ASSESSMENT OF LIGHTING PERFORMANCE OF PVC AND PMMA MATERIALS IN OFFICE SPACES IN TERMS OF VISUAL COMFORT

A Thesis Submitted to

the Graduate School of Engineering and Sciences of
İzmir Institute of Technology
in Partial Fulfilment of the Requirements for the Degree of

MASTER OF SCIENCE

in Industrial Design

by
Müge ÖZTÜRK

November 2006
İZMİR

We approve the thesis of **Müge ÖZTÜRK**

Date of Signature

……………………………………………. **22.11.2006**

Assist. Prof. Dr. Emre ERGÜL
Supervisor
Department of Architecture
İzmir Institute of Technology

……………………………………………. **22.11.2006**

Assoc. Prof. Dr. Önder ERKARSLAN
Department of Industrial Design
İzmir Institute of Technology

……………………………………………. **22.11.2006**

Assoc. Prof. Dr. Funda TIHMINLIOĞLU
Department of Chemical Engineering
İzmir Institute of Technology

……………………………………………. **22.11.2006**

Assist. Prof. Dr. Yavuz SEÇKİN
Head of Department of Industrial Design
İzmir Institute of Technology

………………………………………………………….

Assoc. Prof. Dr. Barış ÖZERDEM
Head of the Graduate School

ACKNOWLEDGEMENT

I would like to thank to my advisor Assist. Prof. Dr. Emre ERGÜL from İzmir Institute of Technology for guiding me and spending time for me much more than given timetable. And I would like to thank to Assist. Prof. Yavuz Seçkin, and my teachers from department for their contribution during my education.

I would also like to thank to Res. Assist. Elçin Dilek KAYA for doing the optical tests for my research and Assist. Prof. Dr. Salih OKUR for sharing his valuable comments on results of optical test.

I especially would like to thank to Prof. Dr. Şazi SİREL and his son Dr. Osman SİREL from Y.F.U., for their sincere approach to replying my questions about lighting and research.

ABSTRACT

ASSESSMENT OF LIGHTING PERFORMANCE OF PVC AND PMMA MATERIALS IN OFFICE SPACES IN TERMS OF VISUAL COMFORT

This research tests the plastic materials which can provide properly diffused illumination level and have smooth transmittance performance. Among these materials, two of them, PVC (polyvinylchloride) and PMMA (polymethylmethacrylate) sheets are evaluated, compared with each other and interpreted according to a criteria set which includes optical and physical properties, application possibilities. Besides, one of most important evaluation criteria for efficient lighting in office spaces; transmission property of these materials is empirically tested in laboratory in the scope of this study. One of these, PMMA is produced on commercial purpose in Turkey and used with its well known name; Plexiglas and the other one; Barrisol is an officially registered trademark of PVC translucent strech sample used in test.

This study is gathered by means of searching lighting literature, rather restricting the data about two specific plastic based materials used in offices and experimenting the transmission characteristics of plexiglas and Barrisol. Scientifically; transmitting and diffusing of a material are unattached properties and rather concerned with chemistry. But there is a measured certainity that Plexiglas has %92 and Barrisol %73 percentage of transmission value. The results of test also supports that; transmission percentage of plexiglas sample is higher than Barrisol.

It is reached to the conclusion that; when light directly comes down on a workplane whithout being regularly dispersed, it will tire viewer’s eyes and deteriorate visual comfort, negatively affecting productivity in offices.

ÖZET

PVC VE PMMA MALZEMELERİN OFİS MEKANLARINDAKİ GÖRSEL KONFOR KOŞULLARI AÇISINDAN PERFORMANSLARININ DEĞERLENDİRİLMESİ

Araştırma; görsel konfor şartları için "düzgün yayılmış aydınlık seviyesi"ni sağlayabilecek, kaynaktan çıkan ışığı düzgün olarak geçirip, yayındıracak plastik tabanlı malzemelerden; PVC (polyvynil chloride) geçirgen tabaka ve PMMA (poly methyl methacrylate)'nın optik ve diğer fiziksel özelliklerini incelemeyi, ofis aydınlatması kriterleri açısından irdelemeyi ve yorumlamayı amaçlamaktadır. Ayrıca çalışma kapsamında bu iki malzemenin; ofis aydınlatmasında uygun aydınlatmayı sağlama açısından önemli bir kriter olan; geçirgenliği laboratuar koşullarında ampirik olarak da sınanmıştır. Ticari amaçla üretilen, aydınlatmada sıkça kullanılan bu iki malzemeden biri PMMA; ülkemizde "Pleksiglas" olarak bir süredir bilinip kullanılmakta olup, diğeri bilinen marka adıyla "Barrisol" olarak anacağımız ince PVC geçirgen malzemedir.

Çalışmada aydınlatma ile ilgili yazın taranmış fakat araştırma alanı daha çok söz konusu iki malzemenin ofis mekanlarındaki performansını sınamak ile sınırlandırılmıştır. Bilimsel olarak; bir özdeğin geçen ışığı yayındırma özelliği ile geçirme özelliği bir birinden bağımsız özelliklerdir. Bir başka deyişle, ışığın belli miktarını geçiriyorsa, belli miktarını da yayındırıyordur denemez. Transparan malzemelerde geçirme, yansıma ve dağıtma sanıldığından daha karmaşık fiziksel bir olaylar bütünüdür, ayrıca özdeğin kimyasal yapısıyla daha yakından ilgilidir. Ancak, seçilen örneklerden Pleksiglasın %92, Barrisol'ün ise %73 geçirme değerine sahip olduğu ölçülmüş bir gerçektir ve çalışma kapsamında elde edilen test sonuçları da bunu desteklemektedir.

Sonuç olarak; kaynaktan çıkan ışığın düzgün yayınmadan, yüksek oranda geçirilerek çalışma düzlemine gelmesi, gözü yorarak görsel konfor şartlarının bozulmasına, iş verimliliğinin negatif yönde etkilenmesine sebep olacaktır.

TABLE OF CONTENTS

LIST OF FIGURES .... **ix**

LIST OF TABLES .... **xi**

CHAPTER 1. INTRODUCTION **1**

1.1. Aim of the Study 1

1.2. Definition of the Problem 1

1.3. Methodology 2

CHAPTER 2. LIGHTING, TYPES AND PROPERTIES **4**

2.1. Aim of Lighting 4

2.2. Comparison of Quality and Quantity of Light 5

2.3. Vision 6

2.4. Some Definitions and Rules About the Quality of Light 7

2.4.1. Light's Directional Structure 7

2.4.2. Light's Spectral Structure 8

2.4.3. Brightness and Glare 10

2.4.4. Form-Shape and Texture 11

2.4.5. Illumination Dispersion 12

2.5. Some of the Fundamental Rules for Good Illumination 12

2.6. Differentiating With Light 14

2.7. Types of Lighting 15

2.7.1. Natural / Daylight 15

2.7.2. Artificial Lighting 16

2.8. Types of Lighting Techniques 16

2.9. Energy Saving in Lighting 16

2.10. Technical Lighting 19

2.11. Computer Programs and Lighting Projects 19

2.12. Lighting Project 20

CHAPTER 3. PHYSICAL AND PSYCHOLOGICAL RELATION OF LIGHTING IN WORKSPACES 22
3.1. Aspects of Office Workspace Lighting 23
3.2. Lighting Design 25
3.3. Responsibility of Lighting Design 26
3.4. Psychological Comfort Parameters 28
3.4.1. Illumination Level Change and Adaptation 28
3.4.2. Lighting System's Impressions 29
3.4.3. Luminosity Incidence 30
3.4.4. Colour Properties of Light Source 30
3.5. Improvement of Visual Comfort Conditions and Performance at Offices 32
3.5.1. Effect of Visual Performance on Office Workers 33
3.5.2. Visual Comfort 33
3.5.3. Economy of Lighting Systems 33
3.6. Effect of Lighting on Human Performance and Health 34
3.7. Office Lighting Systems 34
3.7.1. Lighting Effects 35
3.7.2. Ideal Office Lighting Criterion 35
3.7.3. Office Performance 36
3.7.4. Design of Office Lighting 36
3.7.5. Ideal Luminance at Workplace 37
3.8. Illumination Quality in Offices 38
3.9. Act of Specific Plastic Materials: Plexiglas & PVC in Lighting 39
3.9.1. Plastics in Contemporary Design 39
3.9.2. Plastics in Lighting Applications 40
3.9.3. General Properties of Plastics 41
3.10. Properties of Specific Plastic Materials: Plexiglas & PVC 42
3.10.1. Plexiglas 44
3.10.2. PolyvInyl Chloride (PVC) 45
3.10.3. Some of PVC Sheeting Properties 46
3.11. Diffusion and Measurement of Materials 47
3.12. Assessment of Sample Offices in Consideration with Use of Plexiglas and PVC Sheeting Materials in Lighting 49

CHAPTER 4. CONCLUSION **60**

REFERENCES **63**

APPENDICES

APPENDIX A. GLOSSARY **66**

APPENDIX B. TEST RESULTS **73**

APPENDIX C. MATERIALS USED IN OPTICAL SYSTEMS **77**

LIST OF FIGURES

Figure **Page**

Figure 2.1. Quality of lighting systems after IESNA 5
Figure 2.2. General lighting 8
Figure 2.3. Direct, aimed lighting 8
Figure 2.4. Direct, diffuse lighting 8
Figure 2.5. Indirect lighting... 8
Figure 2.6. Direct and indirect lighting 8
Figure 2.7. The electromagnetic and visible spectra. 9
Figure 2.8. Primary Colours 9
Figure 3.1. Physical-psychological relation of lighting and space perception. 23
Figure 3.2. Blackbody temperature /K 31
Figure 3.3. Light coloured open Office 34
Figure 3.4. Natural light use in Office space 34
Figure 3.5. Another naturally illuminated Office view 34
Figure 3.6. The use of transparent PVC sheeting in the ceiling 35
Figure 3.7. A Workstation with task lighting. 37
Figure 3.8. An Office with indirectly lighted ceiling. 38
Figure 3.9. The use of PVC sheeting in operating room because of its hygienic property. 42
Figure 3.10. The complex blend of surface reflections, internal scatter and refraction. 43
Figure 3.11. The importance of crystalline density wavelength of incident light. 44
Figure 3.12. The use of plexiglas in outdoor lighting. 45
Figure 3.13. Streching application of PVC 47
Figure 3.14. “ldp” experimental setup graphic 47
Figure 3.15. “ldp” graph and renderings. 48
Figure 3.16. The transmission graphic of plexiglas and Barrisol.................................. 49
Figure 3.17. Plan of Opet office. 51
Figure 3.18. View of Opet Office management part. 52
Figure 3.19. View of Opet Office meeting part. 52

Figure 3.20. Plan of Adnan Kilicoglu Office. 54
Figure 3.21. View from Adnan Kilicoglu Office entrance. 55
Figure 3.22. Another view from entrance of Adnan Kilicoglu Office 55
Figure 3.23. Plan of H. Zeki Sungur Office. 56
Figure 3.24. Meeting view from H. Zeki Sungur Office... 57
Figure 3.25. Management view from H. Zeki Sungur Office. 57
Figure 3.26. Whole ceiling is covered with translucent Barrisol above meeting part of H. Zeki Sungur Office 58
Figure 3.27. Almost there is no shadow of a mobile phone put on the workplane... 59

LIST OF TABLES

Table **Page**

Table 2.1. Standard serial of lamp types 18
Table 3.1. Global Variation, Relationships and Priorities 26
Table 3.2. Ncr Building-Tokyo, 1964, expenditure domain rates. 27
Table 3.3. Turkey Foundations General Headship Building-Turkey, 1966, expenditure domain rates. 27
Table 3.4. Illuminance level (E_m), glare index (UGR_L) and colour rendering index (R_a) for offices. 28
Table 3.5. Colour temperature of lamps in ° K 31
Table 3.6. Transmittance of optical glass, PMMA and PVC. 41
Table 3.7. Typical properties* of plastic glazing materials compared with glass. 42
Table 3.8. Necessary values of bulbs for office functions. 50

CHAPTER 1

INTRODUCTION

Lighting encompasses; bringing the daylight rays into a space via various means, that is available during the day. When sunlight reaches a certain low level, augmenting natural daylight with artificial light becomes necessary. Because lighting has a motivating factor in human life.

Lighting is performed in various spaces such as; offices, schools, hospitals, traffic, security and almost all issues to establish comfortable visual conditions. In this work it is aimed to study the feasible materials to establish these conditions. Quality and quantity of light will be examined firstly, then basic rules valid for general lighting issue will form in the specific area; workspaces.

1.1. Aim of the Study

This study is trying to explain and comment on the use of plastic materials in lighting which has a decisive importance in defining qualitative lighting. Some of them have been formulated on the basis of arguments are many times explained by lighting engineers for decades. However, non of the studies seem to have asked whether such arguements correspond to the specific workplace lighting issue.

According to the scientific criteria, ideal lighting forms transparent and smooth shadow and diffused light puts the shadow transparency in this kind of lighting. This research discuss the plastic materials which can provide properly diffused illumination level and have stated transmittance performance. Among these materials, two of them, PVC (polyvinylchloride) and PMMA (polymethylmethacrylate) sheets are evaluated according to their use in office lighting applications.

1.2. Definition of the Problem

Main aim of lighting is not creating a certain level of, but providing the comfort conditions of visual perception for human. Whatever the aim is, to obtain the qualitative vision, some important sub-topics of lighting such as conditions of vision, optical properties of materials used for lighting, effects of lighting on human health must be well-comprehended.

Many researches signifies the positive impact of lighting on physical and psychological health of employees in offices and work places. Therefore the results show that necessary level of homogenous illumination and directed lights to serve the type of work together is the right solution for driving up the productivity of work.

Many factors affect ambience and lighting performance in a space. Apart from the shape of the room, it is essentially about the characteristics of equipment such as the materials used for lighting. The critical parameters in lighting means luminance, glare, surface brightness, color and visual interest. Although these qualities are discussed separately, designers must consider them as a whole duty to create a lighting system effectively.

This study searches the performance of two specified plastic translucent materials; plexiglas and pvc sheeting affecting the quality of light in order to put some attention into lighting considerations, both as possible causational factors and as an examination of what is appropriate for a workspace. Also this study is emphasizing that there is an added benefit of reducing worker fatigue and other symptoms, improving overall productivity.

1.3. Methodology

First of all it is important to understand the light, how it happens physically, its both qualitative and quantitative properties. These are necessary for a complete understanding of the comprehensive issue; lighting.

Second chapter mostly gathers the definition data for light and lighting principles. Because it addresses such a wide region that, there has to be restrictions for the aim of this study. In the same chapter; lighting types and perception criterias are mentioned to emphasize its relation with the 'Psychological comfort parameters'.

Third chapter, slightly entering to specification of workplace lighting, is seeking the technical information about sufficient luminance for different tasks, in the same time questioning the "ideal". Role of plastics in design and general physical, chemical properties of plastics (especially optical widely examined) are submitted. Among whole plastics family, matter is led into the specified types of translucent ones; plexiglas and PVC sheeting. This part first defines, then compares them with their contents that affects optical rate with numerical input.

When we come to the conclusion part; fourth chapter begins with pointing the significance of uniform influent light in workplaces; two important optical properties of plexiglas and PVC sheeting; transmission and diffusion are noted withstanding an experiment. These two specific materials' transmission test under lab conditions is experienced and observed between visible wavelength (400-700 nm). This makes the study also empirical. Also an assessment of sample offices in consideration with use of Plexiglas and PVC sheeting materials in lighting takes place.

In consideration with having similar properties; translucent plastic materials are analyzed according to the same parameters, used for lighting. Two sample materials; plexiglas and Barrisol (officially registered trademark of PVC translucent sample used in experiment) are chosen to compare the use of plastic materials. Then two different materials' performance is criticised considering the ideal office lighting parameters which were described in 2nd and 3rd chapters.

Plainly; this phase of the study is more related with widespread polymer issue within the knowledge of chemistry. It is reached to the conclusion that; considering the criteria for appropriate office ligthing; in a meeting space, when light directly comes down on a workplane whithout being regularly dispersed, it will create sharp-edged shadow. Consequently; after prolonged work hours, luminance contrasts will attract attention, tire viewer's eyes and deteriorate visual comfort, negatively affecting productivity when approached by office lighting appliances.

CHAPTER 2

LIGHTING, TYPES AND PROPERTIES

Lighting, with its brief definition, is applying light to objects, its surrounding and small or wider regions. This definition is mentioned exactly in the same way in (CIE) International Illumination Committee's both old and new dictionaries, which is a total authority on its own profession, founded in 1913.

Lighting as a term; has been mostly used literally to provide vision and to establish perceptual relationship between human and physical environment. Light is not just a physical quantity that provided sufficient illumination; it is a decisive factor in human perception.

2.1. Aim of Lighting

Aim of lighting is not only to make things and space around us visible, but to supply comfortable conditions for vision, that depends on illumination quality.

Lighting is essential in offices, schools, hospitals, traffic, security and almost all issues to establish comfortable visual conditions. Particular aims; establishing illusive, surprising, interesting, extraordinary impressions also requires knowledge about visual conditions and illumination quality .

2.2. Comparison of Quality and Quantity of Light

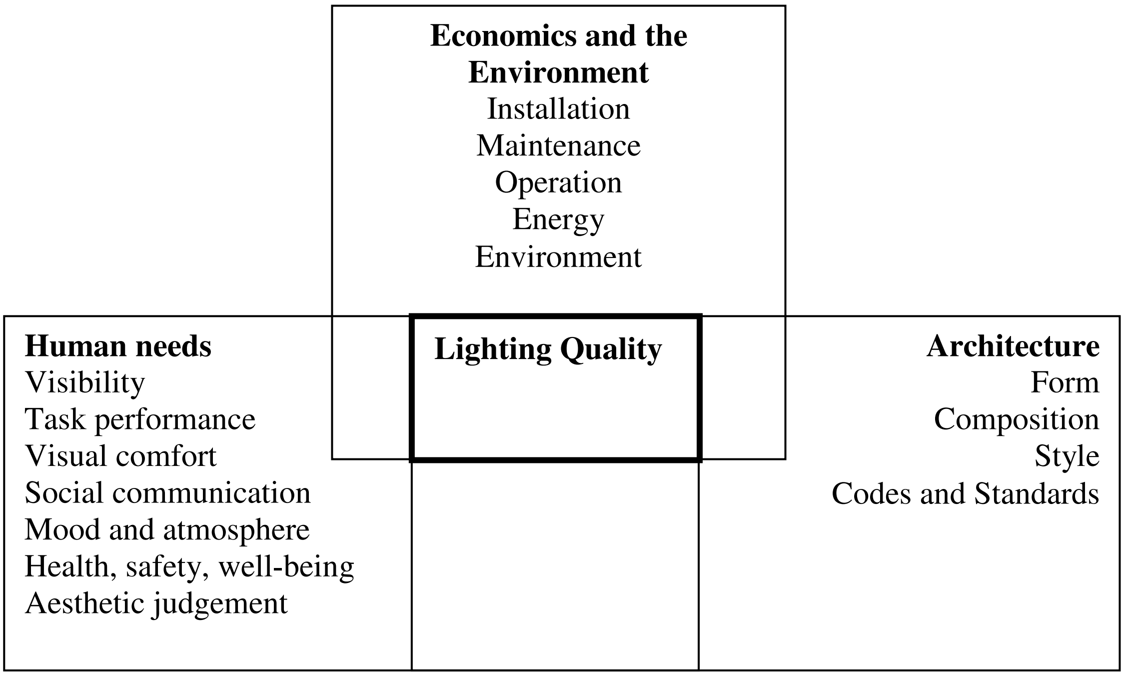


Figure 2.1. Quality of lighting systems after IESNA:
(Source: Hascher, Rainer, Jeska, Simone, Klauck, Birgit 2002)

The Physically ascertainable product fetures are described in the standards. Every lighting system must take account of the following factors: level of lighting, distribution of light intensity, limitation of glare (direct and reflective), colour rendering, colour and direction of light, shadow (IESNA).

Above in the Figure 2.1., there is a diagram demonstrating the components that make the qualitative light. This figure also states the complicated structure of light. In spite of this complicated structure, establishing quality and quantity of light for comfortable visual conditions can be gathered under two obvious ocassions; necessary illumination level, quality of convenient illumination.

Proper quantity of light -lowest and highest illumination levels- in the form of tables and charts are assigned and published by several institutions. Also, essential illumination level can be calculated by using these mentioned tables.

Adaptation of the eye to the illumination level, is related with the illumination level on pupillar, in other words; it depends on average luminance in visual area. It is not related with the necessary illumination levels, this means; human eye spontaneously does the “adaptation” in all conditions and situation, besides; need for illumination level generally varies strongly by age at a high ratio (5-10 times) and also by hour of day, fatigue dose…etc. Human eye can easily adapt between hundreds and thousands lux of illumination. Against this, adaptation changes upon;

- Dimensions of details that have to be seen
- Object's reflectance
- Luminance contradiction of object and its surrounding
- Visual perception duration
- Variableness of vision issue
- Human's age condition "(Sirel 1992)".

2.3. Vision

Seeing happens by means of light. Objects are visible by reflected and transmitted light coming to eye from their surface. That's why the quality of illumination is definite determinative of comfortable vision.

Comfortable visual perception can be proven with certain definitions and criterions in lighting technics. These criterion can be listed as;

- All details and their smaller parts must be easily seen.
- Perceiving the right colour, recognizing even minor colour differences.
- Perceiving forms of surface, two or three dimensional textures and other surface properties.
- Perceiving variableness with its all components like; direction, velocity, acceleration…etc.
- Performing visual perception freely, easily and pursue it indefatigably "(Sirel 1994)".

According to Sirel's stated criteions listed above; it is clear about what we should understand about the term "comfortable visual perception".

2.4. Some Definitions and Rules About the Quality of Light

Before identifying the basic rules, firstly light's structure must be well comprehended. In order to explain the lighting issue, there are some subheadings that should be made clear firstly such as its directional and spectral structure.

2.4.1. Light's Directional Structure

"According to William Lam; orientation is a need for human beings and continuous visual information is required for all physical activities, such as walking, running or working. In a space, the human mind searches for clues that give orientation for experiencing the inner atmosphere. When these clues are distorted or absent, the effect can be disturbing" "(Kutlu 2000)". That is why; light can fulfill that need with a conscious use, when the knowledge of perceptual psychology is regarded during the design stage. This explains the important relation between human perception and direction of light.

Human as a phototropic being react to light. As the brightest view in a space catches one's attention first, brightness becomes a clue for creating movement with light.. Experiments show that light is the strongest stimulus for movement among the alternative choices.

The placement of the light source is important, as the direction of light affects the perception. The right place for a light source is determined by convention of its surrounding structure and object which is to be lit "(Kutlu 2000)".

Shadows and variations in brightness are essential in a space, and only directional light sources can create shadows that are not completely diffused. When a light source is far away from the object, and also small in quantity of produced light, shadow appears sharply "(Sirel 1992)".

Considering these definitions above, we can say that; if factors like direction, direction's proportion, shadow's softness are determined properly and when directed illumination giving soft shadow is accompanying to diffused light, in other words; illumination obtained by the light coming from infinite direction; we can say that best visual conditions are established.

The Figures 2.2., 2.3., 2.4., 2.5., 2.6. below demonstrates examples of different directions of lighting.

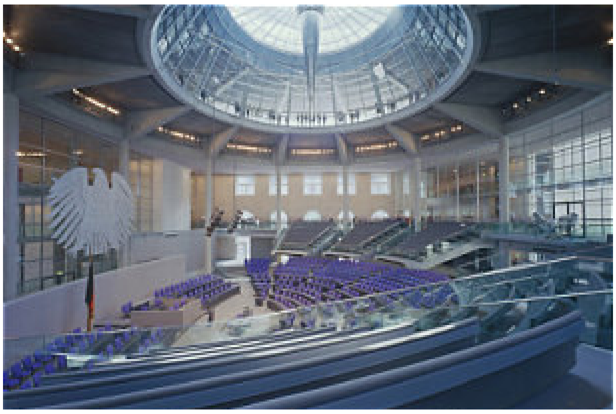


Figure 2.2. General lighting
(Source: WEB_3 2005)

Figure 2.3. Direct, aimed lighting

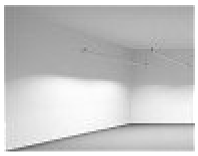


Figure 2.4. Direct, diffuse lighting

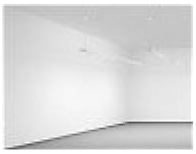


Figure 2.5. Indirect lighting

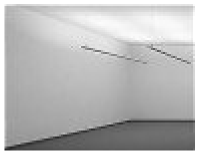


Figure 2.6. Direct and indirect lighting

2.4.2. Light's Spectral Structure

James Clerk Maxwell showed that visible light is an electromagnetic radiation and is simply one small part of the total electromagnetic spectrum in 1873. The wavelength of visible light ranges from approximately 400 nm to 700 nm depending on the observer's eyes.

The total electromagnetic spectrum and the visible spectrum are shown in the diagram below:

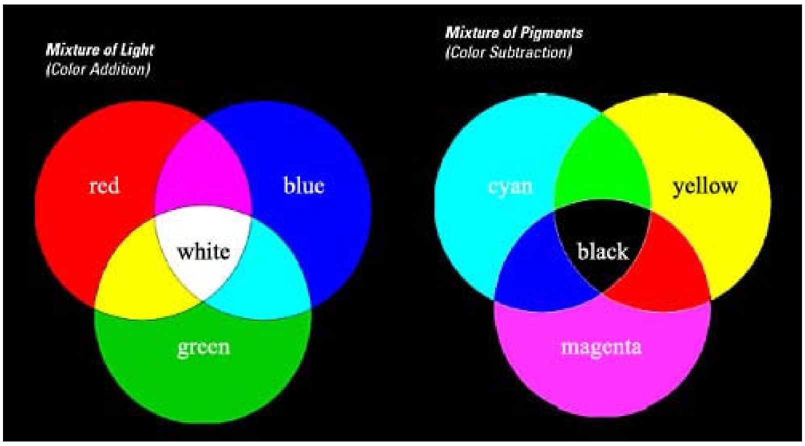


Figure 2.7. The electromagnetic and visible spectra.

(Source: WEB_10 2006)

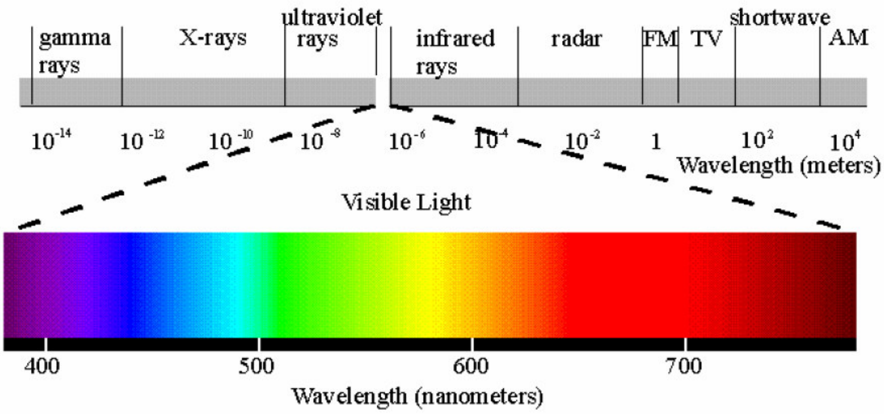


Figure 2.8. Primary Colours

(Source: WEB_3 2005)

A primary color is defined as one that subtracts or absorbs a primary color of light when transmits or reflects the other two color. For example, if material absorbs red light and reflects blue and gren, its color would be called cyan. So, the primary pigment colors are called; cyan, magenta, and yellow which are the secondary colors of light.

An object's apparent colour is related with the multiplication of its spectral reflectance factor curve with spectral curve of the light source illuminating it. If light's spectral curve is a horizontal line (theoretical white light) illuminating the object, as all of the spectral reflectance factor curves will be multiplied with same number, object will be seen in its "real colour" "(Sirel 1992)".

How we see an object and its color depends on the wavelengths emitted by the light source, the wavelengths reflected by the object, the environment in which we see the object, and the characteristics of the visual system. Our conception of the color of an object is a constantly changing, highly dynamic process. It depends on what colors surround the object, how long we have been exposed to the scene, what we were looking at before, what we expect to see, and perhaps what we would like to see "(Sirel 1992)".

Perception of colour means; minimum distortion of colour; in other words; visible colour appears to be closest to its real colour. Real colour is its colour seen under thereotical white luminous. Visible colour is the colour perceived under both natural and artificial light excepting thereotical white luminous. This means that; there is a colour distortion in objects perception, illuminated by non theoretical white luminous according to its spectral property.

Perceived colour of the objects change relatively with the light illuminating them, as both natural and artifical light has a colour, it is variable. This quantity of change can reach up to higher degrees according to the light's spectral curve's properties. For instance; a red object's colour can be perceived as crimson, brown, gray, orange or purple under different kinds of lights. This is valid for all colours. Two different colour can be perceived as in same colour, or we can not sense minor gradations "(Sirel 1992)".

2.4.3. Brightness and Glare

According to Hopkinson ve Bradley's studies in Cornell University Research Centre, in which brightness unit and sources were discussed; it arised that there is not much difference between smaller or bigger brightness sources, only direction of function could make a difference. Major reason of this is; as the source gets bigger; brightness much more affect the illuminance coming to eye. That is why illuminance coming to eye and its conformity level defines its whole view area.

Glare is the excess of brightness in view field and is a major mean for visual discomfort causing dissatisfaction with the lighting. Glare happens with the excess luminance of the surface or object depending on how much light is emitted in specified direction, object's size and its contrast with surrounding.

Discomfort glare causes our pupils to contract, forcing us to turn away or move or shield the cause of glare. Direct glare occurs when we see a bright light source (a luminaire, bright sky, or sun). Reflected glare occurs when we see the image of a bright source (as in a VDT screen, polished surface, or glossy magazine). To control glare from direct lighting, luminaires with good shielding must be selected and located.

Ideal brightness must be spread over the ceiling, indirect lighting must be generally less glary than direct lighting and, therefore, more comfortable. Nevertheless, the ceiling that reflects a hot patch of indirect lighting may wash out contrast in a VDT screen or appear as a distracting, bright spot in the screen. Light reflects off the visual task into the viewer's eyes in a way that overwhelms the task contrast and "veils" the task reflections occur generally when lamps are located in what is called the offending zone, which is in front of the viewer. Veiling reflections are a common problem in both paper based and VDT intensive offices. For ceiling mounted luminaries, veiling reflections have to be controlled by locating the luminary out of the offending zone. Task lights usually mount in the offending zone; or another solution is using lenses to redirect the light and minimize the veiling reflections (WEB_ 8,2006).

2.4.4. Form-Shape and Texture

Lighting is built not to obtain a certain level of illumination, but to provide good vision conditions. Provision of good vision conditions depends on quality of illuminance, not its quantity. There are such special occasions that; best visual conditions are created without illuminating the subject of the vision arguement by making certain regions and its surrounding visible with light.

“Quality of illuminance must reach up to a certain level that depends on properties of vision subject. This is necessary but not enough to provide good vision conditions. Beter vision conditions can not be created by increasing the illumination more than necessary level.” “(Zelanski and Fisher 1995)”.

Briefly; quality of illuminance depends on the object’s properties of visual perception, especially its form, dimension, surface, texture and colour. Thus, comfortable visual conditions can be created even under low illumination levels in the same time lighting reaches its aim.

2.4.5. Illumination Dispersion

"Illuminance dispersion differentiate in a space. A regular dispersed illuminance has static, stable characteristic. Such an illuminance like this means; every part of the space has a similiar function. For instance; offices full of desks, ateliers full of workbenchs…etc." "(Sirel 2005)".

This means; if every part of a place is not used at the same time and frequency; it would be more appropriate to arrange the lighting order with irregular dispersed, less variable and dynamic featured illuminance levels. This also accords with way of using the space, its architectural characteristic and function, likewise; it would be more harmonious with human being's nature and also suitable for economics. For instance; illuminating a hotel room or a living room, even a shopwindow with a regular dispersed light is useless and meaningless in many ways.

Local accent lighting is used in emphasizing a certain region in a space, orientating people to there or if higher level of illumination is necessary for that certain region. In order to have this characteristic of accent lighting, its level should be at least three times higher than general lighting level according to Prof. Dr. Şazi Sirel .

Even if there is a need only for accent lighting; certain level of general lighting should accompany, in order to avoid specific fatigue. There are formulas and diagrams for finding out the minimum level of general lighting which should accompany.

2.5. Some of the Fundamental Rules for Good Illumination

1- The light used for illuminating specific objects or areas, should be oriented on that, and sould not shine in the viewer's eyes. It is both uncomfortable and tiring for the eye also decreasing the beneficial illumination level. In other words; the light coming down to eye causes objects or areas to seem darker.

2- If perception of dents and bumps of a surface is important; for this occasion, descent directed luminary region must be created and be adjusted according to the inclination of dents and bumps of surface. The same rule is also valid for 3d texture's illuminating.

3- It is more comfortable to arrange smooth and transparent shadows in living interiors with regard to the quality of shadow. Illumination with dark shadows is interesting due to its luminance contrast, but tiring at the same time. These kind of ılluminance is suitable for the spaces that are not living and viewed for a short period, such as shop windows or stages.

4- Illuminance with sharp shadows can cause artificial lines or images on non-plane surfaces. Because of this; sharp shadows must be set for special occasions “(Sirel 1996)”.

5- Field of view must be more illuminated than its surrounding. Pages of a book, top of a workbench, face of a chairman must not be dim relatively to its surrounding.

6- Differences of lumminance proportion between field of view and surrounding of comparison field must not form tiring contrasts. Big contrasts blocks smaller contrasts to be distinguished. The same rule is also valid for the color subject. By this way; avoidance of light from the eye rule dicussed above is explained again.

7- There must be a difference between ambient and directional lighting. Everything in the space does not have to be at the same lighting level, the entire area need not to be lit throughout at the same brightness.

8- System design should have sufficient flexibility for likely future needs.

9- Different colors of light sources must not be mixed in the same space, unless that is the effect desired.

10- It should be remembered that human eye will accomodate first to the brightest point of light seen. Everything else surrounding that point will appear less visible. Therefore, gradually decrease the light level leading to very low conservation light.

11- Darker surfaces are likely to absorb much of the light and will be less effective.

12- Highest illumination level should not be used in the room for ceilings. This will leave items at floor level in the dark, the contrast should not be drastic.

13- A mock-up must be done in situation before completing the design and ordering.

14- Provisions should be made to dissipate the heat from the light source.

15- Location of light sources must be easily accesible.

16- All task and/or display lighting must be as adjustable as possible, because even “permanent” installations can change over time, considering future needs.

17- It would be rational to start with the simplest approach first, and only work up to the more elaborate ones needed.

2.6. Differentiating With Light

It is not possible to define a good illuminated space with only quantitive terms. Lighting is a subject that requires knowledge in engineering, psychology and design. By means of lighting issue; it is possible to distinguish two different areas through in a space. It is a kind of classification that the functional differences of light bring.

In order to create different auras in a space through light, different lighting qualities must be generated. If daylight and artificial light is arranged together; this could lead to pleasant solutions in that kind of an intention in space. Distinction could be created by changing the:

Illumination type

- Daylighting
- Artificial Lighting

Lighting System

- Direct Lighting
- Indirect Lighting

Perceived illumination form

- Point
- Line
- Surface
- Volume

“Human is a phototropic being, react to light and follow it. This is an important clue for illuminating a space, when a focal point or movement is desired” “(Kutlu, 2000)”. There are several ways of creating the feeling of direction through light, both natural and artificial. For example making change in lamp types, brightness ratio, color, contrast, arrangement of light sources can cause different effects.

People prefer to move to the brightest view in a scene. Attention can be caught by contarsts in size, color or brightness. For example washing a wall with a warm colored light in a soft illuminated space could attract attention. Likewise artifical light sources can be arranged in a way that they form an order or they create a focus on an object or a part of a space, which influences movement.

2.7. Types of Lighting

A successful lighting scheme is made up of several layers: natural, general, accent and task light. Each type can enhance or deteriorate a living space. People would not realise the bad lighting but would recognise the symptoms: headaches and sore eyes, frustration in the places at not being able to see what they are doing.

2.7.1. Natural / Daylight

Daylight factor is the percentage of sunlight coming down to a reference point in a room, and is related with dimensions of window, its transmission, area of room, surface from which light is reflected. But this a simplificated definition of quite complicated, subjective tool; light.

Daylight is an important part of natural light; it is inspirational and can cause a flushing effect emotionally. Sun’s kinetical movement in an area is the evidence of passing time and most of people prefer this kind of communication with outer world. Illumination’s additive effect to working labour and its power in creating the proper effect for correct perception is absolutely accepted. Relation between light and guilt, security and establishing night economics in urban area is an absolute comprehension.

According to a recent research; it is observed that; receiving high levels of daylight has an extremely positive effect on students’ academical performance and behaviour. This judgement is set on the Pacific Gas and Energy Company research in USA. It is observed that; students receiving high level (% 10) of daylight were % 20 more successful in their mathematics tests. When the same observation performed in Sweden; students were found to be more successful in % 26 ratio. Overall these researches, as a result; students attending to schools when received daylight, are more successful between %7 and 14.

There are several ways to maximise natural light. Releasing light to come through windows without interruptions, removing secondary glazing which absorbs light, choosing light and bright paint colours will affect how light a room is. To make the most of the natural light available in a space, firstly it is needed to know how to use it, and secondly remember that daylight changes throughout the year.

2.7.2. Artificial Lighting

Daylight had always been the defining agent. With the development of more efficient artificial light source, the knowledge that has been gained of daylight technology was joined to artificial light.

Natural indoor lighting means by windows and skylights, artificial indoor lighting means by lamps; electric lights. Lighting refers to the devices or techniques used for illumination comprising artificial light sources; lamps.

2.8. Types of Lighting Techniques

Lighting is classified by its intended use as general, localized, or task lighting, depending largely on the distribution of the light produced by the fixture.

General lighting refers to an even illumination, usually related to a horizontal working plane. Quantitative aspects are often a primary consideration at the work place or in pedestrian traffic zones. General lighting fills in between the two and is intended for general illiumination of an area. Indoors, this would be a basic lamp on a table or floor, or a fixture on the ceiling.

Task lighting is mainly functional and is usually the most concentrated, for purposes such as reading or inspection of materials. For example, reading poor-quality reproductions may require task lighting levels up to 1500 lux, and some inspection tasks or surgical process requires higher levels.

For special occasions, lighting is of the utmost importance for creating the right ambiance. By experimenting with different types of lighting such as; ambient, promotional, building, feature, spotlighting, highlighting, floodlighting, the mood of a space can change.

2.9. Energy Saving in Lighting

We can create comfortable, well lit spaces by choosing the most appropriate types of energy efficient lighting considering the payment rate of artificial lighting costs in the average household. P.M. Van Bergem Jansen, in his announcement, predicated by scientific valid principles, reported that raising the illumination level over 200 lux, is not effective on improving visual perception in many cases and defended that tending to increasing the quality of illumination would be 10 times economic.

The most energy efficient light is natural light, which can be maximised by incorporating energy efficient design features. For example; well designed north-facing windows and skylights let in light without adding to summer heat and winter cold or light coloured interior surfaces reflect more light and reduce the level of artificial lighting required.

Some local spaces require different types of artificial lighting. General lighting is used for illuminating a large space, while special purpose lighting is used to illuminate specific areas, such as bench tops and desks. Different light bulbs and fittings should be used for these two purposes.

There are three main types of lighting to choose from fluorescent, incandescent or halogen which we can supply easily. These lights are suitable for different types of space and purposes.

Generally, fluorescent lighting is most energy efficient and incandescent lighting is the least energy efficient. Fluorescent lights are more useful where lighting is required for long periods of time, such as living rooms, over kitchen benches or on desks.

The cost of running a light is directly related to the wattage of the globe. The higher the wattage, the higher the running cost. Compact fluorescent lamps (CFLs) are cheapest, when the life cycle cost is considered. The cost of your lighting will also depend on the type of lighting you select and the length of time you leave your lights on. The table below shows the lifecycle costs for lighting systems using different globes to produce the same amount of light. Lifecycle costs include purchase, running and replacement costs.

Table 2.1. Standard serial of lamp types

(Source: Sirel 1991)

Lamp Types (Standard Serial)						
	Radiation efficiency [lm/W]		Ratio in radiation efficiency fall	Lifetime [hour]		Lamp ratio going out at the end of theoretical lifetime
	New	At the end of theoretical lifetime		Theoretical	Statistical	
Incandescent Lamp	8-16	7-15	0.93	1.000	500 – 1.500	0.50
Tungsten halogen Lamps	14-25	-	-	1.500–2.000	-	-
Halophosphate Fluorescent lamps	48-74	37-58	0.78	8.000	7.000–16.000	0.05
Triphosphor Fluorescent lamps	60-83	52-71	0.86	8.000	7.000–16.000	0.05
Special substance contributed Fluorescent lamps	45-60	-	-	8.000	-	-
Mercury vapor Lamps	35-60	24-41	0.68	12.000	4.000–24.000	0.12
Metal halide Lamps	60-85	41-58	0.68	9.000	1.000–18.000	0.15
High-pressured sodium vapor Lamps	70-135	61-117	0.87	12.000	4.000–24.000	0.11
Low-pressured sodium vapor Lamps	100-180	-	-	20.000	-	-

Lamps are defined in many encyclopedias as the “Removable part of a luminaire which converts electrical energy to both visible and non-visible electromagnetic energy” , which are commonly called as “light bulbs”. Some types of light source are; tungsten (incandescent), tungsten halogen, fluorescent, led (light-emitting diode), hid (high-intensity discharge)…etc.

2.10. Technical Lighting

The visual subject can be among various objects with shiny or matt surface, and can be more or less important, small or large, mobile or immobile. Human can be inside or outside this space with that objects. These factors mostly affect the quantity and especially the quality of illuminance for that objects to be seen well enough.

Technical lighting is the technic, determining how to form illumination, considering these inconsistents. Thus; technical lighting provides best conditions for visual perception, on the other hand solves its first production and access expenditure in most economic way, also finding solutions about its adaptation to human nature, architecture, aesthetic principles at a satisfying level.

As to be unserstood from the brief explanation above; technical lighting bases upon knowledge from; human eye's visual perception of light and colour,various properties of light sources, lamps and luminaires, reflection and transmission properties of surface and materials, both aesthetic and architectural concepts reaching to quite complicated calculation methods, scientific datas outspread to a wide region and information.

Today, advanced countries have already concluded on this basic reality that; appropriate technical ligting increases; success at schools, efficiency in workplaces, offices, decreases work and traffic accidents, defective production, eliminates unnecessary fatigue, eye and head ache, raising life to more healthier, pleasant and efficient level. Even if we directly examine the matter by decrease in energy used for lighting expenditure, on the other hand, it can be easily shown that, putting technical lighting into practice will increase ratio of success, productivity, decrease various loss, affects economy positively. There is no need to argue its importance for a progressing country. When we come down to technical lighting details; its incandesce and appeal increases. We can understand its importance better with comparision calculations.

2.11. Computer Programs and Lighting Projects

The 1920's witnessed important innovations in lighting became cheaper with the increasing technology. Lighting became a science and new professions came to agenda such as lighting designers and lighting engineers.

Light engineering brought with it its own rules and principles, which mostly stand on quantitive basics and that is why it is exposed to strong critics like the lack of the basic concepts such as psychology.

Light and space have always been in a close relationship through human history. In the 20th century, especially in the second decade of it, through increasing technology, artificial light sources, light systems, and new lighting techniques have joined to this relationship as creative tools. The first category of light as art techniques, hardware, contains both light sources and light fixtures. There are neon light, fiber optics, acrylics, light pipes and acrylic panels.

Acrylics are produced also in panels, and almost all techniques used for fibers and light pipes are also useful partitions for small places. When the panel is mostly etched, it can serve as an acoustic barrier without blocking the view, so it can enlarge an enclosed space. When the partition is mostly frosted, it serves to protect privacy by obscuring the view and also for acoustical purposes.

Technological developments, called intelligent buildings, and lighting systems constitute an important part of it. Hong Kong Bank is one of the first buildings, where daylight is controlled in a technological way.

ERCO designed computer controlled sun scoops, attached to the building exterior and to the top of the atrium, which catches and collects sunlight according to the time of the day and weather conditions to direct it to the iner mirror in top of the atrium. From there the sunrays are reflected down the atrium, then to the ground, as far as to the basement flor. The collectors also contains large lamps, whose color are computercontrolled, which came into use, when the amount of daylight is not enough for the desired lighting condition. And it is impossible to differentiate between daylight and artificial light “(Kutlu 2000)”.

2.12. Lighting Project

Lighting Project is the project defining how to apply lighting tecnics to a certain subject and showing how to do it. Expression here “a certain subject” has to be understood in a narrow meaning. In other words; this expression describes not buildings as; hotels, offices, museums, residences or factories but their individual parts. Because; there are important differences even between same type of buildings such as; their way of management, architectural styles, climate, location properties which require diffrent lighting orders.

Lighting technic is strongly related with the quality, form and character of illumination, on the other hand, its quantity isn't much effective. Reasons such as; easy calculation methods for illumination level, its variability, depending on; sort of job, hour of day, fatigue dose, individual's characteristics, psychological factors and flexibility of human eye in adapting to different illumination levels -that can be achieved by dimmers- can explain immateriality of illumination quantity.

On the contrary; quality and characteristics of illumination is important because; it takes the basic role in visual perception, has properties neither simple, nor complicated which are not easily calculated, but only understanding the whole technic and applying it with mental and inventive efficiency, defines its real importance.

Today, there is a reality assimilated by authority that; illumination quality is the only determinative factor and certain level of illumination is necessary but not satisfying for comfortable vision conditions.

> *"Fine lighting is achieved through careful consideration of two questions: "What goals have been set for this design?" and "How can the success of the system in achieving those goals be measured?" Good lighting must be defined at the start of every Project with each client. Since light is visually evaluated and creates perceptions, numbers methodology cannot fulfill the expectations that abound with every new project. Instead, a clear description of what will make good lighting should be recorded prior to the beginning of the design." "(Jankowski 1997)".*

Lighting project is a kind of project which involves whole sorts of lighting sources, their types, locations, power and knowledge useful for application. Lighting project is about illumination arrangement, not an electrical installation project.

There are four phases in preparation in a lighting project;

1)Building's architectural and functional properties etude

2)Determining the quality for every individual part which are apart by their functional, furnishing and iterior properties.

3)Establishing illumination levels at determined quality and arranging these lighting orders considering their harmony with interior expressions, locality features, characteristics and also constructional necessities.

4)Calculating illumination levels according to achieved data.

CHAPTER 3

PHYSICAL AND PSYCHOLOGICAL RELATION OF LIGHTING IN WORKSPACES

In the lighting manual of IESNA (Illuminating Engineering Society of North America), there is a significantly more comprehensive and above all, more all-embracing view of the goals of lighting design and therefore of the quality of the lighting systems of the future. The goal of lighting design is to provide visual comfort, which comprises the distribution of light intensity and visual attractiveness.

Light intensity is defined as "Lighting strength and degree of reflection on vertical surfaces" and visual attractiveness as "degree of unevenness through light and shadow as well as through light density transitions between the surfaces" (WEB_6 2004).

In future these factors will be supplemented by the following terms: ergonomics of lighting systems, room harmony, mood of light, lighting design, visual comfort, economic efficiency, visual power and room ambiance.

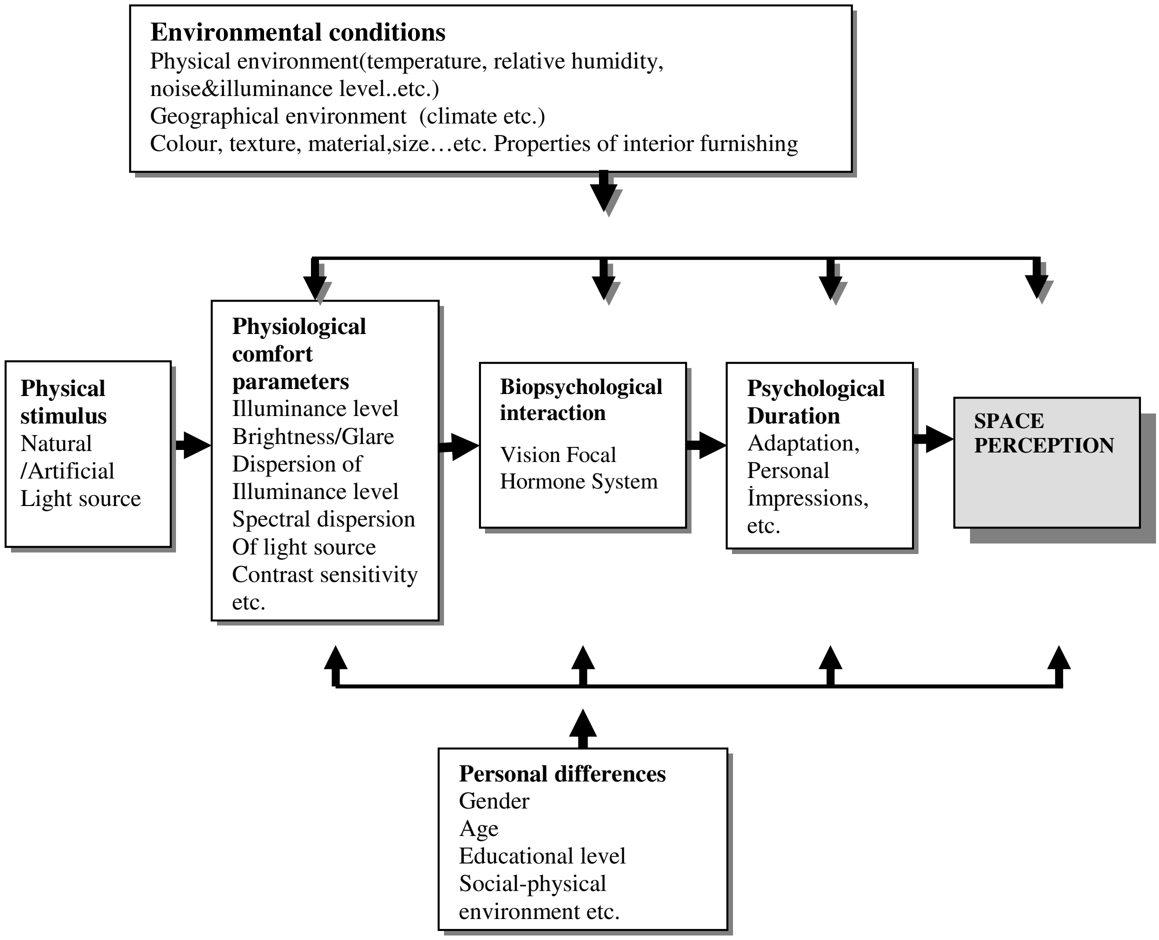


Figure 3.1. Physical-psychological relation of lighting and space perception.
(Source: Yücetaş 1997)

3.1. Aspects of Office Workspace Lighting

With the transition to the information age, businesses and perception levels are fundamentally changing as are our living and working environments. Flexibility and mobility require a variable office environment and all of its components need to be perceived as comfortable, lighting too. The effects of optical radiation on human are well known; they have been scientifically proven. In medicine, intense light is used to treat SAD (seasonal affective disorder); this is also referred to light therapy. Light is recognised as giving a sense of time, and it affects hormone levels, in particular, physiological stimulus, also the influence on the human biorhythm can be observed. The changes in natural light during the course of the day and the year formed both the human visual apparatus and human perceptual habits.

Biological rhythms that repeat at approximately every 24 hours are called circadian rhythms. Light is the main stimulus that helps the circadian clock, and thus circadian rhythms, keep a synchronized rhythm with the solar day. If we are not exposed to sufficient amount of light of the right spectrum, for a sufficient amount of time, and at the right timing, our biological clocks become desynchronized with the solar day; decrements in physiological functions, neurobehavioral performance and sleep may occur.

A better understanding of the quantity, spectrum, timing, duration, and distribution of light that is effective for the biological system is essential, so that light can be applied to mitigate the symptoms of seasonal affective disorder, sleep deprivation (WEB_9 2006).

Daylight is more preferable for human health and well-being than artificial lighting. Given the importance of natural light for humans, this statement appears to be obvious. This verification has a decisive relevance with the necessity of "visual contact with the outside world" without specifying the amount of daylight for the illumination of the workplace.

Long-term experiments on preferred levels of lighting in relation to time of day and time of year have shown that even with daylight levels in the middle range of 800 lux, people will switch on artificial light as well. From this it can be deduced that the need for light is stronger in artificially lighted rooms than the value required by the standards. Moore and Edel point out that in the "24-hour society" people's cheerfullness varies enormously during the course of the day and is influenced by the environment and the light. Higher light levels counteract fatigue; rapid changes in lighting are stimulating, while a monotone visual environment is sleep-inducing.

The beneficial effects of light are undisputed. From an economic point of view, however, opinions differ:

- *Daylight helps to save energy. If a lighting level of 500 Lux can be achieved through the incidence of daylight, artificial light can be switched off reduced – this one view*
- *Daylight intensifies feelings of wellbeing. Being able to experience daylight changing with the time of day and to have a view outside are positive components of daylight. As the supply of daylight increases, however, the need for light inside also increases, and a standardised office with 500 Lux is not sufficient, if the light outside is very bright in comparison. Occasionally more artificial light is needed to compensate for the lack of light intensity; this is the other view. "(Katz 2002)".*

Most lighting systems in offices today are executed according to standards, but frequently do not meet with the occupants' acceptance. Different committees and research facilities have unanmously established that positive assessment of lights and lighting systems by occupants are strongly dependent on appearance and the individual's ability to intervene. The systems analysed were static and could not be regulated depends on the way the light is distributed in the room and the individual's ability to influence it.

3.2. Lighting Design

Lighting design can be defined as the study of gathering proper illumination systems, considering real necessities, ignoring stereotyped ways and calculation methods. Or; the art and craft of creating the visual environment by means of illuminating it. (WEB_6 2004)

Lighting design as it applies to the built environment, also known as 'architectural lighting design', is both a science and an art. Proper comprehensive lighting design requires consideration of the amount of functional light provided, the energy consumed, as well as the imaginery effect provided by the lighting system. Some buildings, like hospitals and sports facilities are firstly concerned with providing the appropriate amount of light for the certain task. Some buildings, like warehouses and office buildings, are concerned with saving money through the reducement of energy consumption used by the lighting system. Other buildings, like cinemas and theatres have to enhance the appearance and emotional effect of architecture via lighting systems. Therefore, it is important that the science of artificial light and luminaire photometry are balanced with the aesthetic application of light as a matter in our environment of buildings.

These artificial lighting systems should also consider the impacts of, and ideally be integrated with, daylighting systems. Lighting design requires the consideration of several design factors:

- Tasks occurring in the environment
- Occupants of the environment
- Initial and continued operational costs
- Aesthetic architectural impact

- Physical size of the environment
- Surface characteristics (reflectance, specularity)
- Dirt and dust generation/accumulation
- Maintenance capabilities
- Operating schedule of the building
- Electrical codes and building codes

The Illuminating Engineering Society of North America (IESNA), in conjunction with organizations like ANSI and ASHRAE, publishes guidelines, standards, and handbooks that allow categorization of the illumination needs of different built environments.

3.3. Responsibility of Lighting Design

The world today can be divided into four major markets for office buildings, each with distinct regional characteristics: The United States, Europe, Japan and Asia. For the present, all other markets can be considered derivatives of those.

Significantly, the Asian market is rapidly increasing in size and eventually will probably be the biggest, especially in tall and large projects. In continental Europe it is established by law that every office worker is entitled to work in natural light. At the risk of oversimplification, we can see four markets as having certain characteristic power relationships and design priorities.

Table 3.1. Global Variation, Relationships and Priorities*.

Power Relationships	United States	Europe	Japan	Other Asia
Owner	1	2	3	1
Designer	3	1	2	2
Contractor	2	3	1	3
Design Priorities				
Exterior Wall	3	1	2	1
Structure	2	3	1	2
Mechanical Systems	1	2	3	3

* With 1 designating the most important party party or priority and 3 the least.

In such cases where commercial value of lighting is really perceived; lighting designers are employed, but also there are some cases, where a proper lighting designer or consultant is not engaged, design has been done by the architect, engineer, other consultant, supplier, exhibit builder, curator, conservator, building maintenance, interior designer, or electrical contractor.

As a source of natural light and ventilation, and as a key energy-conserving feature, the exterior wall is a crucial component justifying greater design consideration and greater investment in this region than in other parts of the world. The table 3.2. below shows the expenditure domain rates costs for lighting systems that has been spent for two random buildings; one from Tokyo, the other from Turkey.

Table 3.2. Ncr Building-Tokyo, 1964, expenditure domain rates.
(Source: Ayverdi)

Expenditure Domain	Amount Rate (%)	Cost Per m² (TL/m²)
Landscape	0,50%	-
Meteorological Emblem	0,80%	-
Kitchen	0,70%	-
Phone Substructure	2,00%	-
Elevators	3,50%	-
Sanitary Fitting	2,70%	78
Air Condition	14,10%	408
Artificial Lighting	13,10%	380
Architectural Structure	62,50%	1800

Table 3.3. Turkey Foundations General Headship Building-Turkey, 1966, expenditure domain rates.
(Source: Ayverdi)

Expenditure Domain	Amount Rate (%)	Cost Per m² (TL/m²)
Architectural Structure	77,30%	720
Sanitary Fitting	4,20%	-
Central Heating	7,20%	-
Lighting Fitting	6,90%	64
Burner	1,90%	-
Cooling	1,10%	-
Air Condition	1,40%	-

3.4. Psychological Comfort Parameters

Comfort conditions include visual and psychological comfort that should be integrated to the project to provide a healthy work place. The presence of comfort conditions satify user's well-being and increase motivation, that will in turn lead to high performance and inprove productivity.

3.4.1. Illumination Level Change and Adaptation

In order not to lose eye's abillity and have problems in adaptation; each 'illumination level differences' must follow other by 1,5 times in quantity according to CIE standards recommendation.

Even if there is different illumination levels between local regions in a place; it must be controlled to avoid glaze and formation of sharp shadows. Regularity factor must be established; differences between illumination levels over the labour plane must not be less than 0,7 and illumination level regularity dispersion between the labour plane – adjacent environment must not be less than 0,5. Manav supports these with the table 3.4. below.

If the labour has large details or has much contrariness differences on it; requiring short duration; illumination level can be decreased.

Table 3.4. Illuminance level (E_m), glare index (UGR_L) and colour rendering index (R_a) for offices. (Source: Manav 2005).

Building Type: OFFICE	**E_m(lux)**	**UGR_L**	***R_a***
Circulation area, photocopy	300	19	*80*
Writing, Reading,data input etc.	500	19	*80*
Drawing	750	16	*80*
Computer Room	500	19	*80*
Meeting/Lecture Room	500	19	*80*
Information	300	22	*80*
Archive	200	*25*	*80*

3.4.2. Lighting System's Impressions

According to ANSI / IESNA's report, result of Flynn and his team's serial of researchs, impressions were gathered under four groups; comfort, relief, visual clarity and contentment.

For 'relief' impression; it is recommended that illuminance level has to be regularly dispersed and interior walls have to be illuminated. For 'comfort' impression; irregularly dispersed illuminance levels, for 'visual clarity' impression; regularly dispersed high illuminace levels, for 'contentment' impression; local lighting on interior walls and creating luminosity differences is recommended.

In a study researching on effects of artificial lighting systems, it was concluded that there is no relation between psychological effects and level of lighting.

Electronic ballast usage in lighting system fixture gives a comfortable impression to the living space. Electronic ballasts are preferred as they are better in energy saving and redounding performance than magnetic balasts. According to the results of this study, it is specified that; local lighting gives positive effects on energy saving and space harmony issues.

Less mistakes are done if there is low difference contrariness. As the contrariness difference increases, more mistakes are done and physical fatigue is observed. Also indirect lighting and lens usage in armatures, help to decrease mistakes.

As the physical conditions get beter, performance increases. This situation, also known as 'Hawthorne Effect', is explained by studying interaction between components of physical environment and personal sensations, perception, prejudgements, beliefs etc. (WEB_4 2005)

Considering illuminance effect on perception duration as a component of physical environment; creating various scenarios by differentiating lighting arrangements and levels can be motivating and performance rising. This also has a positive effect on carefulness and interest to the labour, increasing performance quality.

Lighting systems can be fastened up to a desired level and managed by, remote controls or computers. Electric eyes mounted to the ceiling and remote controls, can dim and switch armature groups, offering design flexibility.

Illumination level changes as a result of solar movement during the day, but desired illumination levels depending on the user requirements can be adjusted with the help of daylight sensors.

3.4.3. Luminosity Incidence

Glaring and accented lighting requires establishing brightness differences, but this quantity must be about standard table value in order not to harms eye adaptation and physiological comfort. It is observed that; under very high or low illumination level, it harms visual clarity. Same thing happens even if the illumination difference between vertical plane and adjacent environment is low “(Zelanski and Fisher 1994)”.

Workers’ psychological and motivation attitude dependant on the brightness levels is observed in Fleischer, Krueger and Schierz’s study. Four different lighting scenarios, in which both natural and artificial lighting used, were prepared. In the result of this study; it is specified that; illumination level over labour plane must not be under 500 lux and colour temperature of fluorescent lamp has to be between 3000°K - 4000°K (daylight colour).

In offices where computers are used; labour plane can be horizontal, vertical and inclined , when calculating illumination level-luminosity incidences, as screens have their own luminosity, it must be considered. Reflections, illumination levels and luminosity of windows, walls and armatures falling on computer’s screen must be calculated to avoid glare “(Sirel 2001)”.

3.4.4. Colour Properties of Light Source

The color appearance of an object or surface clearly depends on the light used to illuminate it. Often daylight is considered a "standard" but it is obvious that the color of "daylight" changes with the position of the sun in the sky, how cloudy or overcast it is and also which direction of the sky we are sampling, e.g. northern sky or southern sky.

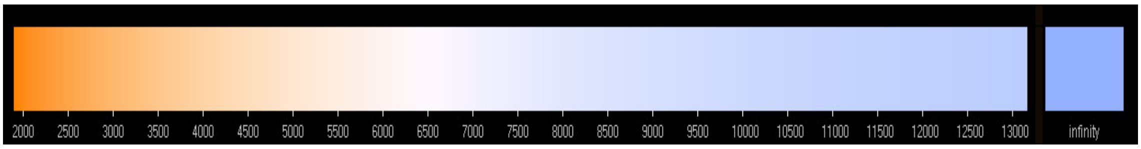


Figure 3.2. Blackbody temperature /K
(Source: WEB_12 2006)

If we want to decide about lamp color, first thing that we must specify is how "warm" or how "cool" a lamp will be selected. This decision is generally a subjective matter. Colour properties of light source must be discussed in two ways; colour rendering and colour temperature. Color temperature of a lamp is expressed in Kelvins and means the degree of coolness or warmth of the light source. Another unit for color of lamps is the Color Rendering Index (CRI). Lamps with high CRI usually have a "natural" look.

Lamps with worst colour rendering performance are; incandescent lamps, some fluorescent lamps and mostly discharge lamps. Lamps with best colour rendering performance are; xenon lamps, and some special kinds of fluorescent lamps. Metal halide lamps have also good performance in colour rendering, if several difficult conditions are provided.

Table 3.5. Colour temperature of lamps in º K
(Source: Manav 2005)

Colour Appearance	**Colour Temperature (ºK)**
Hot	Less than 3300º K
Warm	Between 3300ºK-5300º K
Cold	Over 5300º K

Lamps used in office workplaces must have high colour rendering properties for correct colour perceiving, increasing labour performance and strengthening ‘comfort’ impression. Their colour rendering class must be 1A or 1B and colour rendering incidence must not be less than 80 “(Manav 2005)”.

Kruithof, searched the relation between illuminance level and colours. In his study, he asked experimental group about their impressions who were illuminated in places with different illumination levels and colours. Results showed that; at low illumination levels; cold colour has given negative, hot colour has given positive effect.

Another study researching ‘contentment’ impression showed that; it is directly related with the increase in illumination level.

In a study searching relation between light source colour temperature and illuminance level, five different illuminance level, four different colour temperature is used. As colour temperature falls, place is evaluated as ‘positive’, as colour temperature rise, it is evaluated as ‘smaller’.

In another study about relation between lamps’ light colour and interest-performance on labour, at low illuminance level (150 lux) and hot coloured light sources, productivity and performance has been positively affected. Additionally; light sources with permanent and regular spectral concentration has better score than light sources with irregular spectral concentration (WEB_4 1995).

3.5. Improvement of Visual Comfort Conditions and Performance at Offices

A certain direction and level of illumination affects human eye’s threshold value and sight rapidity, as a result; seeing, adaptation, glare, contrast sensitivity, colour perception, form sensitivity facts happen. Human body also reacts this interaction; quantity and direction of light coming to eye, colour rendering properties of the light source, dispersion of illumination level and shadow formation in a place can cause physical diseases or affect “physical comfort”. Our body reacts to light affecting our hormonal and nervous systems. While some hormones being activated, some of hormones’ activation level fall via signals reaching to brain affected by the illumination level.

According to the change in labour conditions, hours and illumination level, spectral properties of light source; human biorhythm can be affected and cause problems like; sleeping disorders, gastric and digestion problems, memory blurriness, fatigue, difficulty in adaptation. Further more heart diseases and psychological problems are met due to a research done among people having frequent changes in labour hours depending on biorhythm imbalance “(Robertson 1989)”.

3.5.1. Effect of Visual Performance on Office Workers

There is an undeniable effect of visual performance on office employee. Accordingly, it affects their motivation and speed of work. Clearly, this effect can be negative or positive up to the lighting environment's success. Qualified lighting is directly relevant with rising up the interior conditions and visual comfort since improper light causes eyestrain.

Main office job involves; viewing text, drawing, data in any forms, screens, monitors.. etc. Proper lighting would lead workers to perform their visual tasks accurately and comfortably.

3.5.2. Visual Comfort

Employee's peformance and productivity is connected with the lighting system working in an office space. But we have to identify the 'disturbing' feeling in order to fulfill the terms of motivating kind of light. In other words we have to manifest the means of improper effects on people. These can be expressed as; glare, over brightened surface or sharp shadow patterns on the workplace caused by misguided systems. Workers only perceive the effects as, 'bright', 'glary', 'dim', 'dull'.. etc. but through the structure of light, we can recognise the relation to its distrubition over the specific task area.

3.5.3. Economy of Lighting Systems

A lighting system's economy term involves cost of luminaire and all other devices to install, control and maintain the whole practice. In some types of luminaires, it would be expensive to set the system firstly, conversely in some types to maintain it. Usually the expenditure of the lighting system accords with its type as mentioned in second chapter. Using linear fluorescent seems to be most economic in a lighting system, but in the same time we must to meet the color rendering quality.

So we can say that a lighting system's expense has to be evaluated as a complete calculations of light's quality, quantity and other economic input totally. In the same time we must not forget; regular maintenance, reducing number of lamp types and sometimesuse of fewer lamps lower the lighting systems' budget.

3.6. Effect of Lighting on Human Performance and Health

There is a belief stating; artificial lighting improves human performance. It was easy to prove the positive impact of better lighting in some work areas for instance; work with visual tasks or depending on visual performance. Increasing the illuminance level in such environments seemed to improve the performance of the worker. It gave rise to an arguement based on the proportion of illuminance level to human performance.

Figure 3.3. Light coloured open Office
(Source: WEB_5 2005)

Figure 3.4. Natural light use in Office space
(Source: WEB_5 2005)

Figure 3.5. Another naturally illuminated Office view
(Source: WEB_5 2005)

3.7. Office Lighting Systems

From beginning of this part of the chapter; informative explanations under significant titles on the specific topic: improving user comfort and performance at offices, will be summarized.

Office lighting systems include lamps, ballasts, fixtures, and controls. Together, a fixture with appropriate lamp and ballast forms a luminaire. Selection of a lighting system, however, begins not with the equipment, but with the lighting effects to be created by the system.

3.7.1. Lighting Effects

Speaking in terms of lighting effects, rather than just equipment, enables us to describe the intended results of the lighting system, not just the means. For instance some effects are Direct Lighting, Indirect Lighting, Direct/Indirect Lighting, Diffuse Lighting.. etc

In office lighting, the desk represents the most common work plane for measuring light levels. Ceilings, walls, and furniture partitions are other critical surfaces. In hallways and other circulation areas, the floor becomes the lighting work plane.

Figure 3.6. The use of transparent PVC sheeting in the ceiling.
(Source: WEB_5 2005)

3.7.2. Ideal Office Lighting Criterion

Before putting in order the basic rules for an “ideal office lighting”, we must assign its meaning or what we are trying to imply. The term “ideal office lighting” includes conditions such as; eployee’s visual comfort, interior ambience and energy consumption of the lighting systems. An “ideal office lighting” has to satisfy employee, employers in both physical and psychological ways.

- As “subjective brightness” evaluation, is not a measurable quantity but perceived quality, it is concerned with issues taking place in visual area such as; surface and objects' reflectance factors, colours, location and illuminance level dispersion of light source (natural-artificial) etc.

- Lighting system must integrate with architecture. The lighting system must be arranged suitable for office building's structure, interior office types, chosen furniture and properties.
- Workplace plane and adjacent environment every part in visual area must not have the same illuminance level, there must be hierarchy among focal points. Thus; we can interfere with monotonousness.
- With automation systems, it is possible for us to adjust both daylight and artificial light at a level, also they offer more comfortable and effective workplaces "(Carlson, Sylvia and Verne, 1991)".

3.7.3. Office Performance

Suspended indirect lighting can cause excessive ceiling brightness which reflects on computer screens, reducing user comfort and productivity. A furniture mounted unit can spread light smoothly across the ceiling to eliminate these hot spots. They balance the brightness of the ceiling with the workstation and provide comfortable illumination to surrounding spaces.

When workstation surfaces are brighter than their surrounds, occupants are drawn to their work and distractions are reduced. This helps to direct office speech into sound absorbing partitions, and no recessed lighting means more acoustical ceiling tiles.

3.7.4. Design of Office Lighting

Suspended indirect lighting systems reduce apparent ceiling heights. Furniture mounted lighting eliminates the clutter and increases the distance between the luminaires and the ceiling. This improves brightness ratios and reduces the number of luminaires required.

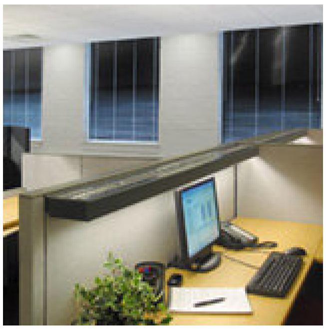


Figure 3.7. A Workstation with task lighting.
(Source: WEB_3 2005)

Task/ambient units provide downlight (task) and uplight (ambient) from a single luminaire. This eliminates the need for both task lights and ceiling luminaires and results in an unequalled sense of spaciousness. This means you can compose and take bids on several different furniture systems knowing that the lighting you've chosen will be compatible. By this way; workstations can be easily reconfigured and relocated without sacrificing quality as the lighting moves with the furniture. Rearrangements are achieved with less downtime and lowest cost.

3.7.5. Ideal Luminance at Workplace

Luminance means the amount of light that strikes an object or surface. The IES recommends luminance levels in a range depending on the task. The office environment includes different visual activities. Office work requires various luminance levels over a wide range; around VDT tasks, too much light should not wash out the screen and make nearby papers brighter and uncomfortable for vision. On the other hand, graphic design and other visual performances require much more. Most other visual tasks such as; circulation, reception, and people interaction require less. (WEB_9 2006)

In general, luminance over 50 fc is most effectively obtained by a combination of local and general lighting systems. A convenient task/ambient system vary the overall light level, delivering the light where it is needed, that helps saving energy

A local accent, where brightness exceeds the guideline, adds visual interest and relieves visual fatigue. Generally, office and furniture surfaces should be of light color and high reflectance avoiding high contrast with visual tasks and also reducing the output required of the lighting system, making it more economical and energy efficient.

Providing visual interest through selective use of highlights and accent colors makes a space more appealing and enhances workers' sense of well-being.

Over task areas however, task luminance should be relatively uniform to prevent distracting bright and dark patches. Uniformity is the ratio between the minimum and average levels of luminance. (WEB_9 2006)

Balanced luminance ratios, appropriate luminance hierarchies, reduced clutter, and precise glare control contribute to visual comfort and create offices where people prefer to work and feel good about their jobs. This can help retain valued employees.

Figure 3.8. An Office with indirectly lighted ceiling.
(Source: WEB_3 2005)

3.8. Illumination Quality in Offices

Generally arranging linear fluorescent lamp rows in wiev direction is one of the basic rules. This rule can be practised if there is a certain direction of wiev in the office. In this case; tarnsparent shadowed and regularly dispersed illumination can be established in horizantal level.

In computerized offices, surely first precaution should be to choose matt screens. Subsidiary; to establish clear shadows, fixtures should be arranged to avoid luminance contradictions. Therefore; a kind of directional light without companionship of dispersed light is against human nature. Another precaution about disturbing luminance contradictions, can be choosing the tables with matt and medium dark laquared surfaces. The ceiling should be well illuminated with lighting fixtures and be matt white coloured “(Hedge 1989)”.

3.9. Act of Specific Plastic Materials: Plexiglas & PVC in Lighting

Many factors affect ambiance and lighting performance in a room. Apart from the shape of the room it is essentially the characteristics of equipment such as the materials used for the floor, walls and ceiling which determine how light is propagated within the room. The dimensions and positions of light-absorbing areas and also those which reflect light are essential factors that determine whether a room's illuminating properties are "good" or "bad". "Good" lighting means that the conditions are appropriate for the use to which the room is put. Obviously a meeting room needs a different set of lights from those of a administrative office or a waiting room.

Offices are places where people spend most of their days,so visual performance comes into prominence. That is why lighting must be designed technically for visual comfort in office applications. In this spesific part of the study, firstly our aim is to gather the ideal qualities for the office space from different samples.

Theoretically, every room can be structured to provide optimal lighting for its use. The shape and dimensions of the room are as important, when designing the lighting, as the choice and positioning of materials for the interior and other types of equipment. The sample work spaces – for an equitable comparison – must have some similar properties such as; function, approximate dimensions, type and material of lighting equipment.

In consideration with having similar properties; three offices were analyzed in next chapter. Then these will be criticised according to the parameters which will be listed to the end of the chapter.

3.9.1. Plastics in Contemporary Design

Before going on to the optical properties of plastics, it's necessary to briefly touch upon the history and introduction of it into the industrial and consumer society. The definition of the word plastic is to form something. With the Industrial Revolution came man's exploitation of natural resources and scientists in western civilization began to experiment with these resources and organic chemicals.

Plastics were invented in the last century, and until the middle of this century they were used only to imitate natural materials. Since that time, technology has brought polymers to a very sophisticated level of formal and structural evolution. Today's plastics are sturdy, resistant, and beautiful. They can take on many shapes, from the most straightforward to the most articulated. No form is absolute: mutant plastics can resemble translucent and transparent glass, they can be molded to match the organic shapes of parts of our body, they can be treated to look like folded, articulated plans.

The fabulously prolific family of plastics is represented in different objects, manufactured using a variety of techniques. Some of the most archaic processes, such as compression molding, are particularly suitable for objects made with recycled polymers. More sophisticated technologies, such as injection-molding--in which granules of raw material are conditioned by heat and pressure to reach a fluid state and then injected into a steel mold--are now frequently employed for the common polymers.

3.9.2. Plastics in Lighting Applications

Certain plastics are attractive materials for use in lighting applications because of their light weight, ease of handling and installation, high light transmission and better shatter resistance than glass. Greater freedom of design is another advantage that plastic has over glass: it frees the designer from the restriction of flat surfaces and permits curved or forms. Although plastic glazing is usually more costly initially than glass, repeated replacement of glass with break-resistant plastic glazing makes it more economical and safer.

Diffuse lighting is spread out, emanating from a large area of brightness, such as an overcast sky, an indirectly lighted ceiling, or large lighting fixtures with diffusing optics. Diffuse lighting can be either direct or indirect. It minimizes shadows and intense glare, which improves most office task visibility.

“I prefer to refer to use of artificial light as situational. The lamp lighting should be recognized and used simply, straightforwardly, speedily or, not. This is a contemporary, a sensible, artistic sense. No time for contemplation, psychology, symbolism, or mystery.” says Dan Flavin explaining his art of light “(Flavin 2000)”.

Fluorescent lamps, which are large light sources, create an inherently diffuse light distribution, which is very well-suited to office applications. A pool of diffuse lighting, such as from a decorative pendant or wall sconce, can create a pleasing local brightness. Note, however, that totally shadow-free, uniform lighting tends to be dull.

3.9.3. General Properties of Plastics

Optical Properties:

Both thermoplastics and thermosetting plastics may be highly transparent, opaque, or have any degree of clarity and light transmission. When no colorant has been used the amorphous plastics tend to be optically clear. The table below shows the study's specified materials in terms of luminous transmittance and therefore, optical clarity comparative with optical glass.

Table 3.6. Transmittance of optical glass, PMMA and PVC.
(Source: WEB_10, 2006)

Polymer Family	**Luminous transmittance of base polymer (%)**
Optical Glass	99.9
PMMA	92
PVC	76

Fire Behaviour:

Plastic materials are combustible or softened by heat. Recommended practices must be observed for safe design when these materials are used in glazing and lighting applications.

Impact Resistance:

As plastics have an impact resistance greater than glass, they are recommended for applications where resistance to shattering or vibration is required. Although some plastics have good impact resistance (Table 3.7.), they are not unbreakable.

Formability:

Plastics offer great possibilities for design. They are easily and economically formed in two and three dimensions to -edged pieces rather than the sharp fragments that may fly from a smashed glass window. Moreover, the light weight of the plastic imparts little momentum to the broken pieces so the injury hazard is greatly reduced "(Blaga 1978)".

Scientifically; transmitting and diffusing of a material are unattached properties. We can not say that amount of the light which is not transmitted means to be diffused or there is a direct proportion between them. While the light is penetrating through the material, there occurs a complex blend of surface reflections, internal scatter, and refraction which is rather concerned with its chemical structure.

Table 3.7. Typical properties* of plastic glazing materials compared with glass.

Glazing Material	Specific Gravity	Coeffient of Thermal Expansion 10-5/°C	Visible Light Transmission	Tensile Strength MPa	Impact Strength (notched specimen), J/M	Flexural Modulus GPa
PMMA (acrylic)	1.19	3.1	91-93	72	21-27	2.4-3.4
Polycarbonate	3.8	3.8	82-89	62-72	640-860	2.2-2.6
GRP**	1.40-1.60	3.4-4.4	76-85	76-117	430-1070	50-100
PVC**	1.30-1.40	5.0-10	76-89	38-62	13-64	2.60-3.7
Sheet glass (Soda-lime glass)	2.46-2.49	0.85	88-90	--	brittle	--

* As the materials produced by various manufacturers differ, these data should be regarded as guides only.

** Transparent and translucent glazing sheet containing 25-35 weight per cent of glass reinforcement in the form of chopped strand mat.Blaga 1978).

Figure 3.9. The use of PVC sheeting in operating room because of its hygienic property. (Source: WEB_2 2006)

3.10. Properties of Specific Plastic Materials: Plexiglas & PVC

"Acrylics" term refers to a family of plastics, the most important and widely used being poly methyl methacrylate (PMMA). PMMA sheet, one of the most weather-resistant plastics, produced worldwide under several proprietary names, e.g. lucite, plexiglas, perspex, and oroglas. Acrylic plastics used for light transmission applications are made by the cell casting process. With knowledge of physics that the optical properties will also be directly related to the structure of the basic polymer.

It is possible to measure the degree of light transmission using ASTM D-1003 (Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics), and this test method is used to evaluate light transmission and scattering of transparent plastics for a defined specimen thickness. As a general rule, light transmission percentages over 85 are considered to be 'transparent' (WEB_10 2006).

The surface reflections at the air/plastic interface create significant transmission losses. For example, PMMA's transmission loss is around 93%. These surface reflections can come from two basic causes: specular reflection, which is the normal reflection from a smooth surface, and diffuse reflection, which is dependent on the surface flatness of the sample. The transmission loss as a result of surface roughness or embedded particles is more often termed 'haze', and this is generally a production concern and not a property of the material. In producing blown film, haze can be caused either by melt fracture at the surface or by interfacial instability between the layers of the film. This complex blend of surface reflections, internal scatter, and refraction is shown in the diagram below:

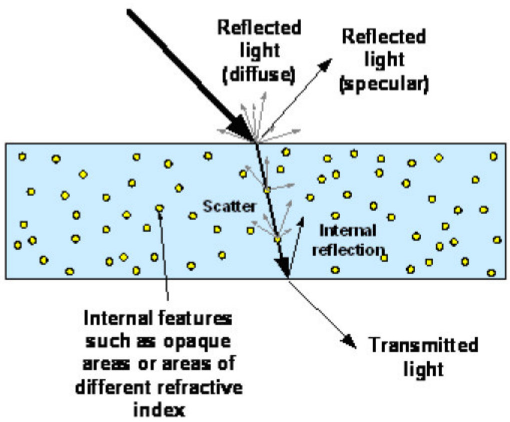


Figure 3.10. The complex blend of surface reflections, internal scatter and refraction. (Source: WEB_10 2006)

"If a light ray is reflected, refracted or absorbed during transmission then the amount of transmitted light and optical clarity will also decrease" (WEB_10 2006).

Also, the optical behavior of crystalline plastics is more complex because of the presence of the crystallites and their effect on the light. The density of the crystalline areas is a key factor in the optical clarity of crystalline plastics because the refractive index changes with the density of the material. Below there is a figure demonstrating the act of crystalline density. If the crystals are larger than the wavelength of the incident light (crystalline density is significantly different from the matrix), then the material will tend to be opaque.

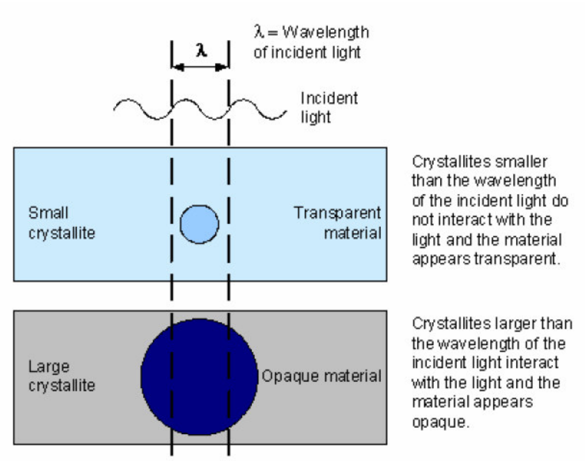


Figure 3.11. The importance of crystalline density wavelength of incident light.
(Source: WEB_10 2006)

Optical clarity of plastics is largely a function of the structure of the polymer. Despite this it is possible to modify the structure of polymers, specifically the fluoropolymers, by controlling the degree and type of crystallinity to produce highly transparent plastics even when they would normally be opaque (WEB_10 2006) .

3.10.1. Plexiglas

Acrylic resins were first prepared in 1931 for industrial coatings and laminated glass binders, the better known derivative of methacrylic acid, polymethyl methacrylate. PMMA and other acrylics have good resistance to many chemicals, including salt spray or corrosive atmospheres but are attacked by aromatic and chlorinated hydrocarbons, esters, ketones and ethers.

"It was not introduced until 1936 as a transparent sheet and in 1937 as a molding powder. Thus the beginning of the acrylic era and Plexiglas. Acrylic sheet played an important role in World War II as bullet resistant glazing in warplanes. It was found to be light and very strong and could be easily formed to fit into the structural designs. Plexiglas soon found its way into homes and factories for safety glazing, electrical and chemical applications, skylights and windscreens and hundreds of other beneficial applications" (WEB_8 2006).

Acrylic offers high light transmittance and strength, can be easily heat-formed without loss of optical clarity that is why it's commonly used on commercial purpose in many ways.

Figure 3.12. The use of plexiglas in outdoor lighting.
(Source: WEB_5 2005)

PMMA is used for glazing in industrial plants, schools and other institutional buildings where high breakage rate ,usually caused by vandalism, makes use of glass costly "(McCarthy 1965)" .

PMMA given the name; Plexiglas is rather frequently used in lighting. Plexiglas can be built into ceilings and overhangs by installing panels of white translucent types below fluorescent lamps. The Plexiglas panels rest on the projecting edges of the wood moldings or metal framing.

3.10.2. PolyvInyl Chloride (PVC)

PVC is the most economical of plastics. Vacuum forming of vinyl sheeting adds to the variety of applications, e.g., industrial glazing and textured light diffusers. Its commercial value results from these characteristics:

1. Basic properties: chemically inert; water, corrosion and weather resistant; high strength-to-weight ratio; tough, dent-resistant; an electrical and thermal insulator; and maintains properties over long periods of time.

2. Process versatility; can be made in different form to permit processing on a wide variety of equipment; each form can be altered further by compounding to achieve particular properties in end products which range from soft to rigid in nature.

3. Properties can be provided at an economic cost. In the long term, PVC products are less energy-intensive on an installed basis than most conventional materials. Their light weight, insulating-and maintenance-free characteristics contribute to conservation of energy over the life of the product.

For the three important particle properties of PVC; molecular weight, size, configuration; causes it to be produced in various types, in many kind of applications (WEB_1 2006).

PVC is a thermally sensitive thermoplastic. Certain compounding ingredients must be added to the resin to permit it to be converted to an end product. Such ingredients are required for both processing and performance. Plasticizer is the major additive in a PVC compound (or formulation) since it imparts workability, flexibility, extensibility and resilience to a polymer system.

PVC liner materials are produced in roll form in various widths and thicknesses. PVC compounds contain 25% to 35% of one or more plasticizers to make the sheeting flexible and rubberlike. Plasticized PVC sheeting has good tensile, elongation and puncture and abrasion resistance properties (WEB_1 2006).

3.10.3. Some of PVC Sheeting Properties

Informative explanations about the specific material; *PVC sheeting* is essential for a complete comprehension of study. PVC sheeting fabric is a product developed by a producer in stretch ceiling systems field. Its transmission was found to be 73,5% as demonstrated in the photometric measurements (LSC 8233) attached in the appendix. It can be custom tailored to fit any space, and is thus useful for architects, designers and contractors. Some of the benefits of PVC sheeting are: lightweight, meets flame spread method (BS 476), European Regulations for hygienic cladding applications, high resistance to many chemical properties, shock resistant properties, can be easily fabricated with conventional tools, vacuum or thermo formable, accommodating with most fixing systems, printable. (WEB_2 2005)

Figure 3.13. Streching application of PVC.

3.11. Diffusion and Measurement of Materials

Below, there is a schematic explanation of computer simulated program's basic working principle for measuring diffusion of glazing materials called "Light Diffusing Power".

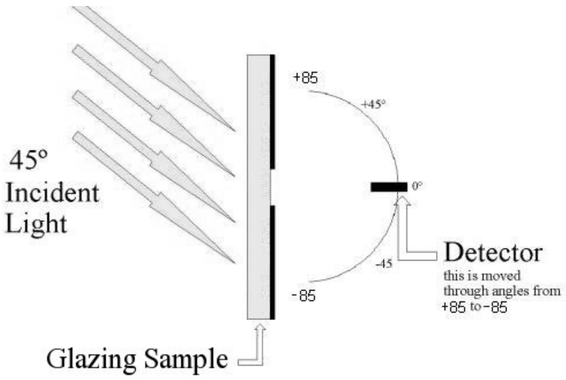


Figure 3.14. "ldp" experimental setup graphic.
(Source: WEB_11 2006)

The renderings below show the daylight pattern for different glazing.

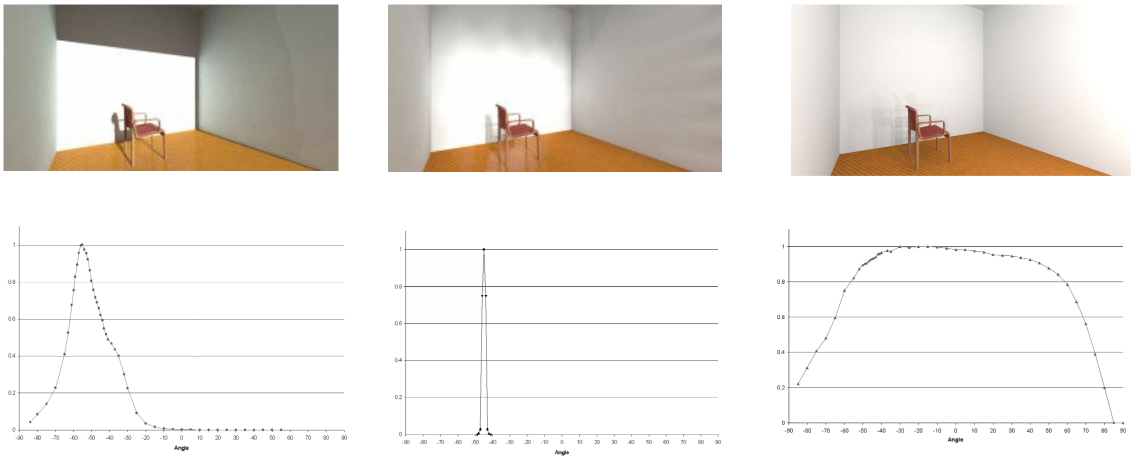


Figure 3.15.. “ldp” graph and renderings.
(Source: WEB_11 2006)

The images above show computer simulations of daylight patterns in a very simple space, when glazing with various light diffusion power. Light diffusing glazings are powerful elements for designers who wish to bring high quality natural light into interior spaces. Translucent glazings vary greatly in their ability to diffuse light, and selecting the right glazing can be critical to the success of a project. However there is no simple rating system that allows a designer to simply compare the performance of light diffusing glazing at a glance. Full characterization of a translucent glazing results in a large multidimensional set of data that is too complicated for anything but an optics expert or a computer simulation program. On the other hand, simple numbers like ASTM’s ‘haze’ are not designed for this purpose and cannot differentiate between common glazing with very different light diffusing abilities.

There is a brief explanation about how this system measures;

“The glazing sample is illuminated by a quartz halogen spotlight, at an incidence of 45 degrees. A light meter measures the radiant intensity leaving the aperture in the mask that covers the back of the sample. The measurement is repeated over a range of angles from -85 to +85 and the results are recorded. (Measurements at exactly 90° not physically possible)” (WEB_11 2006).

Below, there is a chart expressing the results of transmission performance, experienced with Plexiglas and Barrisol. (Officially registered trademark of PVC translucent sample used in experiment)

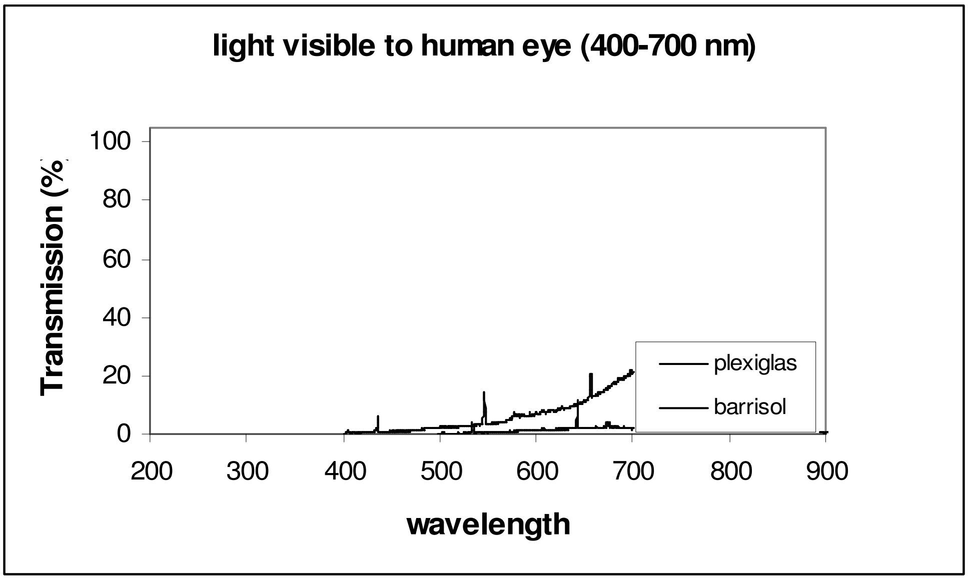


Figure 3.16. The transmission graphic of plexiglas and Barrisol.

3.12. Assessment of Sample Offices in Consideration with Use of Plexiglas and PVC Sheeting Materials in Lighting

With the growing amount of economic related competitive conditions bringing long office work hours causes diseaes It is an obligation to pay some attention into lighting considerations, both for possible factors and an examination of what is appropriate for each individual task. Negative effects of glare and poor or inefficient lighting is an important matter for loss of productivity. At the end of this evaluation; considering the arguement on energy saving, employers and governers could direct their consumption of electricity with an extra help to reduce worker fatigue, improving productivity.

In consideration with having similar properties; three offices are analyzed in this part of the chapter. In these three of offices chosen, there is a unique space for both management and meeting functions in a room, receiving daylight only from one side. Technical illumination fixtures differ in some ways but PVC sheeting is used commonly in various shapes in these sample workspaces. First their dimensions, wall-floor-ceiling covering materials etc. physical properties will be described, supported by their schematic plans and interior photos. Then they will be criticised according to the data explained in previous chapters.

The combination of following three lighting types were used for these offices in this phase of study: task lighting with "table lamps", general lighting with both ceiling-mounted and streched pvc sheeting luminaires, lighting with two components; ceiling luminaires and table lamps.

Following lighting systems are suggested to be the proper verification of the solution in terms of ideal office lighting system:

- General lighting from ceiling-mounted luminaires with maximum 200 cd/m2 luminance to avoid glare at VDT, with an indirect component; semi-direct lighting.
- Workplace-oriented lighting with features to avoid reflected glare and increase the contrast efficiency.
- Indirect lighting which accomodates general lighting with task lighting which accomodates direct lighting.

Before examining the samples, below there is a review of needed qualities of light for specific office functions.

Table 3.8 Necessary values of bulbs for office functions.
(Source: Sirel 2001)

OFFICES	LUX	COLOUR TEMPERATURE	COLOUR RENDERING
General Working Areas	500	3300º K - 5000º K	70 - 84
Open-Plan Offices	750	3300º K - 5000º K	71 - 84
Drawing Offices	1000	3300º K - 5000º K	85 - 100 / 72 - 84
Project Rooms	750	3300º K - 5000º K	70 - 84
Accounting Rooms	500	3300º K - 5000º K	70 - 84
Computer Rooms	500	3300º K - 5000º K	70 - 84
Administration & Manager Rooms	250	3300º K - 5000º K	70 - 84
Waiting Rooms	150	3300º K - 5000º K	70 - 84
Meeting & Conference Rooms	200	3300º K - 5000º K	70 - 84

According to the quantity of light; illumination level must be 500 lux in cellular offices, 750 lux in open offices. Also considering the quality of light; colour temperature must be 4000º K, colour rendering index (CRI) must be 80, ideally. If the same kind of labour is performed in a place, light has to be regularly dispersed. Lastly lighting system has to be economic, accomodate with the architecture and structure.

OPET MANAGEMENT & MEETING OFFICE:

This sample work area is an office in a building, one side surrounded by reflective windows. Amount of daylıght is controlled by them. This office has a rectangular form and has 9.50 m. length, 5.00 m. width, 2.40 m. Height as shown in Figure 3.19.. The room is seperated into two functions with a plaster board wall.

The office's floor is coated with white epoxy (A kind of chemical resin), walls are covered with textured white wallpaper and ceiling is coated with plaster. The workspace is mostly in white colour, furnishing is white laquered too.

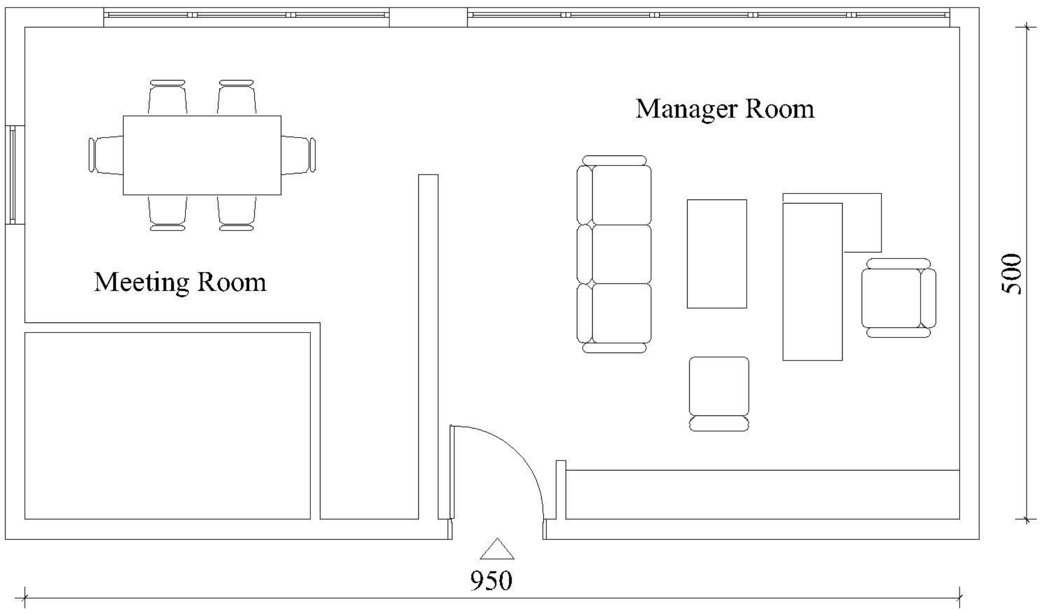


Figure 3.17. Plan of Opet office.

Figure 3.18. View of Opet Office management part.

Through the long side of office, near window, ceiling height is lowered to 2.18 m. in order to recess flourescent lamps which would illuminate PVC based transparent three striped sheeting.

Figure 3.19. View of Opet Office meeting part.

On the other side; halogen and par spot lamps are recessed into the ceiling. By this way, as the space is divided into two functions, it becomes also divided by lighting although that part serves for the function; meeting. This lighting disorder also breaks homogenious effect of PVC sheeting.

It would be correct if three striped PVC sheetings's axial have catched the table's. This situation would also avoid the coincidence of sunlight and artificial lighting coming from the windows.

As one side of the office is covered with reflective glazing window; it frees the interior from glare effects of direct sun beams. But both flor and furniture is coated with white lacquered, it will seem glossy arising reflecting and glare. In the meeting part, three stripe translucent PVC sheeting helps to build up general lighting.

Besides; on the other side of the ceiling; there is recessed spotlights which can help to put forward the average of general lighting.

As seen in the Figure 3.19.; PVC sheeting material offers a uniformly dispersed light giving a smooth ambience. Partial use of PVC sheeting can give a chance to replace it with Plexiglas which could also help to establish o proper level of general lighting.

ADNAN KILICOGLU OFFICE:

This sample work area is an office in an apartment, again long side of the room is covered by reflective windows. This office has a 8.50 m. length, 6.50 m. width, 2.27 m. height. The room is not seperated into functions with an architectural component; all meeting, administrative and waiting functions take place in the room freely as shown in following Figures; 3.20., 3.21., 3.22.

Figure 3.20. Plan of Adnan Kilicoglu Office.

The office's floor is coated with natural stone (honned travertine), walls are mostly covered with dark wood plated and ceiling is coated with plaster. The workspace is mostly in white and soft-bright coloured. Furnishing is dark wood plated too.

In this sample, apart from the previous one, a more complicated plan is set. In open offices; a lighting system has to be arranged accomodated with ceiling's structure, in the same time considering needed illumination levels (200lx above circulation areas, 500lx above work planes) for certain functions.

There are two kinds of PVC sheeting; one is translucent, the other opaque lacquered types are used. First criticism for this lighting scheme is the misuse of materials. Because the translucent one is used over the circulation areas; where an average of illumination level could be enough. But rather important part; over the meeting end of the table; Brown opaque sheeting makes the ambience dull and poor in lighting as shown in Figure 3.22

Besides; daylight strikes onto the table from left side. This situation probably will create sharp shadows disturbing the observer's visual comfort during viewing a drawing or going through a text. Also brown, opaque, lacquered PVC is directly illuminated that can cause deceptive effects on workplane.

Figure 3.21. View from Adnan Kilicoglu Office entrance.

Figure 3.22. Another view from entrance of Adnan Kilicoglu Office.

Against these fundamental rules there is an illusive confusion with the use of circular PVC sheeting above the entrance of room; as if it was the most important part of space. It is appropriate not to use lighting fixture in the vicinity of windows. Also it is positive that there is not excessive illumination level, but for pointing human perception there is a lack of task lighting above the end of meeting part of the table.

H. ZEKI SUNGUR OFFICE:

This sample work area is an office located in the first two floors of an apartment, windows take place by the short side of room. This office has a 9.05 m. length, 4.20 m. width, 2.35 m. height. The room is seperated into two functions; meeting and management with a folding transparent door embedded in wall.

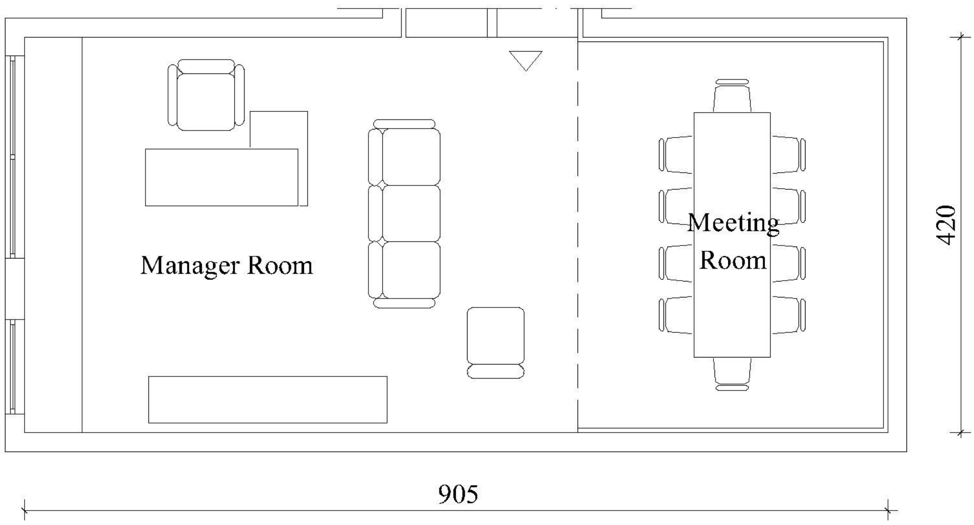


Figure 3.23. Plan of H. Zeki Sungur Office.

The office's floor is coated with gray carpet, walls of the meeting part are covered with matt-black laquered wood, walls and ceiling of management part is coated with white plaster. The workspace is mostly in white and black coloured. Furnishing is matt-black laquered too. Apart from the former systems, local lighting was aimed in certain areas. This sample has better characteristics because of lighting's concentrated and functional property.

This lighting system consists of; PVC sheeting streched on a special construction in ceiling and fluorescent armatures embedded inside. By the help of system, a constant and homogeneous dispersed level of illumination was obtained. Also system avoided glare effect that coul probably appear on VDT which disturbs presentation work.

Figure 3.24. Meeting view from H. Zeki Sungur Office.

Figure 3.25. Management view from H. Zeki Sungur Office.

Lighting fixtures embedded under the transparent PVC sheeting were arranged modularly with TL-5, electronic ballasted, dimmable, high radiation efficient (96 lumen/lux) armatures paying regard to those principles mentioned at the beginning.

Whole ceiling of meeting part is covered with Barrisol that will give absolute transparent and smooth shadow shown in Figure 3.26 Besides, the proper choice of placement and meeting part's wall matt veneer keeps the space away from probable reflecting and glare.

Figure 3.26. Whole ceiling is covered with translucent Barrisol above meeting part of H. Zeki Sungur Office

However there's no chance to replace Barrisol with Plexiglas theoretically since this situation requires construction, using Plexiglas on a such wide surface, wouldn't be eligible. Especially, considering the low height of the ceiling, use of Plexiglas with a high percentage of transmission can cause disturbing glare and deteriorate the viewer's perception.

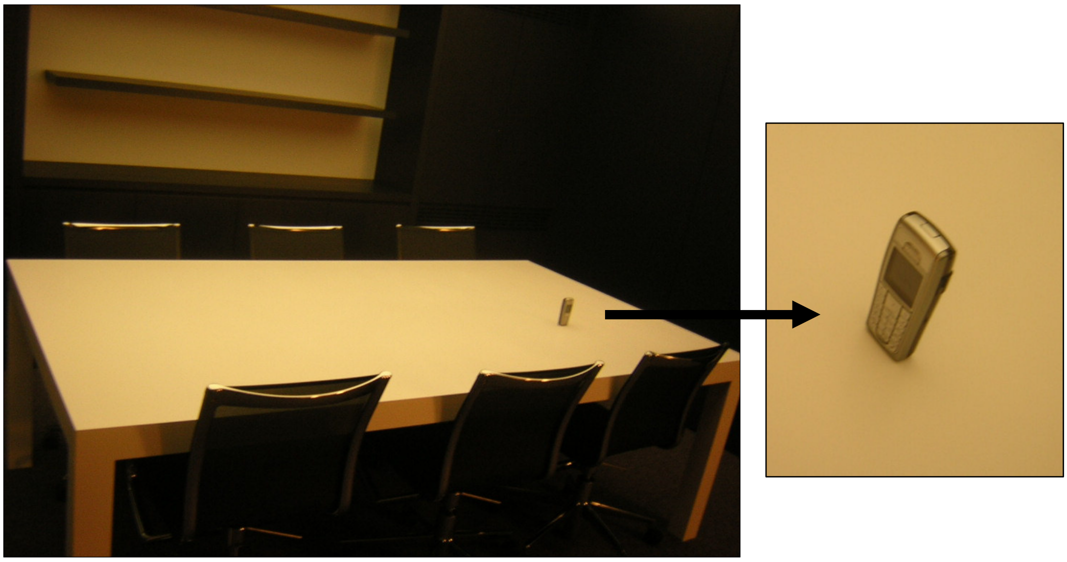


Figure 3.27. Almost there is no shadow of a mobile phone put on the workplane.

As mentioned in the lighting quality issue before, transparent shadow is not so desirable. That is why shadow of the mobile phone put on the semi-matt, white table as shown in figure 3.27 it seems like it does not have three dimension. This is obviously because of the overspread light over the meeting space.

Light coming from the embedded fluorescent source ; itself has a distributive property. By the help of translucent material; Barrisol, light almost totally loses its directional structure which is a qualitative property.

There is a dimmable construction and when it is used in highest level, visual perception becomes virtually impossibl because of highly dispersed light level and glare both coming from ceiling and reflecting from the table's surface. This is not desirable for an ideal perception.

CHAPTER 4

CONCLUSION

Because of its quality, lighting has positive effects on human visual performance, activation, work performance and well-being. Lighting should be designed in a way as to fulfill its qualitative goals and to accomplish the identified space with harmony. The lighting of work-areas effect on the health and well-being of those who work there, verifying that; ideal lighting of work-areas would diminish human fatigue.

The work-area lighting must be recognised without difficulty of visual environment. It should bring the feeling of willingness and activation, avoiding visual fatigue. The matter of visual performance becomes the central concern for the lighting of work-areas.

Artificial lighting has effects on human health and well-being. These are determined by the lighting types. Evaluation of lighting can not be decided by only the properties of the artificial lighting installation, but rather by a number of different factors, such as the optical properties of the environment objects or the optical properties of the fixture and furniture (reflectance, glare of surfaces, etc.)

There has to be a preference about the general lighting of the workplaces, an even lighting, which would creat nearly the same visual conditions at all parts of the work area. General lighting has to be implemented, this is a rule. A workplace oriented form of general lighting is accepted to be appropriate in such situations where different areas of the room are planned for performing different tasks which also differ in their demands.

The major factor of uniform light influence is not the type of lamp used in an installation but the type of lighting selected for a particular environment.

IES / CIBSE / CIE recommendation specifies parameters providing physical comfort. These specifications are involved with measurable quantities. Such as; transmission, reflectance, size, density ... etc.

There are computer aided simulations for measuring the optical properties of translucent materials mentioned in the previous chapter. Also we must consider 'Psychological parameters' that are not calculable with physical measurement devices. But its existence is explored by various studies and affects individuals' impressions. These effects that can be defined as 'Psychological comfort parameters' which are essential for creating more efficient workplaces.

The results of this test research suggests that; transmission percentage of plexiglas sample is higher than Barrisol. Referencing chapter 3, " The transmission loss as a result of surface roughness or embedded particles is more often termed 'haze', and this is generally a production concern and not a property of the material" relying on this statement; hazes scatter the light in diffrent ways which causes the loss of transmittance. But we can not say that amount of the light which is not transmitted means to be scattered or there is a direct proportion between them "(Sirel, Osman)". It seems that, this issue is rather about their chemical content.

Not the aim, nor the conclusion of this study is to prove dominance of one material to the other. But we can only put a comment upon its' eligibility, since plexiglas has a higher performance in transmission and barrisol in diffusion. In other words; according to this conclusion; one of the two similar material used in office lighting appliances; Barrisol would be more appropriate for office ligthing.

However there are some properties that we can not fix because of two reasons. Firstly because they are not measurable, secondly variable parameters that are personal. So we can not take them as a scientific input data. It is not about a constant judgement, since one can find the ambience relieving that the other defined as dull.

Also there is another important limitation for a complete scientific and objective judgement. We must not forget that; this result is only valid for the chosen two samples, so that we can only comment upon these ones excluding the other types that can be used for lighting. During the search, I could only gather a little bit information to satisfy my work from the comprehensive plastic field, leading me to the chemistry, where it is out of this study's restriction.

We have no doubt; optical plastics are a growing market and the unique properties of the fluoropolymers means that they will play an increasingly critical role in a range of emerging technologies.

Improvement in lighting quality can give high benefit for business era. By providing accurate levels of light and reducing glare would gain worker productivity. Although the energy cost for lighting is significant, it becomes almost negligible when compared with the labour cost. Therefore, these earnings in productivity may be even more worthy than the energy consumption savings put together with improved lighting technologies. In office spaces, comfortable and spacious lighting design can redound businness capability.

In lighting matter; three quality parameters; glare, uniform illuminance, color rendering qualities are discussed around.

Probably the most important determinant when compared with other qualities is obviously glare. Glare is a perception arised by luminance levels in the visual field of human that are too bright and this may cause annoyance, discomfort or reduce productivity.

An object does not cause glare alone, but if it's bright and in front of a dark ground colour, it will. Contrast is the relationship between the luminance of an object and its background. **Visual task generally becomes easier with increased contrast, too much contrast causes glare and makes the visual task much more difficult. Increasing contrast usually improves visual comfort, but too much contrast deteriorates perception, so there is a tender adjustment.**

In order to reduce glare, there are two restrictions; not passing over the recommended illuminance levels and using the proper equipment with fixture. Proper fixture placement would probably reduce reflected glare on work surfaces or computer screens.

The uniformity of illuminance means homogenous spread light over a definite task area. Even average illuminance of the room is suitable, proper fixture with reflectors must be placed. Lack of illuminance uniformity brings deficient light levels in some parts. Especially during tasks that require changing levels, if there is not a uniform lighting, poor lighting will be disturbing.

REFERENCES

American National Standards Inst., 1975. *"American National Standard Safety Performance Specifications and Methods of Test for Safety Glazing Materials Used in Buildings,,* (American National Standards Inst., Inc., New York), p. 97.

Ayverdi, Aligül. *"Mimari Aydınlatma"*, (İ.T.Ü. Mimarlık Fakültesi) p.3,6,8

Blaga, A., 1978. *"Use of plastics in solar energy applications"*(Solar Energy), Vol. 21, 331.

D. E. McCarthy, 1965. "*The Reflection and Transmission of Infrared Materials: IV, Bibliography"*, (Appl. Opt. 4) p.507

E. Carlson, Sylvia and Verne, 1991. "*Professional Lighting Handbook"*, (Focal Press, Boston, London) p. 6,7

Flavin, Dan., 2000. *"The Architecture and Light",* (The Solomon R. Guggenheim Foundation, New York) p. 87

Hascher, Rainer, Jeska, Simone, Klauck, Birgit, 2002. *"A Design Manual Office Buildings"*, (Birkhauser Publishers, Medialis, Berlin) p. 58

Hedge, Alan, Ph D, 1989. "*Lighting the Computerized Office-A Comprehensive Field Study of a lenses-Indirect Uplighting System and a Parabolic Downlighting System"*, (Cornell University, Oct. 1989)

Illuminating Engineering Society, 1991. "*An Introduction to Light and Lighting"*, (ED-50-Published by IESNA)

Illuminating Engineering Society, 1981. "*Office Lighting"*, (RP-1-Published by IESNA)

Jankowski, Wanda, 1997 "Creative Lighting", (St. Martin's Press, New York) p.1

Katz, Kohn, 2002. *"Office Buildings"*, (John Wiley and Sons, USA) p.44,45,74,75

Kutlu, H. Gökhan. *"The Peculiarities of Light as a Quality in Architecture",* Sep. 2000 Master of Arch. Ar.

Manav, B. *'Ofislerde Aydınlık Düzeyi, Parıltı Farkı ve Renk Sıcaklığının Görsel Konfor Koşullarına Etkisi: Bir Model Çalışması'*, Mayıs 2005, İTÜ Fen Bilimleri Enstitüsü, Doktora Tezi, İstanbul.

Manav, B., 1999. "*An Experimental Study on the Appraisal of the Visual Environment at Offices in Relation to Colour Temperature and Illuminance"*, 5th International Lighting Conference, published on Architectural Science Review , March 1999

N. Kay, Gersil, 1999. *"Fiber Optics in Architectural Lighting Methods and Applications"*, (Mc Graw – Hill Companies, USA) p.61-73, 251-257

Zelanski, Paul and Fisher, Mary Pat 1995. *"Shaping Space"*, (Harcourt Brace College Publishers, USA) p.136-150

Robertson, A. S. et al, 1989. *"Building Sickness, Are Symptoms Related to the Office Lighting?"*, (Annual Hygiene – V33. No 1) p.47-59

Sirel, Şazi, 1991. *YFU Yapı Fiziği Uzmanlık Uygulamaları Yayınları*, Vefabayırı Sok. No:38, Gayrettepe, İstanbul Yayın no: 4, 6, 7, 8

Sirel, Şazi,. *"Aydınlatma",* Lighting Design Türkiye, 2005, Sayı 6, p.60.

Sirel, Şazi,. *"Aydınlatmanın Geçmişi",* Lighting Design Türkiye, 2006, Sayı 7, p.64.

Sirel, Şazi,. *"Bürolarda Aydınlatma",* Tasarım, 2001, Sayı 49, p.107.

Sirel, Şazi, 1997. *"Aydınlatma Sözlüğü"*, (YEM Yayın, İstanbul)

Taşpınar, Adnan Selçuk, 1977. *"Mimaride Günışığı"*, (ODTÜ Mim. Fak. Basım İşliği, Ankara) p.19-22.

WEB_1, 2000. WhatIsPVC, 10/12/2006. http://www.geomembrane.com

WEB_2, 1999. microsorber. 12/12/2005. http://www.barrisol.co.uk

WEB_3, 2005. Types of Lighting. 20/10/2005. http://www.erco.com

WEB_4, 1995. Testing the hypothesis on the positive impact of lighting on human performance and health, 11/09/2005. http://www.healthylight.de

WEB_5, 2004. Dinamik Aydınlatma. 08/09/2005. http://www.lighting.philips.com/tr

WEB_6, 2004. Glossary, 12/12/2004. http://www.schorsch.com

WEB_7, 2006. Optical Properties of Plastics, 12/09/2006. http://engr.bd.psu.edu/pkoch/plasticdesign/optical.htm

WEB_8, 2006. Brief History of Plastics, 02/10/2006. http://www.ridoutplastics.com/briefhisofpl.html

WEB_9, 2006. Light & Health, 22/8/2006. http://www.lrc.rpi.edu/programs/lightHealth/

WEB_10, 2006. Optical Clarity, 01/11/2006. http://www.zeusinc.com/

WEB_11, 2006. Light Diffusing Power, 24/08/2006.
http://www.advancedglazings.com/ldp/

Yücetaş (Manav), B. "*Effects of Different Lighting Arrangements on Space Perception*", Yüksek Lisans Tezi, Haziran 1997, G.S.T.M.F Bilkent Üniversitesi, Ankara.

APPENDIX A

GLOSSARY

Accommodation: The process by which the eye changes focus from one distance to another.

Ambient light: general lighting in an area. It can come from artificial or natural sources.

American National Standards Institute (ANSI): consensus organization that coordinates voluntary standards for the physical, electrical, and performance characteristics of lamps, ballasts, luminaires, and other lighting and electrical equipment.

American Society for Testing ınstitute (ASTM)

Balast: auxiliary piece of equipment designed to start properly control the flow power to gas discharge light sources such as fluorescent and high intensity discharge (HID) lamps. This is also called control gear or transformer.

High frequency electronic ballasts run the lamp at frequencies between 20 and 40 kHz and:

- Consume up to 30% less circuit power than a wire wound balast for a given light output.
- Are lighter in weight than their wire wound equivalents.
- Are silent in operation
- Lamps start at the first attempt without annoying flashing.
- Lamps last longer.
- The quality of light is improved with the elimination of flicker and stroboscopic effects.
- There is automatic switch off at the end of life, eliminating any lamp flashing.
- The lamp can often be operated at less than its nominal voltage.
- Lamps are overvoltage protected.

Note: Protected against harmonic effects caused by electronic ballasts must be taken.

Brightness: The subjective description of **luminance**. A perceived characteristics of objects which does not vary directly in a simple mathematical relationship with their physical or measured brightness, which is corretly termed their **luminance**.

The term brightness is often misused to mean *luminance*. If so, it should be qualified as "measured" brightness, to distinguish between the absolute attributes ("measured" brightness) and the perceived attributes ("apparent" of "subjective" brightness) of the object in question.

Candela (CD): intenational unit (SI) of luminous intensity. Sometimes the older term candlepower is used to describe the relative intensity of a source.

Color temperature (chromaticity): scientific measurement of the balance of wavelengths making up any “white” light. The unit of measurement is Kelvin, abbreviated K. A high color temperature means a cooler, bluer source. Incandescents are 2800 K (warm); halogens are 3500 K (neutral white, flattering to skin tones); and metal halides are 4000 K (clear white). Metal halides are also available in 3000 K; noon sunlight is 5000 K; an overcast sky is 7000 K.

Color Rendering Index (CRI) General Color Rendering Index: A method for describing the effect of a light source on the color appearance of objects, compared to a reference source of the same *color temperature* (CCT). It serves as a quality distinction between light sources emitting light of the same color (*metamer*). The highest CRI attainable is 100. Typical cool white fluorescent lamps have a CRI of 62. Lamps having rare-earth phosphors are available with a CRI of 80 and above. In a *daylighting* context, the color rendering index defines the spectral transmissive quality of glasses or other transparent materials. In this case, values of 95 or better are considered acceptable.

The general color rendering index: R_a is a measure of the average appearance of eight standardized colors chosen to be of intermediate saturation and spread throughout the range of hues. If a color rendering index is not qualified as to the color samples used, R_a is assumed.

Contrast (Luminance Contrast): is the relationship between the *luminance* of a brighter area of interest and that of an adjacent darker area.

Cost of light: determined primarily by the cost of the electricity used to power the lamp. In the United States, 80 to 88% of the cost of the light is Money spent on electricity. Labor)8%) and cost of the lamp (4%) make up the balance of 100%. While the purchase price of energy efficient systems may be higher than conventional ones, the rapid payback more than makes up for the initial outlay.

Daylight: encompasses all natural *light* that is available during the day and originates from the radiation of the sun in the visible spectrum.

Daylighting:

1.Bringing the sun's rays into a building via glass, fiber optics or light pipe.

2.Augmenting natural daylight with artificial light, usually by automatically switching the latter on when a certain low level of sunlight is reached

Dichroic lamp: type of light source in which heat, normally produced by light, is directed backward, away from the path of the light, where it can be dissipated by a fan or natural ventilation.

Direct Lighting: Lighting provided from a source without reflection from other surfaces. In daylighting, this means that the light has travelled on a straight path from the sky (or the sun) to the point of interest. In electrical lighting it usually describes an installation of ceiling mounted or suspended luminaires with mostly downward light distribution characteristics.

Direct/Indirect Lighting: Lighting that is mixed from direct sources and indirect reflection. In daylighting this means that some part of the light of the sky or the sun is bounced off some surface, while at least part of the sky is still visible from the point in question. In electrical lighting, it says that luminaires of different types are installed, or there are luminaires that emit light both up to the ceiling and down to the workspace.

Directional lamp: lighting aimed at an area or object to accomplish a tas kor to highlight.

Discharge lamp: one whose illumination is produced by an electrical discharge through a gas, a metal, a vapor, or a mixture of gases and vapors.

Fluorescent lamp: one in which electric discharge of ultraviolet energy excites a fluorescing coating (phosphor) and transforms some of that energy into visible light. This requires a transformer/balast.

Halogen lamp: short for tungsten halogen lamp. These are high-pressure incandescent lamps containing halogen gases, such as iodine or bromine, which allow the filaments to be operated at higher temperatures and higher efficacies. A high-temperature chemical reaction involving tungsten and the halogen gas recycles evaporated particles of tungsten back onto the filament surface.

High-intensity discharge lamps (HID): general term for mercury, metal Halide, and high-pressure sodium lamps. HID lamps contain compact arc tubes that enclose various gases and metal salts operating at relatively high pressures and temperatures. These lamps require a transformer for the operating voltage.

Illuminance: density of light (lumens/area) incident on a surface. The amount of light arriving on a surface is illuminance. It is measured in lumens per square meter, usually referred to as lux.

Illuminance (usually 'E' in formulas) is the total amount of visible light illuminating (incident upon) a point on a surface from all directions above the surface. This "surface" can be a physical surface or an imaginary plane. Therefore illuminance is equivalent to *irradiance* weighted with the response curve of the human eye. Standard unit for illuminance is **Lux (lx)** which is lumens per square meter (lm/m^2).

Incandescent lamp: one that provides light when a filament is heated to incandescence by an electric current. It is the oldest form of electric lighting technology. It does not require a transformer.

Kelvin (K): a unit of measurement of color temperature.

Kilowatt (kW) : watts x 1000 = kilowatts

Light: radiant energy capable of producing a visual sensation in human observer.(also called **Nits** in the USA, from latin "nitere" = "to shine").

Light:

1.The natural agent that stimulates the sense of sight.

2.Medium or condition of space in which sight is possible.

The Concise Oxford English Dictionary Fifth Edition, 1964 (noun)

Radiant energy that excites the human visual system. The visible portion of the electromagnetic spectrum extends from about 380 to 770 nm.

Also (colloc.), a source of illumination such as the sun, the sky or an electric lamp.

Lighting Design: The art and craft of creating the visual environment by means of illuminating it. There are two general fields of lighting design:

Daylighting: This means all measures that influence the input and use of natural *daylight*, be it the diffuse light off the *clear or overcast sky* or the directed light of the sun, into built spaces. Daylighting is influenced by the general structure of a building, the design of facades, windows and skylights, and can be further extended by the use of special devices for redirecting or transporting light.

Electrical lighting: This is sometimes a misnomer, as it ignores the many cities that are still illuminated by gas lamps. Generally speaking it covers all measures to illuminate spaces inside and outside of buildings with the help of technical light sources, either in combination with or in absence of natural daylight.

Lumen: basic unit of measurement for light. This is the quantity of light energy per unit time arriving, leaving, or going through a surface.

The unit of luminous flux is the lumen (lm).

Luminaire: conventioanlly, a light fixture with one or more lamps and housing. It controls the distribution of light from a lamp and includes all the components.

Luminance or brightness: luminace is a measurable quantity, whereas brightness is a subjective sensation.

1.The human eye does not see the light arriving, but the light reflected from an object, which is called its brightness or luminance.

2.It is usually expressed in candles per square inch or lamberts or foot lamberts.

3.Luminance of a surface is equal to luminance x reflectance. In metric, it is measured in candelas per square meter, abbreviated to cd/m². Before the modern term candela, the luminous intensity, or strength of light in a given direction, had the older term canle-power.

Luminous flux density: is photometrically weighted *radiant flux density*, which means *luminous flux* per unit area at a point on a surface where the surface can be real or imaginary. An imaginary surface can for example be used to measure or calculate illuminance anywhere in space, maybe to determine the daylight factor on the workplane.

Lux: SI (International Sysytem) unit of illumination, which is 1 luman uniformly distributed over an area of 1 square meter.

Metal Halide lamp: high-intensity discharge light source in which the light is produced by teh radiation from mercury, together with halides of metals such as sodium and scandium.

Perception: A meaningful impression obtained through the senses and apprehended by the mind. Perception goes beyond plain *sensation* in that it includes the results of further processing of the sensed stimuli, either conceously or inconceously.

Photometry: a system developed to measure light, taking into account the psychophysical aspects of the human eye/brain system. I takes accurate measurements of the distribution of light within the scene.

Photometric brightness: is an old and deprecated term for luminance. The physical measure of *brightness*. *Luminous intensity* per unit projected area of any surface, as measured from a specific direction.

Photometry: Photometry is the science of measuring visible light in units that are weighted according to the sensitivity of the human eye.

Sunlight: is the part of daylight that is radiated directly from the sun to the area of interest.

Task (or local) lighting: lighting design to illuminate a task area.

Transmittance: is the ratio of the total radiant or luminous flux transmitted by a transparent object to the incident flux, usually given for normal incidence.

Transmissivity: The ratio of the directly transmitted light after passing through one unit of a participating medium (atmosphere, dust, fog) to the amount of light that would have passed the same distance through a vacuum. It is the amount of light that remains after the *absorption coefficient* and the *scattering coefficient* (together the *extinction coefficient*) are accounted for.

Ultraviolet (UV) radiation: radiant energy in the range of abaout 100 to 380 nanaometers (nm).

Watts: amaount of power in. Lumen = amount of power out.

Wavelength: scientific term for the color of the light travelling in the fiber.

In lighting, the basic measure for the amount of light produced by a light source is called a lumen.

Standard unit of luminance is candela per square meter (cd/m2).

APPENDIX B

TEST RESULTS

LIGHTING SCIENCES CANADA LTD.
440 Phillip St., Unit 19, Waterloo, Ont., Canada N2L 5R9
Tel: (519) 746-3140 Fax:(519) 746-3156

Test Report No. LSC 8233

Transmission/Distribution of Translucent Panel #4013
For Barrisol Stretch Ceilings

The transmission of the translucent panel measured was found to be 73.5% as demonstrated by the following two photometric measurements (LSC 8233A and LSC 8233B). These measurements also indicate the very smooth diffusion of the original fixtures distribution through the translucent panel.

Prepared For: Barrisol Stretch Ceilings
Plafonds Tendus Quebec
Thetford Mines, Quebec

Date: May 12, 2000

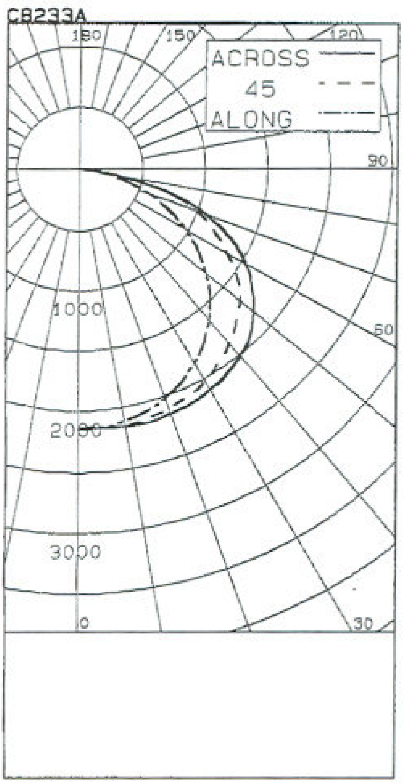
Prepared By: Charles Sisson

Reviewed By: K. F. Lin, Ph.D., MIES

LIGHTING SCIENCES CANADA LTD.
440 Phillip St., Unit 19, Waterloo, Ont., Canada N2L 5R9
Tel: (519) 746-3140 Fax:(519) 746-3156

CERTIFIED TEST REPORT NO. LSC8233A
COMPUTED BY LSC PROGRAM **TEST-LITE**

TYPICAL 2x4 FLUORESCENT FIXTURE
WITH WHITE PAINTED INTERIOR
FOUR 32W T8 FLUORESCENT LAMPS. LUMEN RATING = 2950 LMS.



CANDLEPOWER SUMMARY

ANGLE	ALONG	22.5	45	67.5	ACROSS	OUTPUT LUMENS
0	2145	2145	2145	2145	2145	
5	2137	2157	2142	2135	2140	208
10	2109	2136	2151	2146	2154	
15	2071	2108	2132	2148	2166	600
20	2018	2054	2106	2136	2147	
25	1943	1994	2062	2115	2136	948
30	1849	1931	2019	2075	2099	
35	1741	1846	1947	2033	2064	1209
40	1623	1743	1871	1972	2007	
45	1478	1614	1777	1900	1935	1348
50	1315	1489	1682	1780	1818	
55	1158	1346	1543	1649	1681	1328
60	970	1188	1364	1502	1540	
65	781	1014	1188	1326	1345	1129
70	582	823	1002	1067	1074	
75	395	584	727	747	718	676
80	205	378	392	314	286	
85	48	113	93	51	21	119
90	0	0	0	0	0	

ZONAL LUMENS AND PERCENTAGES

ZONE	LUMENS	% LAMP	%LUMINAIRE
0-30	1755	14.88	23.20
0-40	2964	25.12	39.18
0-60	5640	47.80	74.56
0-90	7565	64.11	100.00
40-90	4600	38.99	60.82
60-90	1924	16.31	25.44
90-180	0	.00	.00
0-180	7565	64.11	100.00

** EFFICIENCY = 64.1% **

S/MH = 1.5
SC(ALONG) = 1.3, SC(ACROSS) = 1.5

LUMINANCE SUMMARY-CD. / SQ. M.

ANGLE	ALONG	45	ACROSS
45	2812	3393	3696
55	2715	3633	3958
65	2486	3796	4296
75	2055	3781	3748
85	735	1440	329

CERTIFIED BY:
Charles Dixon
DATE:
MAY 12, 2000

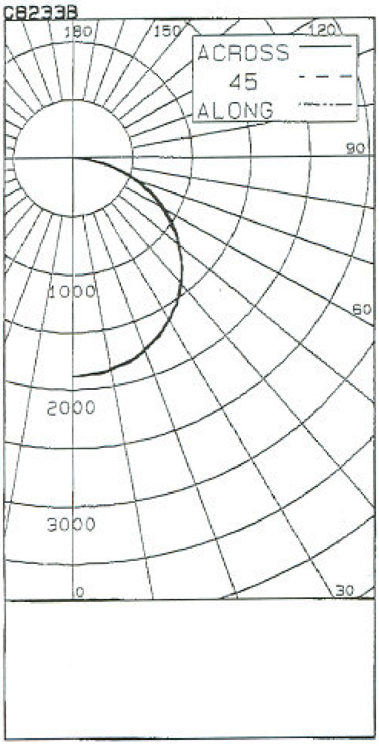
PREPARED FOR:
BARRISOL STRETCH CEILING
PLAFONDS TENDUS QUEBEC
THETFORD MINES, QUEBEC

TESTED ACCORDING TO IES PROCEDURES. TEST DISTANCE EXCEEDS FIVE TIMES THE GREATEST LUMINOUS OPENING OF LUMINAIRE.

LIGHTING SCIENCES CANADA LTD.
440 Phillip St., Unit 19, Waterloo, Ont., Canada N2L 5R9
Tel: (519) 746-3140 Fax:(519) 746-3156

CERTIFIED TEST REPORT NO. LSC8233B
COMPUTED BY LSC PROGRAM **TEST-LITE**

TYPICAL 2x4 FLUORESCENT FIXTURE
WITH WHITE PAINTED INTERIOR AND BARRISOL STRETCH CEILING
MODEL NO. TRANSLUCIDE #4013
FOUR 32W T8 FLUORESCENT LAMPS, LUMEN RATING = 2950 LMS.



CANDLEPOWER SUMMARY

ANGLE	ALONG	22.5	45	67.5	ACROSS	OUTPUT LUMENS
0	1885	1885	1885	1885	1885	
5	1866	1887	1876	1869	1868	181
10	1843	1857	1860	1851	1853	
15	1812	1822	1825	1811	1819	512
20	1760	1767	1763	1751	1761	
25	1695	1700	1700	1694	1692	780
30	1609	1621	1619	1606	1611	
35	1526	1526	1516	1506	1522	948
40	1419	1415	1407	1399	1408	
45	1302	1301	1291	1290	1290	993
50	1165	1167	1154	1152	1157	
55	1031	1024	1012	1012	1015	908
60	878	868	858	864	873	
65	724	724	703	716	714	707
70	568	556	555	559	557	
75	399	394	395	393	404	419
80	247	249	233	243	240	
85	90	87	87	87	98	107
90	0	0	0	0	0	

ZONAL LUMENS AND PERCENTAGES

ZONE	LUMENS	% LAMP	%LUMINAIRE
0-30	1472	12.48	26.51
0-40	2420	20.51	43.58
0-60	4322	36.63	77.81
0-90	5554	47.07	100.00
40-90	3133	26.56	56.42
60-90	1232	10.44	22.19
90-180	0	.00	.00
0-180	5554	47.07	100.00

** EFFICIENCY = 47.1% **

S/MH = 1.3
SC = 1.3

LUMINANCE SUMMARY-CD. / SQ. M.

ANGLE	ALONG	45	ACROSS
45	2476	2466	2463
55	2418	2383	2390
65	2305	2246	2283
75	2076	2054	2109
85	1395	1344	1525

CERTIFIED BY:
Charles Sisson
DATE:
MAY 12, 2000

PREPARED FOR:
BARRISOL STRETCH CEILING
PLAFONDS TENDUS QUEBEC
THETFORD MINES, QUEBEC

TESTED ACCORDING TO IES PROCEDURES. TEST DISTANCE EXCEEDS FIVE TIMES THE GREATEST LUMINOUS OPENING OF LUMINAIRE.

TEST REPORT

marlin

Test Number: 2699
Brief number: N/a
Requested by: S.Dove
Circulation: SD / DH / RAF
Prepared by: J.White / N.Poulter
Approved by: [signature]

Component description: Stretch Ceiling Panels. Stretch Ceilings UK, Whitehall Farm Lane, Virginia Water, Surrey.

Origin of Components: Lighting Design
Reason for Test: Reflectance and Transmission Characteristics
Results:

For the reflectance tests the front finished face of the frames was tested.

For the transmission tests the light source was placed behind the frame and the light leaving the front finished face was measured.

Panel	Reflectance %	Transmission %
02011 White reflective	78.8	9.6
01010 Matt white	81	9.8
02073 Blue reflective	10	0.1
Special translucent	39.2	74.9
04013 Translucent	43.8	72

Note. A tolerance or uncertainity of +/- 5% on the above figures should be allowed for.

Date: February 19, 1997

marlin Hanworth Trading Estate, Hampton Road West, Feltham, Middlesex tel: 081-894 5522 fax: 081-755 3887

APPENDIX C

MATERIALS USED IN OPTICAL SYSTEMS

Material	Production Methods	Appearance	Optical Characteristics	Optical Properties Transmission Coefficient	 Reflection Coefficient	Other Characteristics
Plastics Acrylics	Sheeting, Moulding, Insufflation, machinery Injection-Moulding	Transparent	High Transmission	92 - 9	5 - 81	Quite Light, Durable, Easily Scratched, Melts over 80°C Gathers Dust, Fire Resistant, Constant Coloured, Expensive
		Coloured	Direct or Diffuser			
		Semi-transparent, Variable density	Almost Total Diffuser			
Polystrene	Shrinking, Injection-Moulding	Transparent	High Transmission	90		Light, Durable, Easily Scratched, Long Lasting Gathers Dust, Fire Resistant, Varied Colours, Cheap
		Semi-transparent, Coloured	Good Diffuser	54		
Vinyl P.V.C.	Sheeting, Grooved, Vacuum-Moulding Vinyl Sandwich (Acoustic) Double-Plate Vinyl (Acoustic)	Semi-transparent,	Good Diffuser	88 - 50	7 - 45	Light, Rigid Formable Durable, Long Lasting Gathers Dust, Deforms at Low Temp., Consumes Away Itself
		Non-Tranparent		0		
Polyester	Sheeting	Semi-transparent,		65		Durable (Because of Fiber), Decorative Effect Consumes Away Itself Slowly
		Non-Tranparent		0		
Urea Formaldehyde	Moulded	Semi-transparent,		65		
		Non-Tranparent		0		
Glass	Sheeting, Moulded, Insufflation	Transparent	High Transmission, Can be Glazed Critical Optical Systems	90		Heavy, Crispy,Long Lasting Durable at High Temperatured Process
		Argillaceous Semi-transparent	Excellent Diffuser	12 - 40		
		Laminated Semi-transparent	Good Diffuser	30 - 60		
		Sand Processed	Quite Good Diffuser			
		Decorative				
	Silver Added		High Reflection Coefficient, Smooth Surface, Suitable for Different Diffusion Methods	0	87	
Metals Steel Sheeting	Product	Furnace Enamel	Diffuser		75	Quite Heavy, Quite Durable, Long Lasting, Durable at High Temperature
		Glass Enamel	More Diffuser		80	
		Chromium Coated Stainless	Glossy, Average Reflectance		65 60	
Aluminium	Product Sheeting	Furnace Enamel	Diffuser		75	Light, Not Durable as Steel Long Lasting, Durable at High Temperature
		Anodize: Glossy Matt			 80 75	