B features (Köseli, 2018).

Product Picture B		

The company and name of product	Erco GmbH / Lucy Task light
Lighting type	Task light, LED module, dimmable
Lighting direction	Asymmetrical light distribution
Material	Cast aluminium, powder-coated and rotatable on the adapter through 180°
Power	10W
Luminous flux	1230 lm
CCT value	2700K or 4000K
CRI value	CRI≥90

For the intensive working task area, the product A's ground clearance is 2.20 meter. In addition to pendant luminaire, also task light Product B was located. The luminaire layout plan has been shown in Figure 4.15.

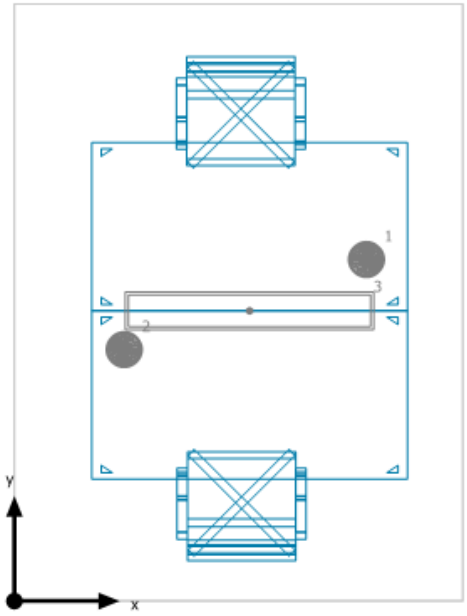


Figure 4.15: The working area lighting layout with table lamps (Köseli, 2018).

The results, with 0.80-meter height and 0.30 wall zone calculation surface, have been given in Table 4.8. The necessary Em, Uo, and UGR levels, which are in standards, have been fulfilled.

Table 4.8 : The illumination (Em), uniformity (Uo), and unified glare rating (UGR) levels for intensive working area (Köseli, 2018).

	Task areas (working surfaces on the table)	Surrounding area
Em	780 lux	670 lux
Uo	0.71	0.41
UGR (only working surface)	18	-

The scenarios four and five have been placed in the working area. The illumination and colour temperature changing suggestions during a day have been shown in Figure 4.16(a) and Figure 4.16(b).

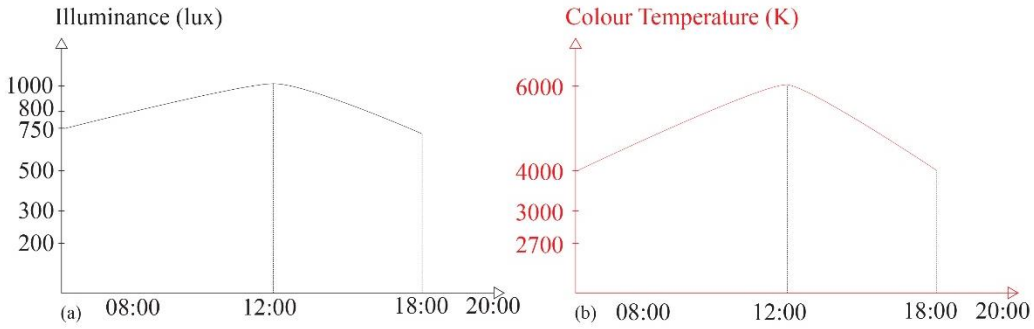


Figure 4.16: The illumination(a) and colour temperature(b) suggestions during a day for intensive working area (Köseli, 2018).

The colour temperature of the task light is 4000K. To provide an excellent colour rendering index the task lighting data has the value CRI≤90. The final illuminated scene has been shown in Figure 4.17. There are two different CCT levels given. The colour temperature for morning time of the day was planned as cool white 6000K in Figure 4.17 (a), and for afternoon mid-cool white 4000K in Figure 4.17 (b). The first picture is for morning time, and the second one is for the afternoon.

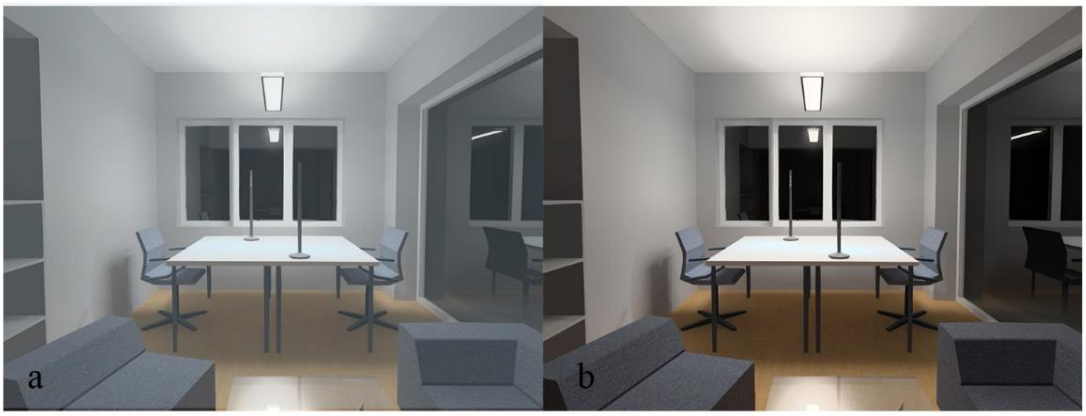


Figure 4.17: The results for the working area with cool (a) and mid-cool white (b) light for intensive working area (Köseli, 2018).

4.2.3 Meeting scenarios

The meeting scenarios are done in a meeting area in the morning and afternoon. The sixth and seventh scenarios have been evaluated for the same area with the same lighting product, but with adjustable colour temperature suggestion. The scenarios for the office tasks are in the morning before 12:00 and afternoon 12:00-18:00.

The illumination levels are same for meeting area during the day. The immediate surrounding area is minimum 300 lux; the task area is minimum 500 lux for meeting required in standards. The only difference is the colour temperature between this time periods. The colour temperature for morning time was planned as cool white light and for afternoon mid-cool white colour temperature.

For the meeting area, the same pendant downlight, Product A, was selected like in the working area. The lighting layout has been shown in Figure 4.18. There has been one pendant downlight.

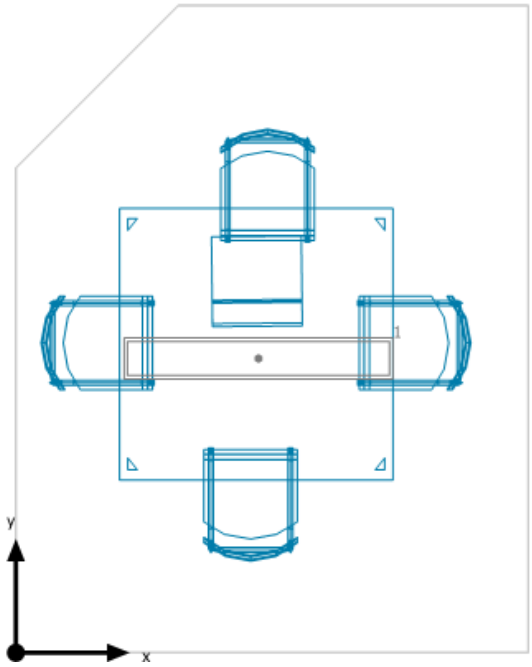


Figure 4.18: The meeting area lighting layout (Köseli, 2018).

The results, with 0.80-meter height and 0.30 wall zone calculation surface, have been given in Table 4.9. The necessary Em, Uo, and UGR levels, which are in standards, have been fulfilled. The pendant light and the task light together create high visual surfaces on the task areas on the desks.

Table 4.9 : The illumination (Em), uniformity (Uo), and unified glare rating (UGR) levels for meeting area (Köseli, 2018).

	Task areas (working surfaces on the table)	Surrounding area
Em	678 lux	527 lux
Uo	0.82	0.40
UGR (only working surface)	10	-

The product has a direct and indirect lighting feature. The direct lighting illuminated the task areas on the desks, the indirect lighting illuminated the ceiling, with reflections light is distributed all around the room. Therefore the immediate surrounding area has over 500 lux. The meeting task areas have the required illumination levels, which are over the minimum level of 500 lux, and sufficient for meeting activities.

The scenarios six and seven have been placed in the meeting area. The illumination and colour temperature changing suggestions during a day have been shown in Figure 4.19(a) and Figure 4.19(b).

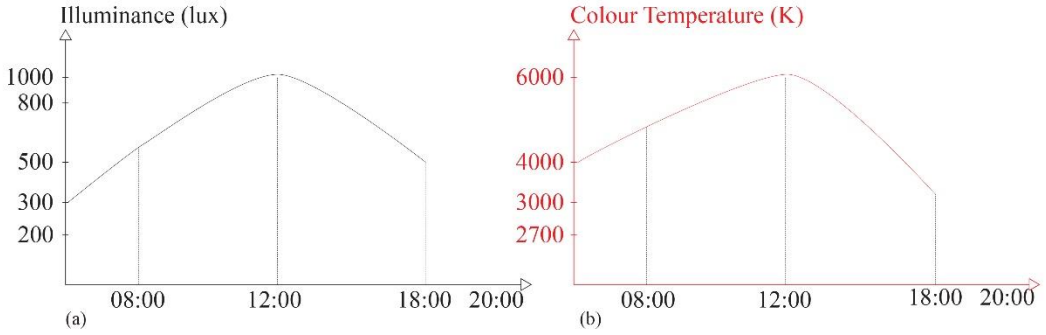


Figure 4.19: The illumination(a) and colour temperature(b) suggestions during a day for meeting area (Köseli, 2018).

In Figure 4.20, there are two different CCT levels given. The colour temperature for morning time of the day is planned as cool white 6000K in Figure 4.20(a), for afternoon mid-cool white 4000K in figure 4.20(b). For evening time, there is not a planned meeting scenario, because the meeting is only required for morning and afternoon. The first picture is for morning time, and the second one is for the afternoon.

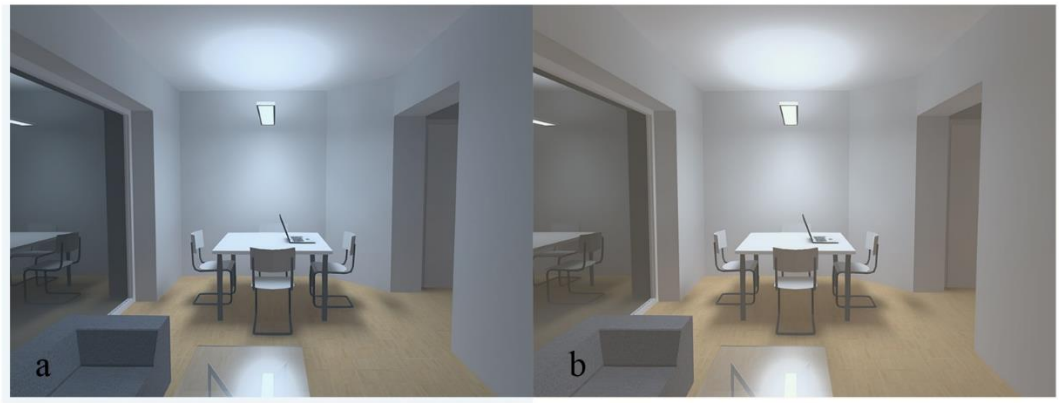


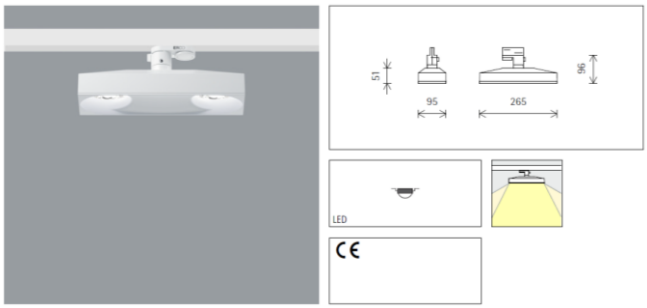
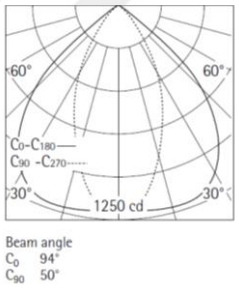
Figure 4.20: The results for the meeting area with cool and mid-cool white light (Köseli, 2018).

4.2.4 General lighting scenarios for daytime and evening time

The general lighting is the illumination for the whole office and has been planned for required lighting without the lighting for working, intensive working, and meeting times. For the project, the selected lighting products' rail have been located with 0.55 meters distance from the walls and 0.55 meters distance from the window, the luminaires mounted on the rail with a height of 2.50 meters from the floor. In this section, the general lighting has been explained without other lighting products.

In the evenings, the general lighting is also used in the lounge area for relaxing activities. The eighth scenario has been suggested for daytime and, and ninth scenario has been suggested for the relaxing time to the occupants. The illumination provided by downlights (Product C) and has been shown in Table 4.10. The product has a rotatable head so that it is possible to create different moods with changing the light direction in the room.

Table 4.10 : Product C features (Köseli, 2018).

Product Picture C	
The company and name of product	Erco GmbH / Skim Downlight oval flood
Lighting type	Pendant, LED module, dimmable
Lighting direction	Direct/indirect
Material	Cast aluminium, powder-coated and rotatable on the adapter through 360°
Power	17W
Luminous flux	1461 lm
CCT value	4000K neutral white
CRI value	CRI≥80
Beam angle	 Beam angle C_0 94° C_{90} 50°

There must be provided cool white, mid-cool white and warm white light during the day which are suitable for human biological body processes, which has been explained in Section 2. In the afternoon the daylight becomes less cool white so that the daylight-like lighting ensured mid-cool light for the whole office. The melatonin needs less suppression of production. In the evening the bodily processes are getting slower, and the body prepares itself to sleep. For this time the melanopic light is not suggested. The human body needs more warm white colour temperature with less light for more relaxing.

Space is used for casual occasions or performance of visual tasks of high contrast and large size which have been explained in Section 2 in Table 2.1. So, 300 lx is appropriate for space. The brightness control and flexibility are the key design elements for space. The selected product has assembled on the rail, has been moved on it, and arranged depends on activities and space usage. The layout of lighting and rail have been shown in Figure 4.21. As general lighting product C has been selected because the light could be movable on the rail and provide changeable situations in the area. There have been six pieces product C placed.

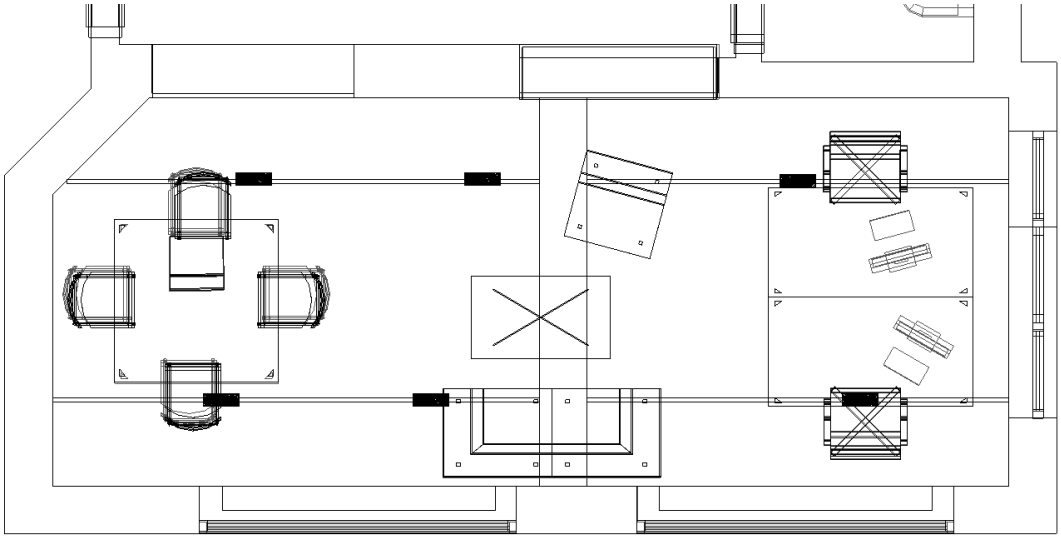


Figure 4.21: The general lighting layout (Köseli, 2018).

The illumination level results are not comparable for the different times of the day; it could be changed at any time of the day in order to provide the necessary illumination to the tasks. However, the colour temperature is a comparable factor for space during the day. For daytime, cool white and mid-cool white colours are suggested, and for the night time warm white colour temperature could be implemented to the room for creating a more relaxing environment.

The results, which have been calculated with Product C, with 0.80-meter height and 0.30 wall zone calculation surface, have been given in Table 4.11. The necessary Em and Uo levels, which are in standards, have been fulfilled. The required illumination has been a success for casual occasions or low visible required tasks. With the profile system, the general lighting downlights could be arranged on the needs.

Table 4.11 : The illumination (Em) and uniformity (Uo) levels for general lighting (Köseli, 2018).

	Lounge area	Surrounding area
Em	340 lux	341 lux
Uo	0.60	0.55

The general lighting also illuminates the lounge area. In the lounge area, for daytime, the cool white light temperature is preferred, for the evening and nighttime warmer white colour temperature was chosen. The colour temperature changing is a suggestion for the project, the existing product data doesn't have the option. The eight scenario is the lighting system for the whole office, and the ninth scenario is the lighting system for the lounge area. Both are illuminated by the general lighting system. The illumination and colour temperature changing suggestions during a day have been shown in Figure 4.22(a) and Figure 4.22(b). Depends on the needs in times, the illumination levels could be arranged. In the morning 6000K cool white, afternoon 4000K mid-cool white, and after 20:00, warm white light 2700K-3000K have been suggested. The transition between the colour temperatures should be gradual. The lowest colour temperature is 2700K and used for a relaxing time in the evenings.

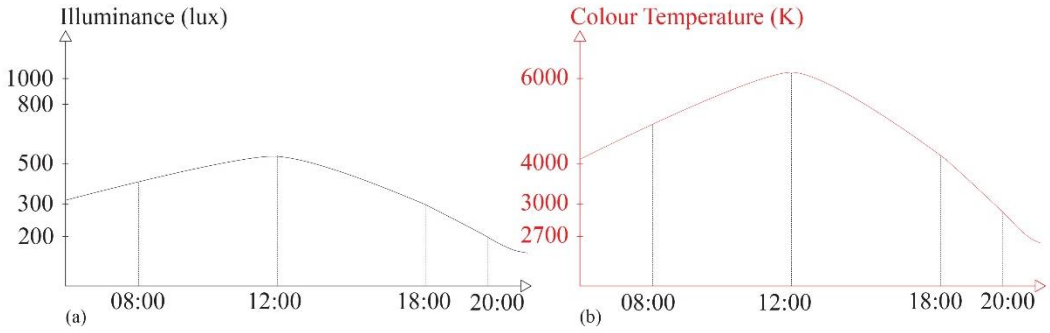


Figure 4.22: The illumination and colour temperature suggestions during a day for general lighting (Köseli, 2018).

The selected products could be used as an interior architectural element that divides the space into the spaces with the help of light in the space. The illumination levels could be dimmable depends on the daylight or user needs. Moreover, the mobile feature of the product has ensured flexible usage spaces in the room. Depends on the need of the occupants, lighting elements could be adjusted. With changing places of

same amount (6 pieces) of light, only the lounge area could be illuminated like in Figure 4.23 (a, b). If the light is only needed in the meeting area, it could be arranged like in Figure 4.23 (c, d). If only the working area is illuminated, it could be like in Figure 4.23 (e,f).

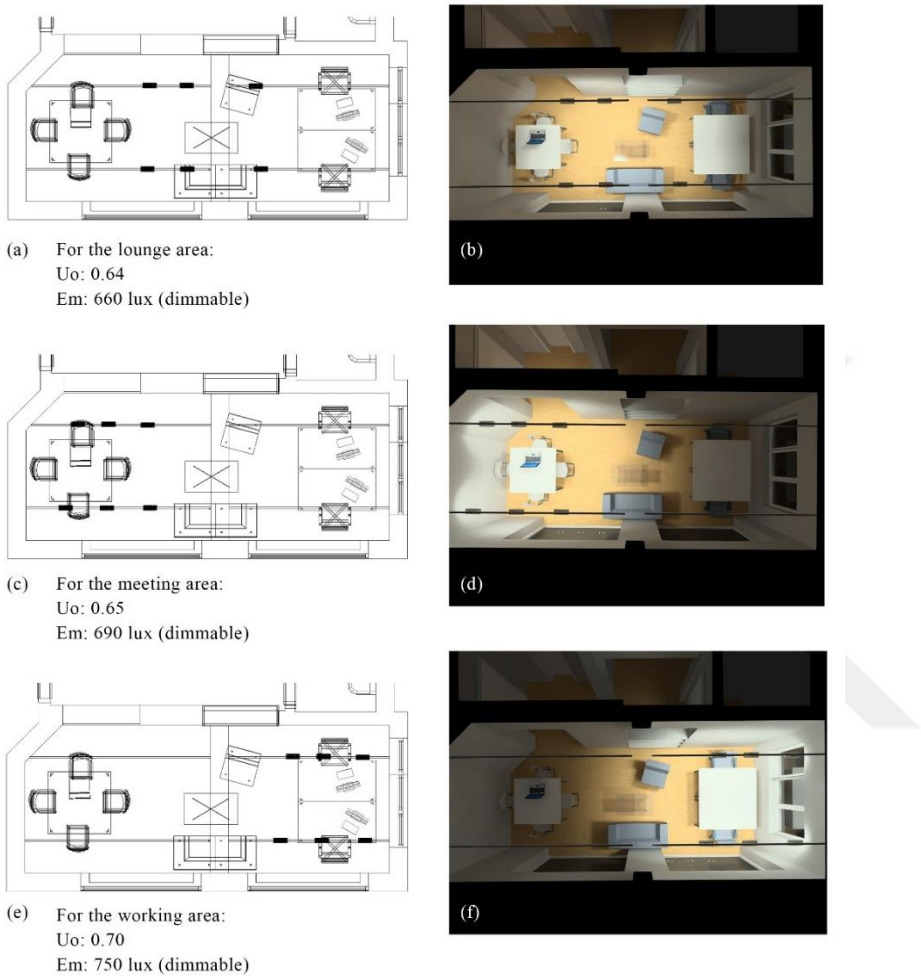


Figure 4.23: The lighting system as an architectural divider in the area, a, c, and e are the plans and b, d, and f are the views (Köseli, 2018).

The lighting results are shown in Figure 4.24. The Figure 4.24 (a) is for general lighting in the morning, the Figure 4.24 (b) is for the afternoon, and the Figure 4.24 (c) is for a relaxing time in the evening. The lighting results have been calculated only with general lighting.

Figure 4.24: The views with general lighting in lounge area (Köseli, 2018).

The dimmable function helps to create alternative moods in the space. In Figure 4.25 (a), the first result was calculated without dimming. The second result was calculated with %50 dimmed lighting in Figure 4.25 (b). The illumination results have been given in Table 4.12.

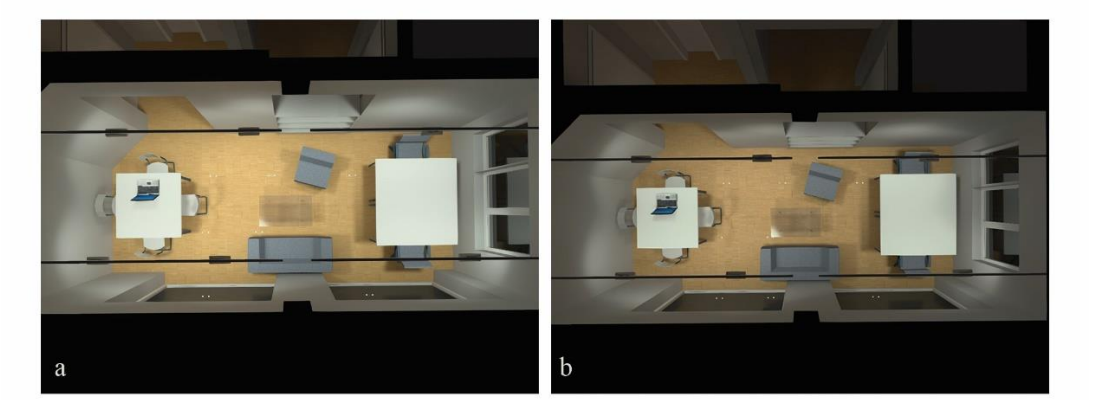


Figure 4.25: The results for general lighting without dimming (a) and %50 dimming (b) (Köseli, 2018).

Table 4.12 : The illumination (Em) levels by %50 dimming with general lighting (Köseli, 2018).

	Em, without dimming	Em, %50 dimming
Surrounding area	229 lux	109

All for nine scenarios, the lighting was calculated separately for each area. However, even though the lighting is calculated separately for the areas, they are used together in daily life.

The project space has been evaluated with the design criteria which were reached in Section 2 and Section 3. First, office area was observed with all details about the space, users, and purposes/tasks. With the results of this observation, the lighting needs have been defined on the users, users' habits, daytime, and tasks. When defining lighting needs, the visual and non-visual requirements were always considered as the critical factors in the concept. Choosing the right light source and luminaires, providing necessary illuminance, uniform distribution of light, glare and disturbing reflections, proper colour rendering, effective colour temperature, and light control, which is brightness control and colour temperature control, ensure the space optimum lighting design. The right product supplies are vital in order to supply energy efficiency.

The above mentioned design criteria were reached in the space. The lighting concept provides changing lighting situations based on tasks and daytime. The users have the opportunity to control lighting. The light is used as an interior element, dividing the interior into three areas. There could be some suggestions for lighting concept in space in order to provide other lighting design criteria which were not reached with existing products in the market.

4.3 The Suggestions for Lighting Design Concept

In the previous section, lighting design implementation and how the design implementation fulfilled with suggested products to achieve the required design criteria for creating human-centric lighting in the office was explained. The lighting results obtained from Dialux Evo with LED lighting products were explicated. Some of the results cannot be provided with the existing products in the market. Moreover, there have been suggestions for future lighting product designs and lighting concepts, which are based on 'Human Centric Lighting'. The suggestions for the office illumination are below:

- Illumination level control (dimmable option)
- Light distribution control (on/off options for direct and indirect lighting for a product)
- The colour temperature control
- Providing daylight-like lighting
- An integrated control system (different lighting fixtures together)

All the information about HCL concept and lighting design criteria have been reported with the literature review in Section 2. With inferences from the information described in Section 2, the listed suggestions for lighting design concept in this section have been explained.

The illumination level control has been ensured with most of the lighting products in the market. In HCL concept, this must be necessarily applied when designing an interior design project.

The light distribution control hasn't been provided with most of the lighting products in the market. The lighting product, if it has a direct and indirect option, should have

only direct or only indirect option in addition to direct-indirect option. In Figure 4.26 it has been shown the working and meeting area has been planned with product A. The product A has direct and indirect light distribution in Figure 4.26(a). The suggestion to the existing product is like in Figure 4.26(b) direct lighting, or like in Figure 4.26(c) indirect lighting for creating different moods in the space. The suggested product has the option to switch off only direct or only indirect distribution.

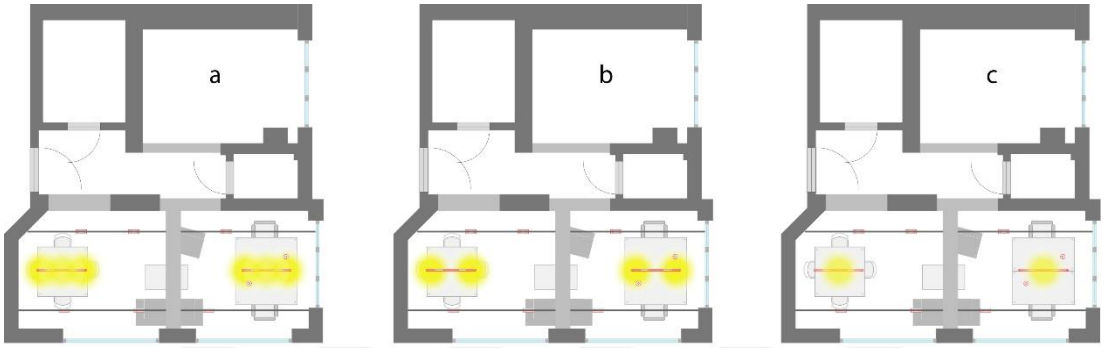


Figure 4.26: Direct-indirect option(a), direct option(b), and indirect option(c) (Köseli, 2018).

The colour temperature control has been provided only as tuneable white in the market. The temperature changing with existing products in the market is not sufficient. The suggestion for design concept is convertible colour temperature for lighting, an automatic way daylight-like lighting and also by personal control. The lighting fixtures have tuneable light temperature, but only have 2-3 different light temperature options.

The automatic colour temperature control of daylight-like lighting provides melanopic lighting and acts like daylight all day. The melanopic effective lighting has been explained in Section 2. The light temperature increases and the light wavelength becomes around 450-490 (cool/blue light colour) nanometer in the morning time. Around this wavelength, melatonin suppression is affected most, the melatonin level in the human body decreases. At the low melatonin level, more cortisol hormone is secreted in the human body and becomes more vigorous. Afternoon, the light temperature is reduced to prepare bodily functions for evening time. For the evening time melanopic, effective lighting is not suggested as it has been explained in Section 2. For this reason, the warm light temperature is recommended the area for evening and night time. Between 08:00-18:00 period, biologically effective light for office space was designed. This lighting design has especially non-visual effects on users.

The required colour temperature levels and the wavelengths during a day in HCL have been shown in Figure 4.27. The colour temperature transition should change smoothly during a day. The gentle transition is suggested for the project like in Figure 4.27(a, b, c, d, e). In the morning in Figure 4.27(a, b) the colour temperature should increase till the mid-day. The highest recommended colour temperature is 6000K cool white light for this project. In the afternoon in Figure 4.27(c,d) the colour temperature should decrease, and the suggested level around 4000K mid-cool white light till 3000K warm white light. After 18:00 in Figure 4.27(e), melanopic effective light is not recommended. Moreover, the suggested colour temperature is around 2700K, the lowest level.

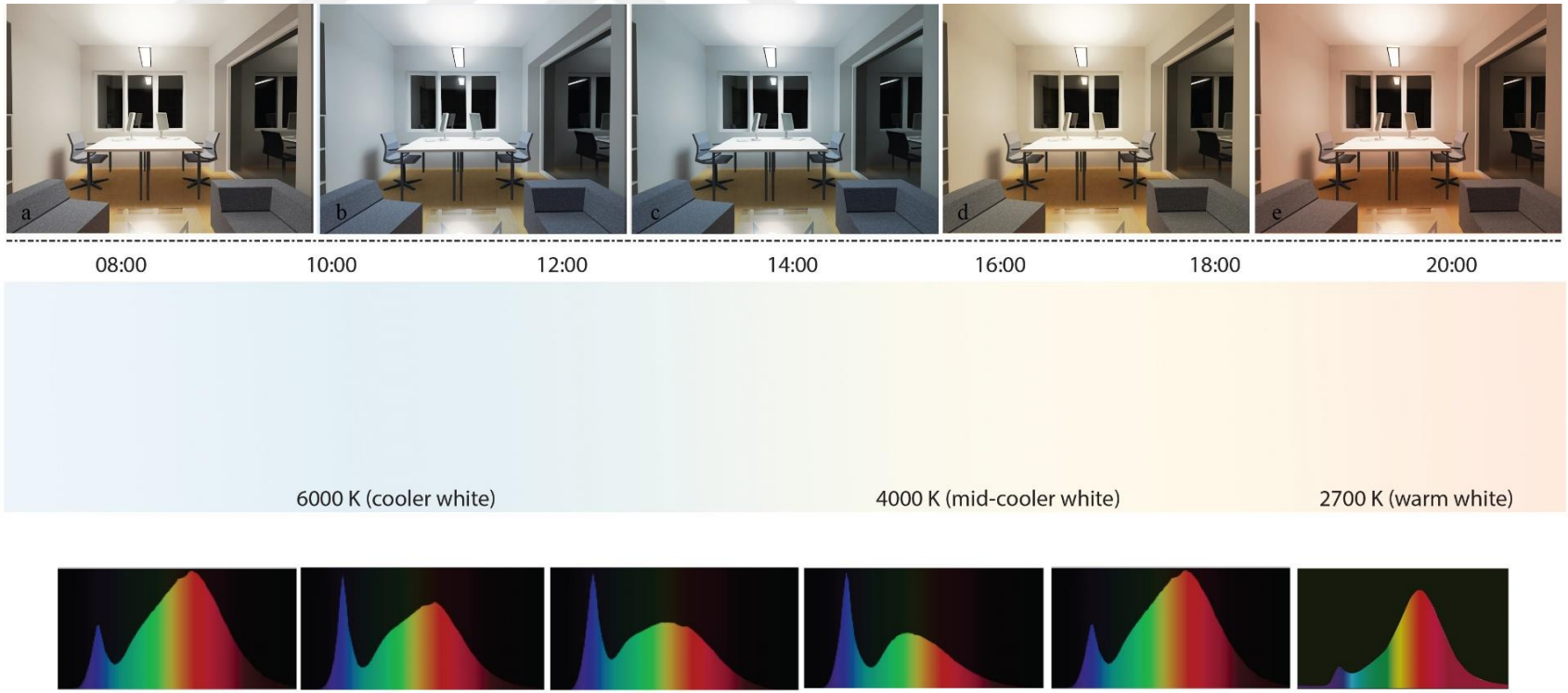


Figure 4.27: The daylight-like lighting suggestion for the office (Köseli, 2018).

The last suggestion to existing products and also for the project is an integrated control system for all illumination in a space. The control provides switching, dimming, and changing light colour temperature, shortly all in one. For this project, it was suggested that collect all lighting control units in a centre, and present to the user's control of lighting of the whole office.

The example of integrative control system options has been given in Figure 4.28. In Figure 4.28(a) all the light products are on. The general lighting could be used with office work area lighting like in Figure 4.28(b) when meeting lighting is turned off. Another example has been given in figure 4.28(c), general lighting could be turned on with meeting area lighting, or only with task lighting on the desks like in Figure 4.28(d). The other switchable and flexibility suggestion is for the product C, which are used for general lighting in the office. The product C could be moved through the profiles like in Figure 4.28(e) and Figure 4.28(f), and also could be turned on/off one by one like in Figure 4.28(g). The system controls also dimming, switching light directions and changing colour temperature. For example in Figure 4.28(h), the indirect lights of pendant products are off on the meeting and working area, only the direct lights on. In Figure 4.28(i) the general lighting on and the indirect light of pendant products are on. In Figure 4.28(j) in the whole room, only the indirect light of pendant products are on. The suggested integrated control system enables to create conditions for the scenarios which are given in previous section, and also other possible lighting requirements.

The developing technologies and communication tools, change people’s lives. Most of the spaces are used for different occasions by different kind of occupants in different times of a day. So the lighting design should be planned in order to provide all the needs of these people, an also should be flexible for future scenarios to supply the sustainability of space.

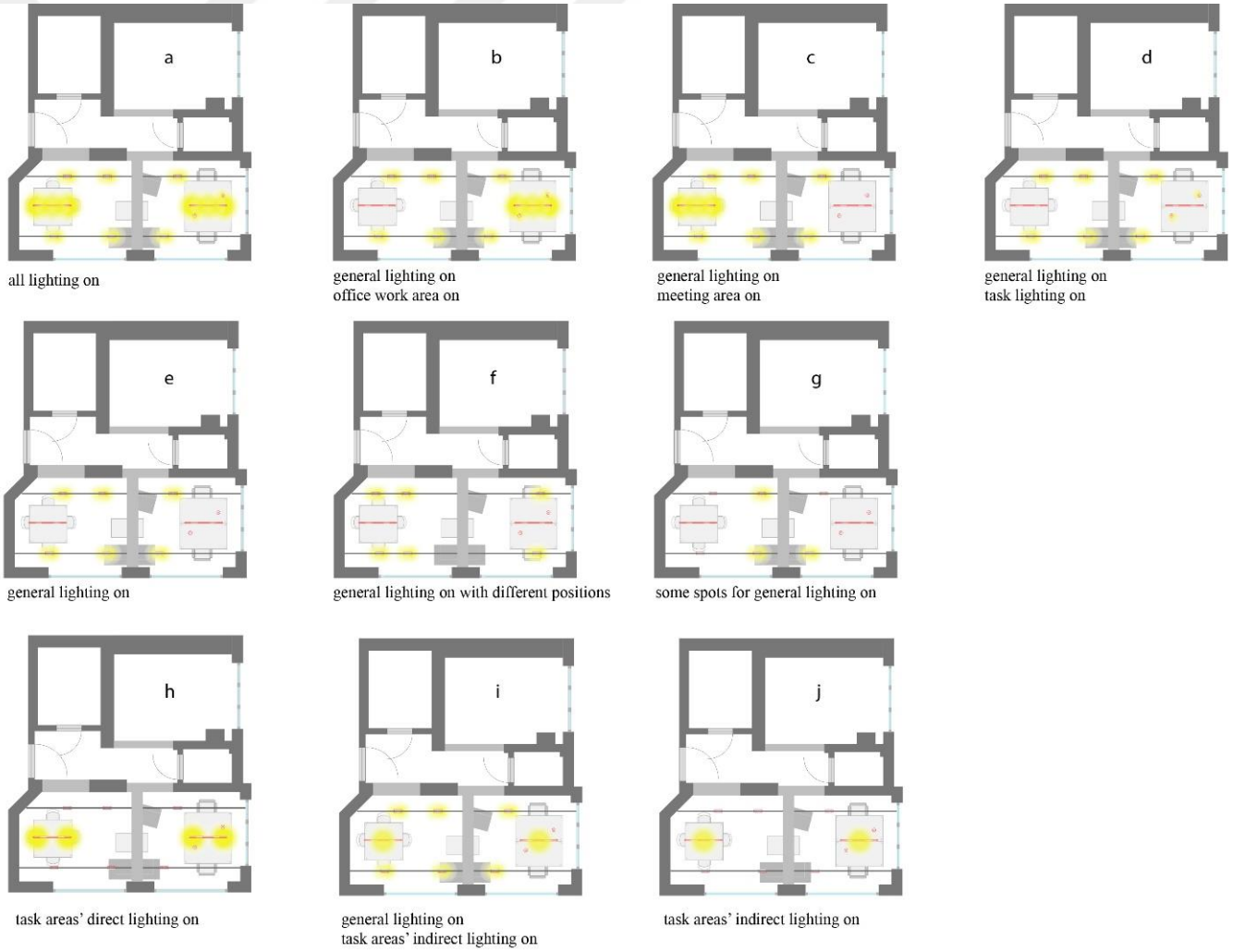


Figure 4.28: The suggestions for the integrated control system (Köseli, 2018).

5. CONCLUSION

As people spend more time indoors, their contact with natural environment decreases. Living isolated from the nature affects human body negatively. On the other hand, natural light is a critical need for human beings in terms of their bodily processes, physical, and psychological needs. It can be said that the human being, who is distant from the outside world and nature, is also distant from the daylight and the benefits of daylight. Some of their needs are not satisfied and spending most of their time indoors makes them unhealthy and unhappy.

When designing interiors, it is essential to provide a good quality of life, healthy, motivational, and productive environments to human beings. The visual and non-visual effects of light should be considered. The lighting is one of the crucial elements of interior design. There are international standards for quality lighting to provide vital needs to humans. The non-visual effects of light have not sufficiently placed in these standards. It is not possible to design a lighting system exactly with the same features of daylight because of the technical reasons and energy concumption problems. But it is possible to create a daylight-like lighting system with right lighting features on right time.

The people need a quality environment for being more productive in office interiors. So the lighting system in offices is very important to ensure better working areas. In this thesis, the related literature is investigated and basing on this research the design criteria steps for office interior design are defined.

During the studies, existing lighting concepts have been investigated. In recent researches a new lighting design concept gains importance supplying quality environments in offices for people. The name of this concept is Human Centric Lighting (HCL). In HCL concept, in addition to the International Standards of lighting design which are mostly focused on the visual effects of lighting, the non-visual effects of light are also considered. The non-visual effects of lighting include the effects of

colour temperature and illuminance levels, which should be provided in spaces with right levels and right times in a day.

In the project part, the steps in line with the research have been applied to provide both International Standards and HCL concept requirements. The required illuminance and colour temperature needs have been fulfilled with product A, B, and C. Moreover, there have been entirely five suggestions (illumination level control, light distribution control, the colour temperature control, providing daylight-like lighting, an integrated control system) to these products in order to provide the HCL concept in the office. The existing products in the market have some of these features, but not all of them provide all HCL concept requirements. Therefore, by using the existing products and by adding new features to them, there has been new product proposals for future lighting product design processes were aimed.

In the project, with the reference products, visual criteria were fulfilled. These are sufficient illumination level, glare limitation, harmonious brightness distribution, avoidance of reflections, good modelling, and appropriate colour rendering which come with the visual effects of light.

Moreover, for creating the HCL concept in the office area, suggestions were made to consider the non-visual effects of light. These suggestions could be used for future office lighting projects. The suggestions have been aimed to achieve the other critical factors like correct colour temperature during a day, changing lighting situations, personal control, energy efficiency, daylight integration.

The control of illumination levels and distributions creates different environmental moods depending on the needs. The user can change illumination level based on daylight situation or their needs for the activities.

The control of colour temperature in the space is essential to provide daylight integration, users' bodily processes continuing healthy, create motivational and productive environments for occupants during a day. The light temperature alteration is essential for hormones and circadian rhythms. The control could be provided with the automatic daylight-like system. So the office environment has suitable conditions unaffected by the seasons and the time of day.

The flexible lighting system creates changing lighting situations in the office. Therefore, users can adapt the lighting for different scenarios. When the controlling is provided to the users, the lighting could be used as an interior element to create different spaces in one room. For example in the project, with moving the downlights on the rail, only lounge area or only working area could be illuminated. It is not necessary to use a physical divider to divide the space. The light could be the divider, and the light could define different areas in one room.

Moreover, the light distribution control could ensure the users to decide more focus light or more harmonious light in the whole room. Depending on the activities, direct or indirect lighting needs are changed. This is also a critical factor for users' visual comfort.

For future lighting products and concept designs for offices, to provide the HCL concept in spaces, first, space should be evaluated with the occupants, their needs, possible usage scenarios, and interior physical features. If there is not enough daylight, it is critical to ensure daylight-like lighting for users'visual and non-visual needs, considering physical and psychological factors coming with lighting. The steps and suggestions could be applied for other office lighting design projects for designing quality lighting systems and quality environments for the users.

The aim of this study is pointing out the importance of HCL (Human Centric Lighting) concept. The research that has been done in this thesis, and the results concluded in the project section, can be helpful for the further studies. There have been also some questions from the study. Do the existing standards and the suggestions fulfill the Human Centric Lighting in spaces? Is the changing colour temperature with required illumination levels possible as technically? Are there another effects of cool light temperature on human bodies?

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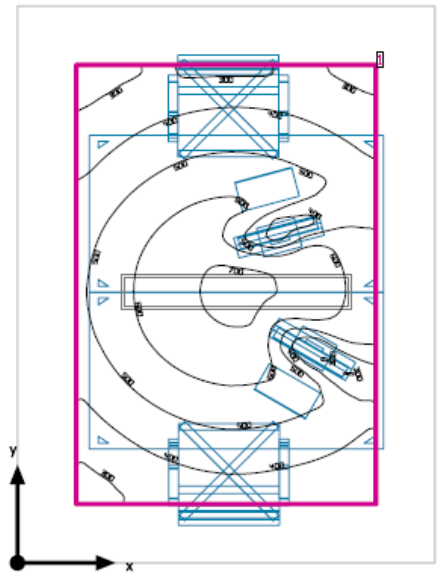
Url-1 < *https://vimeo.com/66914262* >, date retrieved 29.08.2018.

Url-2 < *https://www.google.com/maps* >, date retrieved 06.10.2018.

APPENDICES

APPENDIX A: Isolines for working and meeting areas in space

APPENDIX A



Clearance height: 2.700 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 38.6%, Maintenance factor: 0.80

Workplane

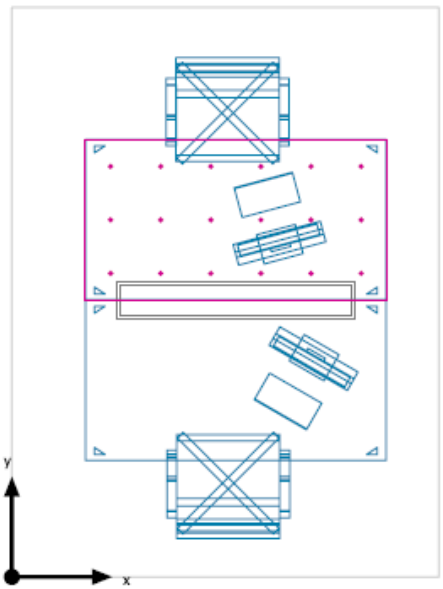
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Working area	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.300 m	482 (≥ 300)	253	717	0.52	0.35

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
1	XAL - 059-5264637P-10 TASK S suspended DIRECT / INDIRECT POWER e2 LED 840 P	6034	49.8	121.1
	Total via all luminaires	6034	49.8	121.2

Lighting power density: 8.23 W/m² (Floor area of room 6.05 m²),
Lighting power density: 14.53 W/m² = 3.02 W/m²/100 lx (Area of working plane 3.43 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 68 - 110 kWh/a of maximum 250 kWh/a

Figure A.1: The isolines for office working area (Köseli, 2018).



Task area: Perpendicular illuminance (Grid)
Light scene: Light scene 1
Average: 541 lx, Min: 327 lx, Max: 707 lx, Min/average: 0.60, Min/max: 0.46
Height: 0.800 m

Isolines [lx]

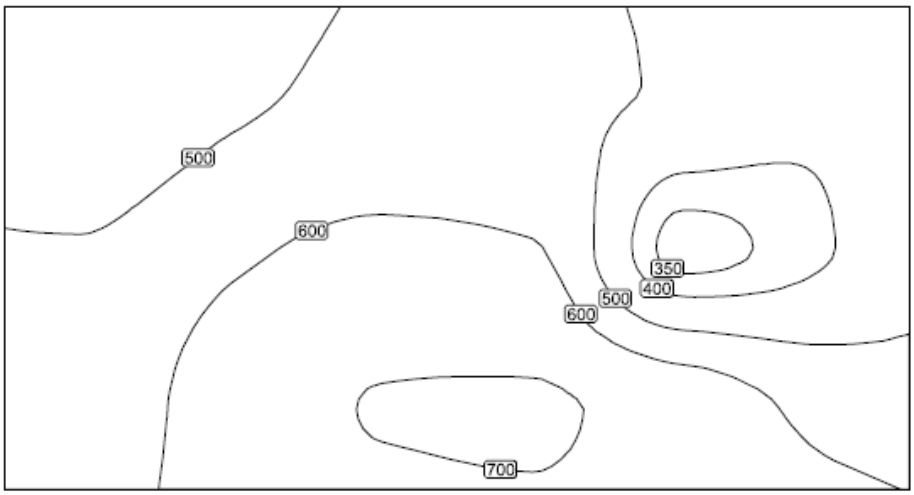
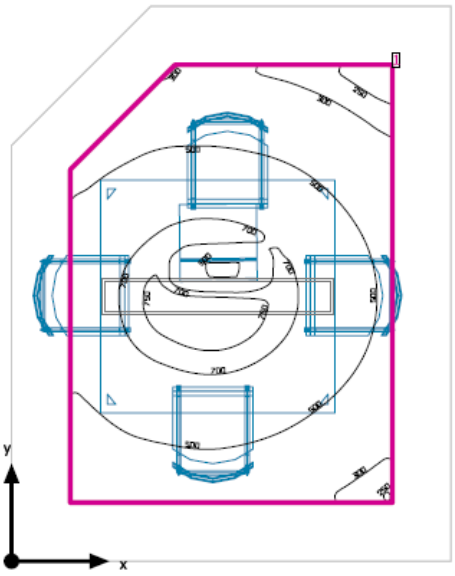


Figure A.2: The isolines for task area in working (Köseli, 2018).



Clearance height: 2.700 m, Reflection factors: Ceiling 70.0%, Walls 50.0%, Floor 38.6%, Maintenance factor: 0.80

Workplane

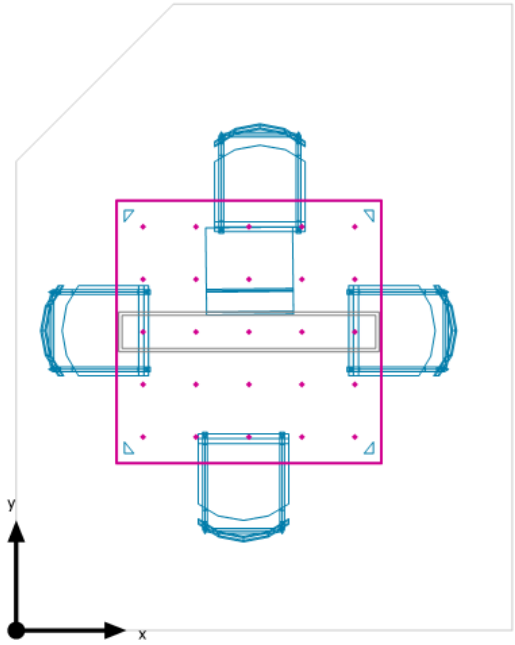
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Meeting area	Perpendicular illuminance (adaptive) [lx] Height: 0.800 m, Wall zone: 0.300 m	527 (≥ 500)	212	791	0.40	0.27

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
1	XAL - 059-5264637P-10 TASK S suspended DIRECT / INDIRECT POWER e2 LED 840 P	6034	49.8	121.1
	Total via all luminaires	6034	49.8	121.2

Lighting power density: 8.12 W/m² (Floor area of room 6.13 m²),
Lighting power density: 14.03 W/m² = 2.66 W/m²/100 lx (Area of working plane 3.55 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 140 kWh/a of maximum 250 kWh/a

Figure A.3: The isolines for meeting area (Köseli, 2018).



Task area: Perpendicular illuminance (Grid)
Light scene: Light scene 1
Average: 678 lx, Min: 558 lx, Max: 787 lx, Min/average: 0.82, Min/max: 0.71
Height: 0.800 m

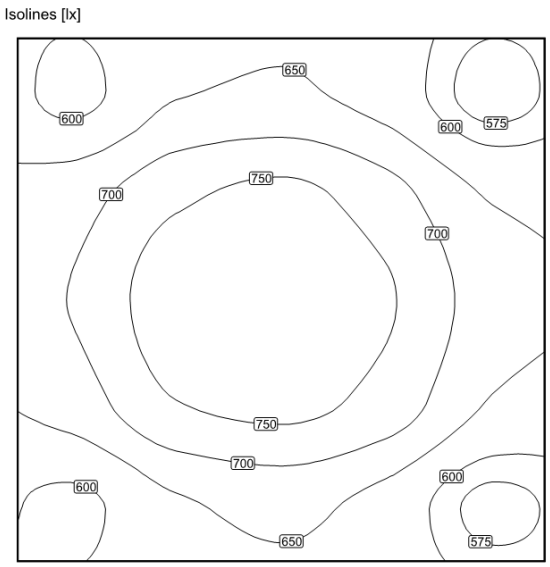


Figure A.4: The isolines for task area in meeting (Köseli, 2018).

CURRICULUM VITAE

Name Surname **:** Cennet Gökcen KÖSELİ

Place and Date of Birth **:** Denizli /TURKEY 26.01.1990

E-Mail **:** gkoseli@gmail.com

EDUCATION **:**

- **B.Sc.** **:** 2013, Istanbul Technical University, Architecture Faculty, Industrial Product Design Department

PROFESSIONAL EXPERIENCE AND REWARDS:

- 2013-2015 Product Designer at Delta Office İstanbul TURKEY.
- 2017 Lighting Designer at Nimbus Group GmbH Stuttgart GERMANY
- 2018- …Lighting Designer at XAL GmbH Stuttgart GERMANY