IMPORTANCE OF DAYLIGHT

AS A COMPONENT OF SUSTAINABILITY IN SHOPPING MALL

EXAMPLES

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IMPORTANCE OF DAYLIGHT

AS A COMPONENT OF SUSTAINABILITY IN SHOPPING MALL EXAMPLES

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Title of the Thesis : **IMPORTANCE OF DAYLIGHT AS A COMPONENT OF SUSTAINABILITY IN SHOPPING MALL EXAMPLES**

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The use of natural light in interior spaces of shopping malls is very beneficial because energy consumption can be reduced in this big scale building type and conditions for employees and numerous users of these spaces can be enhanced, which positively affect their health. The concept of sustainability is a rapidly growing area of focus for many interior designers. Interior designers are among professional groups who have a considerable impact on sustainability. The research explores the effects of daylight in the interior spaces of shopping malls for achieving sustainable interior spaces. The research hypothesis is that shopping mall with more daylight will be sustainable in many aspects such as enhancing indoor environment quality, energy efficiency, and as well daylight affects human behaviors and psychology. This research would contribute to the awareness on the necessity and ways of providing daylight in buildings, especially in shopping malls interior spaces. Ways of bringing natural light into inner spaces will be examined through providing examples and studies which have been done in this matter.

Keywords: Sustainability, Shopping Malls, LEED, Daylight, Indoor Environment Quality, Light Transport Systems (LTS)

ÖZ

ALIŞ-VERİŞ MERKEZLERİNDE SÜRDÜRÜLEBİLİRLİK BAĞLAMINDA DOĞAL IŞIĞIN ÖNEMİ

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İç mekanlarda doğal ışık kullanımı özellikle alış-veriş merkezlerinde oldukça yararlıdır çünkü bu yolla enerji tüketimi düşürülebilir ve aynı zamanda doğal ışık çalışanlar ve bu merkezlere gelen insanların da sağlıklarını olumlu yönde etkiler. İç mimarlar için sürdürülebilirlik hızla gelişen bir çalışma alanı olmaya başlamıştır. İç mimarlar artık sürdürülebilirlik konusunda profesyonel guruplar oluşturmaktadır. Bu çalışma alışveriş merkezlerinde doğal ışık kullanımının sürdürülebilirlik bağlamında uygulanabilirliği üzerinedir. Araştırmanın önerisi; iç mekanlarda daha fazla doğal ışık kullanımının iç mekan yaşam kalitesini yükselteceği, enerjinin verimli kullanılacağı ve insan sağlığı ve psikolojisi üzerine olumlu etkileri olacağı üzerinedir. Aynı zamanda bu çalışma; binalarda doğal ışık kullanımının olumlu etkileri üzerine bir farkındalık yaratmayı, özellikle de alışveriş merkezlerinde bu olumlu etkinin daha fazla hissedileceğini iddia etmektedir. Doğal ışığı iç mekanlara getirebilme yolları örneklerle ve yapılan çalışmalara atıflarla izah edilecektir.

Anahtar Kelimeler: Sürdürülebilirlik, Alış-veriş Merkezleri, LEED, Doğal Işık, İç Mekan, Kalitesi, Işık Aktarım Sistemleri (LTS)

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INTRODUCTION

1.1. Aim of the Study

The focus of this study is to demonstrate the effect of daylight in interior spaces of shopping malls as one of the indoor environment quality strategies to achieve sustainability. Accordingly, the study aims to provide designers with the knowledge and tools to use in assessing future projects concerning the role of daylighting in indoor environment quality as one of sustainable interior space features. The main intention of the research is to investigate the relationship between the daylight in the enclosed spaces of shopping malls and its capability to increase the quality of indoor environment as astep toward being sustainable interior spaces by investigating the modern technologies system of bringing daylight in innermost spaces. In the end, the study comprises a research of light transport systems as a proposal for bringing natural light into the most problematic interior spaces of shopping malls.

1.2. Significance and Scope of the Study

Wellbeing of building occupants and healthy environment can be achieved in interior spaces of shopping malls by following the techniques of sustainability. Thus, sustainability concept selected to study in this research has already become a requirement in any design for any building nowadays. Shopping malls are usually the places, which are densely used and thus become part of many people's lives in today's era. Considering the high amount of users of interior spaces in shopping malls, the study will be concerned with this huge structure building type.

A better understanding of the proper application of daylighting strategies in shopping malls can be an improvement when trying to enhance the indoor environmental quality and energy efficiency. When we talk about shopping mall buildings especially, daylight has a specific significance, due to the various activities performed in interior spaces of shopping center. Accordingly in this study, research in a related sustainability criterion indoor environment quality and the affect of daylight in this point will be discussed .The study will attempt to describe the link between daylight and sustainability concept. In addition, providing good daylight can easily affect the indoor environment in a positive way according to its ability to support healthy environments, influence thermal performance, air quality, toxicity and mold. Thus, studying daylight performance and its psychological influences to users in order to achieve healthy and comfortable interior spaces in shopping centers is significant.

A considerable ratio of shopping centers interior spaces have serious problems in terms of natural illumination, and consequently, use more energy for artificial lighting which results in poor conditions for occupant's health and employee productivity. One solution to the problem of daylighting illumination of multistorey buildings is the introduction of natural light by means of atriums or light wells, but this solution is not suitable for whole interior spaces of these large buildings . Light transport systems may therefore be a practical solution to bring natural light into the depths of buildings. Introduction of light transport systems may also be related to spatial and economical constraints.

However, the scope of this research will mainly seek to answer the following questions:

1- What is the role of daylight in indoor environment quality and accordingly, what is the link between daylight and sustainability ?
2- How can natural light be brought into the problematic areas of shopping malls as deep plan buildings, so as to improve energy efficiency and interior space conditions for building occupants ?

1.3. Methodology

The main data of this study, literature survey was conducted as based on theses, publications in libraries, articles and web sources. Literature survey on the concepts, discussions and examples maintained the information to determine the sustainability concept criteria, the role of daylight in sustainablitiy of shopping malls and the

techniques for bringing daylight into interior spaces of deep plan and multistorey shopping mall buildings.

This study is composed of five chapters. Next chapter introduces literature survey in sustainability concept. Sustainable architecture definition and the two worldly recognized assessment rating systems LEED and BREEAM are discussed within the context of sustainability and the final review demonstrates the link between daylight and sustainability.

The third chapter introduces shopping mall definition, and the literature review addresses the three main subjects and their relations to be discussed :Human being, daylight and shopping malls. Then the problem of shopping malls in introducing natural light into their interior spaces is discussed by determining the most problematic spaces in terms of daylight abundance, through some shopping mall examples in Ankara. The review of the chapter shows that human being is much affected by daylight and daylight is discussed in the context of shopping malls buildings in the last section, which is the general evaluation of daylight in shopping malls.

In the fourth chapter ways of bringing daylight into multistory and deep plan buildings is examined through providing the review showing the different technologies and available systems to transport natural light into interior spaces of buildings. This chapter includes the definitions of the information about these different systems which consists of three major components: light collection, light transportation, and light distribution and every component is explained in details. Finally examples and studies done in different types of building are discussed in the last section of this chapter

CHAPTER 2

DAYLIGHT AND SUSTAINABILTY CONCEPT

2.1. Definition of Sustainability

The meaning of sustainability in dictionaries is given as below:

> Sustainability means "conserving an ecological balance by avoiding depletion of natural resources".

Sassi (2006,p3) describes sustainability as "ensuring a better quality of life for everyone now and for generations to come", the author beleives that "Anyone involved in building design, procurement or maintenance in recent years will have been confronted in one way or another by the term sustainability".

> "sustainability is not an academic pursuit or even a professional activity: it is a way of life affecting everything an individual does. Knowing what kind of a relationship we want to have with the global and local environment is the first consideration.Then we should address how to achieve this relationship.To move from theory into practice it is necessary to understand the impacts associated with our work- and life-related activities". (Sassi ,2006,p 8)

According to the university of California reports, Sustainable Architecture and Building Design (SABD), many other definitions of sustainability have also been offered.

Among them the most related one with built environment are:

1- According to World Conservation Union (WCN) (1992); “Sustainability is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations”.
2- According to World Wide Fund for Nature (WWF). “Sustainability is taken to mean a positive rate of change in the quality of life of people, based on a system that permits this positive rate of change to be maintained indefinitely”.

According to Ratcliffe and Stubbs (1996,p.10) “there are serious problems facing our global environment such as the scarcity in the natural sources of the environment ,increasing the problems of ozone pollution and the fear of the rising temperature of the earth”. There are many dimensions can easily be evaluated in the light of sustainability such as environmental, economic and social dimensions of sustainability .Therefore, the author argues that generally difficult to find specific text in sustainability definition and it depends on the intentions and directions of the problem. Foremost among these ideas he defines sustainability

“ as an attempt to minimize negative impacts and conserve resources, not exhausted much as poossible” (Ratcliffe and Stubbs,1996,p12)

Hence, sustainability term is related to the environment issues, and there are another terms synonymous to sustainability such as “eco”, “green” and “environmentally friendly”. As Karen (2010,p36) states “People often use the word green to describe

things that are good for nature and the environment. When people stop doing something that pollutes the environment, they say they're going green".Other terms to describe things that are good for the environment are 'Earth friendly','eco-friendly',and'environmentally friendly'.

According to Yaldiz and Magdi (2010,p2) "Sustainability is a multi-dimensional concept that has environmental, social, political, economic, cultural and spiritual dimensions. Therefore, sustainability can be described as a system or, in other words, an ecosystem within which various parts/elements interact".So in that case sustainability is a long-term issue and can be used in various and different dimensions as well as in diffrent professions.

Also, according to Halliday(2008.p 4) "There can be few within the professions involved in the built environment for whom sustainability is a new idea. Recently, government policies, international politics and architectural responses mean that it is an issue rarely out of the press and the office. It is an increasingly important aspect of client briefs".

Researchers of the National Park Service in America have emphasized that sustainability can achieve a quality of life (or standard of living) that can be maintained for many generations because it is:

1) Socially desirable, fulfilling people's cultural, material, and spiritual needs in equitable ways;
2) Economically viable, paying for itself, with costs not exceeding income;

3) Ecologically sustainable, maintaining the long-term viability of supporting ecosystems.

According to Halliday(2008,p .5) "Sustainability is not a single clear and specified concept dealing with mathematics, or based upon hypothesis, inputs, and equations. Accordingly, specific results are not expected to be accomplished in a specific time. Basically, Sustainability is a methodology that can be viewed to represent a continuous and dynamic way of life".

According to Sustainable Architecture and Building Design (SABD) university of California reports, there are three dimension in sustainability concept: Environmental Sustainability,Economic Sustainability and Social Sustainability

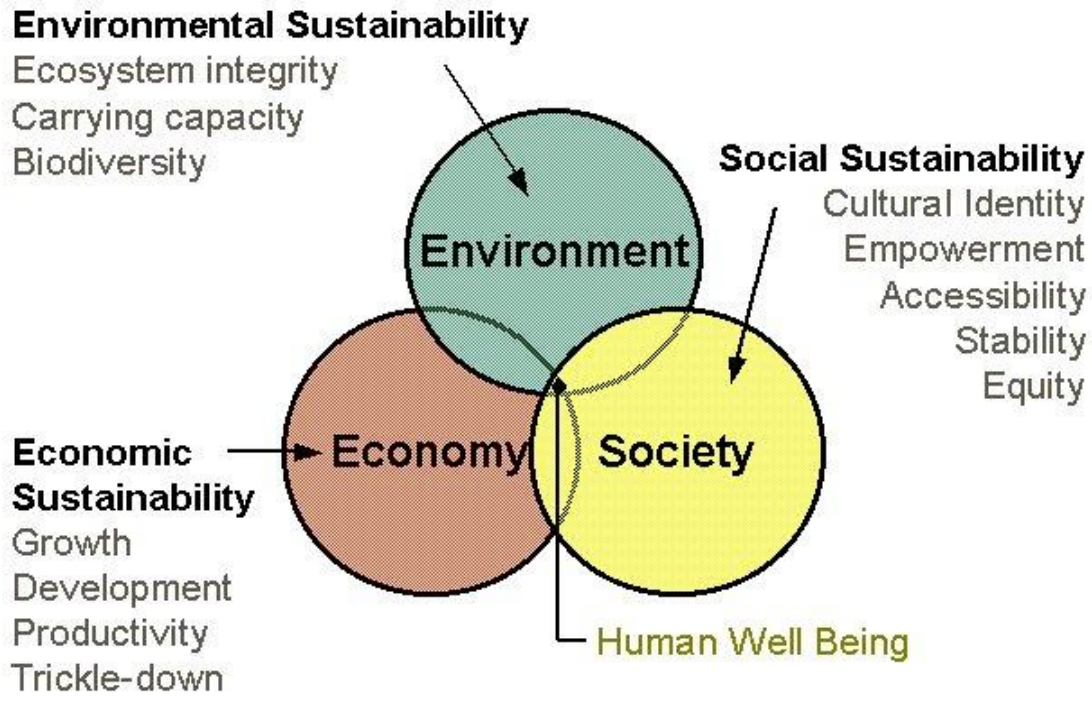


Figure 2.1 Three Dimensions of Sustainability

While researching on the objective of sustainability in the available resource I find the interesting and brief ones as Foster (2003,p.9) explain that "sustainability seek to improve the natural and built environment through conservation and rationalization consumption of its resources.Trying to achieve great balance between the social and the environment and reduce the cost of the risks that await future generation".Sustainability, as a result is a wide ranging term and multi-dimensional issue. Simply it is related with the future, concern to all human beings living on the Earth and forever.

There are many international institutions and organizations which try to explain the meaning of sustainable development such as International Union for the Conservation of Nature and Natural Resources (IUCN), World Conservation Union (WCN), United Nation Environment Programme (UNEP), and World Wide Fund for Nature (WWF).However, the most commonly and universally accepted definition is:

> "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" .

As formulated by the World Commission on Environment and Development (WCED), led by the Norwegian prime minister Gro Harlem Brundtland, in 1987. (World Commission on Environment and Development ,1987,p.2).

According to the WCED report (1987), the definition is based on two concepts:

1. The concept of needs, comprising of the conditions for maintaining an acceptable life standard for all people.

2. The concept of limits of the capacity of the environment to fulfill the needs of the present and the future, determined by the state of technology and social organisation.

The needs consist firstly of basic needs such as food, clothing, housing and employment. Secondly, every individual, in every part of the world should have the opportunity to try and raise his or her life standard above this absolute minimum, the limits consist of natural limitations like finite resources. (World Commission on Environment and Development ,1987,p.2).

2.2. Sustainable Architecture

After explaining the definition of sustainability in this chapter I will try to conect the concept with our profession under the title sustainable architecture .

Sustainability concept has gained significance in the last 30 years due to huge threats to nature. This concept is influencing any part of life as well as architecture. As Yaldiz and Magdi (2010,p.8) claims "sustainable architecture occurred in the architectural domain after the sustainability paradigm was first defined and architects will play a significant role in challenging this equation".

For Kremers (1995,p.1) "Sustainable architecture has emerged as a movement in architectural design towards the sustainability of the built environment". And there were many disputes on the meaning and implecation of this concept. There has been no agreement amongst scientists and architects in defining the term and on how it should be implemented in practice. Some other terms such as "green building" and

"ecological design" have also been used in parallel with "sustainable architecture" in order to clarify or more specifically express its implications.

Luu Duc Cuong (2007,p.2) says that "sustainable architecture should be understood in a broader meaning rather than in the meaning of words. It can be interpreted as an approach to architectural design that minimizes resource consumption, utilizes natural energy, mitigates environmental damages, and improves human health". The author in conclusion paragraph of his article add to his argument the definition of sustainable architecture (2007.p12) as "more importantly, it should also be considered as a tool for raising people's awareness of environmental protection or in other words a response to mother nature, who always coexists and supports mankind".

Sassi (2006,p 8-9) explain the main aims for sustainable architectural design

> "First, sustainable buildings should metaphorically 'tread lightly on the Earth' by minimising the environmental impacts associated with their construction, their life in use and at the end of their life. Sustainable buildings should have small ecological footprints
> Second, buildings should make a positive and appropriate contribution to the social environment they inhabit, by addressing people's practical needs while enhancing their surrounding environment and their psychological and physical well-being."

According to Arsan(2003,p14) "The terminology of sustainable architecture is very broad. To avoid confusions, it is useful to point out that sustainable architecture consists of the whole environment friendly building development. Besides, it is not only environmentally-friendly, but also economically, culturally, socially, aesthetically and health-friendly. Terminologically, the terms that are used for naturefriendly movements in architecture are altering in time".

2.3. Sustainable Building Rating Systems

As noted before in sustainability definition "green" is synonymous term to sustainability and usually this term is used to describe things that are good for the environment to be Earth friendly.As (Bromberek,2009,p.83) argue that "green buildings are designed and constructed with consideration for the protection of the environment and comfort and health of the inhabitants". Although, "green buildings are not completely sustainable, they are certainly a step toward achieving sustainability". Sustainable design is a general state of combining with nature.Sustainable building rating systems are "determined as tools established for the purpose of examining the performance or performance expected for a whole building" .(Fowler, 2006,p.24)

Before a revision of theory about green building rating systems consideration should be taken to define green building. According to Halliday (2008,p.61) green buildings can be defined as "healthy facilities designed and built in a resource-efficient manner, using ecologically based principles".He (2008,p.61) says the term green building refers to the quality and characteristics of the actual structure created using the principles and methodologies of sustainable construction.

Consequently, the aim of these assessment rating systems according to the U.S. Green Building Council's (2009) web source is " to improve occupant well-being, environmental performance and economic returns of buildings using established and innovative practices, standards and technologies".

All around the world there are numerous tools for building evaluation. These tools contain and evaluate different types of projects concentrating on sustainable development. Among these diffrent rating systems “The two worldly recognized assessment rating systems LEED and BREEAM” (Fowler.2006,p 21) will be examined in this study .

Many of the international rating systems developed their origins from BREEAM and LEED Rating Systems. There are also other rating systems that are originally formed within their principles . CASBEE (Comprehensive Assessment System for Building Environmental Efficiency), GBTool, Green Globes™ US are the examples of rating systems that are formed originally (Halliday ,2008,p.69) .For Fowler (2006. p26) LEED and BREEAM Rating Systems are the most important ones through them.

2.3.1. LEED Rating System

Leadership in Energy and Environmental Design the LEED Rating System was developed by members of the USGBC in an effort to help define, evaluate and reward buildings for achieving specified levels of sustainability (USGBC, 2008). LEED is a voluntary certification program and the nationally accepted benchmark for the design, construction and operation of high performance green buildings .The program provides independent, third-party verification that a building is environmentally responsible and a healthy place to live and work. (USGBC, 2008).

LEED promotes a whole-building approach to sustainability by evaluating performance in six key categories .LEED certification is based on the number of “points” (Table 1) that a building is able to get in each of six areas.

Table 2.1 LEED NC Rating Categories and Associated Points

Category	point
1. Sustainable site development	26
2. Water efficiency	8
3. Energy efficiency	35
4. Materials selection	14
5. Indoor environmental quality	15
6. Innovation and design process .	10
Total	108

According to LEED Reference Guide (2009) for new construction and major renovations certifications are awarded according to the following scale:

Table 2.2 LEED NC Rating Award and Associated Points

Level	point
Certified	40–49 points
Silver	50–59 points
Gold	60–79 points
Platinum	80 points and above

Prior to beginning the certification process, a firm must first determine under which LEED program the project is eligible (LEED Rating Systems, 2009). Below is a list of the current LEED programs:

“· New construction (LEED-NC)
LEED for new construction and major renovations is designed to guide and distinguish high-performance commercial and institutional projects.
· Existing Buildings (LEED-EB)
LEED for existing buildings: operations and maintenance provides a benchmark for building owners and operators to measure operations, improvements and maintenance.

· *Commercial interiors (LEED-CI)*
LEED for commercial interiors is a benchmark for the tenant improvement market that gives the power to make sustainable choices to tenants and designers.
· *Core and shell*
LEED for core and shell aids designers, builders, developers and new building owners in implementing sustainable design for new core and shell construction.
· *Schools*
LEED for schools recognizes the unique nature of the design and construction of K-12 schools and addresses the specific needs of school spaces.
· *Retail*
LEED for retail recognizes the unique nature of retail design and construction projects and addresses the specific needs of retail spaces.
· *Healthcare*
LEED for healthcare promotes sustainable planning, design and construction for high-performance healthcare facilities.
· *Homes*
LEED for homes promotes the design and construction of high-performance green homes.
· *Neighborhood development*
LEED for neighborhood development integrates the principles of smart growth, urbanism and green building into the first national standard for neighborhood design"(LEED Rating Systems, 2009 p.222).

2.3.1.1. Daylight in LEED Certification

With the movement towards sustainable design, the USGBC (United States Green Building Council) developed the LEED (Leadership in Energy and Environmental Design) guidelines which offered a rating system to quantify a building's level of sustainability. LEED was created to define 'green building' by establishing a common standard of measurement; to promote integrated, whole-building practices; to encourage and recognize environmental leadership in the building industry; to raise consumer awareness of green building benefits; and, to transform the building market. (LEED, 2009).

The Leadership in Energy and Environmental Design (LEEDTM) rating and certification system developed by the United States Green Building Council (USGBC) for sustainable building design and construction has quickly penetrated and transformed the building design industry. The LEED system awards credits toward sustainable certification for achieving specified performance goals in a wide variety of sustainable areas, including site selection, water retention, material selection, energy use, and interior environmental quality. With adoption by an increasing number of clients, architects, and institutional and government agencies, the scientific basis of the credit system has come under examination. (Karen ,2009).

Daylighting Credit 8.1 in the Interior Environmental Quality category and the methods of compliance documentation accepted. The credit intends to:

> "provide for the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.In order to be awarded the IEQ 8.1 credit a building has to "achieve a minimum daylight factor of 2% (excluding all direct sunlight penetration) in 75% of all spaces occupied for critical visual tasks. Spaces excluded from this requirement include copy rooms, storage areas, mechanical plant rooms, laundry, and other low occupancy support areas." (LEED Reference Guide ,2009)

While the daylight factor is a tool to quantify daylighting within a space, it does not reveal the quality of daylighting. Potential glare problems, for example, might go unnoticed if the daylight factor is the sole method for evaluating daylighting performance. (LEED Reference Guide ,2009)

The LEEDTM daylighting requirement addresses this to some degree by requiring all openings to include some means of glare control, such as adjustable blinds, light-

shelves, exterior shading, louvers, or fins. However, more often than not, additional daylight analysis is required to insure good daylighting design. (Karen,2009,p.5)

2.3.1. BREEAM Certification System

Building Research Establishment Environmental Assessment Method is an UK based certification method generally known as BREEAM. "BREEAM is the world's foremost environmental assessment method and rating system for buildings, with 200,000 buildings with certified BREEAM assessment ratings and over a million registered for assessment since it was first launched in 1990". (What is BREEAM, 2009,p 65) .

The objectives of BREEAM certification system are:

"1· To provide market recognition to low environmental impact buildings.
2· To ensure best environmental practice is incorporated in buildings.
3.To set criteria and standards surpassing those required by regulations and challenge the market to provide innovative solutions that minimize the environmental impact of buildings.
4· To raise the awareness of owners, occupants, designers and operators of the benefits of buildings with a reduced impact on the environment.
5· To allow organizations to demonstrate progress towards corporate environmental
Objectives". (What is BREEAM, 2009 p.66).

BREEAM system evaluates the performance of buildings in the following areas:

"• **Management**: Overall policy and site management, commissioning and procedural issues.
• **Health and well-being**: Indoor and external issues affecting health and well-being.
• **Energy**: Operational energy and carbon dioxide (CO2) issues.
• **Transport**: Transport-related CO2 and Location related factors.
• **Water**: Consumption and water efficiency.
• **Materials**: Environmental implication of building materials including life-cycle impacts.

• **Waste**: Waste products.
• **Land use and Ecology**: Greenfield and Brownfield sites and ecological value conservation and enhancement of the site.
• **Pollution:** Air and water pollution issues (What is BREEAM, 2009 p.68).
The typical components of BREEAM's assessments are:
Carbon dioxide emissions with quantified benchmarks
Healthy building features
Air quality and ventilation
Minimizing ozone depletion and acid rain
Recycling and reuse of materials
Ecology of the site
Water consumption and conservation
Noise
Risk of Legionnaire's disease
Hazardous materials assessment
Lighting
Environmental impact of construction materials
Transport implications of buildings". (What is BREEAM, 2009 p.191)

Table 2.3 BREEAM Environmental Weightings

BREEAM Section	Weighting %	
	New builds, extensions and major refurbishments	Building fit-out only
Management	12	13
Health and Wellbeing	15	17
Energy	19	21
Transport	8	9
Water	6	7
Materials	12.5	14
Waste	7.5	8
Land use and Ecology	10	NA
Pollution	10	11

BREEAM offers a variety of benefits ranging from environmental to financial gains. For a long time BREEAM has been used to evaluate the environmental performance of both new and already existing buildings.

Financial benefits – Reduces energy and other running costs, improve staff productivity, make office buildings more aesthetic and thus are able to attract higher rental incomes.

Publicity benefits – Makes offices more attractive to potential customers or tenants by demonstrating environmental commitment.

Benefits to management – Provides a thorough checklist for benchmarking building performance, setting realistic targets for improvement, apart from complementing wider corporate management strategies.

Benefits to staff and building users – Creates a better place for people to work more productively, by providing a healthier and comfortable indoor environment.

(What is BREEAM, 2009 p.96)

BREEAM is tried and tested, both in terms of its robust technical standards and its commercial delivery and expert advice continues to inform almost every issue in BREEAM(What is BREEAM, 2009, p.127).

BREEAM also helps the developers and designers to increase the chances of getting a higher rating from the beginning of the process by encouraging the issues above. The credits are awarded from the each criterion. After that these credits are added together to form an overall score. These scores then are rated on chart of Pass, Good, Very

Good or Excellent (What is BREEAM, 2009).BREEAM covers a wide range of building types such as offices, homes, industrial units, retail units, schools, leisure centers, laboratories, and even prisons.

The example of BREEAM Certificated projects in Turkey is more seen in shopping malls. The first building that achieved BREEAM certification is Erzurum Shopping Mall (Figure 2.1,2.2) with the Very Good standard. Gordion Shopping Mall in Ankara (Figure 2.3,2.4) has also achieved BREEAM Very Good certification score.These buildings are the first BREEAM Certificated buildings in Turkey. (Sarimanoglu,2010,p.61)

Figure 2.2 Erzurum Shopping Mall, Erzurum BREEAM Certificate, Very Good

Figure 2.3 Erzurum Shopping Mall, Interior View.

Figure 2.4 Gordion Shopping Mall, Ankara Interior View, Very Good

Figure 2.4 Gordion Shopping Mall, Ankara BREEAM Certificate, Very Good

2.4. Indoor Environmental Quality (IEQ)

Indoor environmental quality comprises one significant category in LEED (Leadership in Energy and Environmental Design) rating system. This category has significant role by dealing with reducing indoor pollutants, improving the thermal comfort, indoor air quality and indoor lighting. Thus, Interior architect can play an important and effective role in this category by using correct placements through the design process.

As Guerin (2003,p.6) states, the knowledge and participation of an interior architect in this category is essential. Environmental sustainability is becoming a major concern within the interior design field due to the extensive resources needed for interior use

The current opportunities in sustainable development, which is a very fast growing area offers interior designers a wide range of possibilities for the future.Guerin (2003,p.6) tells that

> "Interior architects who focus on environmentally responsible design plan, specify, and execute solutions for interior environments that reflect concern for both the world's ecology and the inhabitant's quality of life".

Interior designers, are positioned to have a major impact on sustainability and can participate to this sustainable design effort. Sustainable interior design practices are actions that lessen environmental impact due to site selection, water use, energy use, and material selection (Rider, 2005).

With these considerations, interior designers are able to provide a physiologically and psychologically healthy indoor environment Kang and Guerin (2009,p13). Overall, environmentally sustainable interior design minimizes negative effects and maximizes positive effects on environmental systems over the life cycle of a building by blending solutions of the past with new technology of today. (Kang and Guerin,2009,p.14)

Rider (2005,p19) defined sustainable interiors as "interiors designed in such a manner that they sensibly address the impact of all their functions, parts and elements on the global environment".

Ruff and Olson (2009) defined environmentally conscious interior design as professional practice that attempts to create indoor spaces that are environmentally sustainable and healthy for the occupants. In this review of literature the following

sustainable interior design topics as parts of the indoor environmental quality will be examined: indoor air quality(IAQ) and daylighting.

According to Wong (2007, p.1) today the concept of an acceptable indoor environmental quality (IEQ) as an integral part of the total building performance approach is still not fully appreciated. "Physical environmental parameters such as air temperature, relative humidity, acoustics, air quality, daylighting, ventilation and air distribution are all interrelated, and the feeling of comfort is a composite state of an occupant's mind responding to the senses to these factors".

According to the Environmental Protection Agency's Indoor Air Quality Program.

> "The quality of the indoor environment can significantly impact building occupants. Quality indoor environments can result in:
> 1- Increased occupant satisfaction
> 2- Enhanced performance/productivity
> 3- Reduced absenteeism
> 4- Marketing advantage
> 5- Reduced liability
> 6- Lower operations and maintenance costs" (http://www.epa.gov/iaq/)

2.4.1. Indoor Air Quality (IAQ)

The Environmental Protection Agency (EPA) and in the website of National Institute of Occupational Safety and Health (NIOSH) defined good Indoor Air Quality (IAQ) as :

"The introduction and distribution of adequate ventilation of air, control of airborne contaminants, and maintenance of acceptable temperature and relative humidity". (http://www.epa.gov).Indoor air pollution is introduced into a space through materials, finishes, furnishings, and equipment, chemicals used inside a building, and through human activities and biological processes (Spiegel and Meadows,2006, p.5).

According to Kang and Guerin (2009, p17), Interior Designers help control Indoor Air Quality (IAQ) by taking precautions with construction or renovation procedures . For example: raising the base of partitions one to two inches from the floor to allow airflow around acoustic partitions in an office space, placing exhaust fans in enclosed spaces or where pollutants are contained (e.g. a kitchen, smoking lounge, or bathroom), and using plants in interior spaces when fitting.

Additionally, as new materials can release harmful chemicals prior to occupancy,delaying occupancy prevents occupants from any unnecessary volatile organic compound (VOC) exposure .Designers are responsible for addressing a client's needs, including the exposure to dangerous chemicals found in the air. Human health, safety, well-being, and productivity can be affected by the choices designers make (Ruff and Olson ,2009,p22).

The (EPA) Environmental Protection Agency (1998) noted that common symptoms of Indoor Air Quality (IAQ) in inclosed controle climate spaces such as interior spaces of shopping malls include headaches, shortness of breath, coughing, sneezing, fatigue, sinus congestion, skin irritation, nausea, eye, nose, and throat irritation, and dizziness.

Sick Building Syndrome (SBS) is a term sometimes used when no cause or illness explains such symptoms; rather, these symptoms become effects of the time an occupant spends in the building. Building Related Illness (BRI) is a diagnosable illness, such as asthma, where symptoms are attributed to environmental agents and exposure

to building air. Multiple Chemical Sensitivity (MCS) is a condition affecting a small percentage of individuals sensitive to indoor air chemicals occurring at low concentrations (EPA, 1998).

Ventilation ensures a proper ratio of natural and mechanical air. Designing with building orientation in mind can facilitate cross-ventilation and negative air pressure. Controlled ventilation manipulates air pressure with mechanical systems that ventilate with controlled pressures (Spiegel and Meadows,2006, p.8)

The boundary between goals for indoor air and occupational exposure standards has become blurred in buildings that act as one person's workplace and another's public place (for example, shopping center). Indoor air goals must consider different factors and risk levels from those in the work environmen.(International Council of Shopping Centers, 2004).

Good indoor air quality is essential to occupants in enclosed spaces such as interior spaces of shopping center where many people spend the greatest proportion of their time.There are many important reasons to provide an environment that has stable indoor air . Careful control of temperature and humidity not only makes occupants more comfortable, but also achieves significant operating and maintenance savings over the life of a building. Furthermore, thermally comfortable buildings are more likely to retain employees and occupants, raising property values and income. (Spiegel and Meadows,2006, p.9)

According to the Environmental Protection Agency's Indoor Air Quality Program

"The Importance of IEQ

1- Indoor air is often more polluted than outdoor air, sometimes as much as 25% more polluted, and occasionally more than 100 times as much.
2- Americans spend approximately 90% of their time indoors.
3- Sick Building Syndrome - 30% of new & renovated buildings.
4- Lost productivity costs billions of dollars annually.
5- Indoor air pollution is one of the top five public health risks".

As in America, indoor air quality is important in all developed and developing countries today, where people spend much time indoors.

2.4.2. Daylight

Another factor related to sustainable interior design is the use of daylight and consequently providing a connection to the natural environment. Daylight can simply be defined as the practice of bringing light into a building interior and distributing it in a way that provides more desirable and better quality illumination than artificial light sources (Halliday ,2008, p.225).

The term "daylight", technically, means only sunlight diffused by particles and clouds in the sky. Daylight has been considered the most desirable light form due to its unique characteristics of continually changing patterns, advantageous for dynamic play on illuminating designed spaces, as well as its excellent efficacy(Deru, et al,2005, p.8).

The National Lighting Product Information Program (NLPIP) introduce daylight as :

> "Daylighting reduces the need for electric lighting by introducing daylight into a building. Effective daylighting is achieved through the strategic placement of skylights and windows, as well as lighting controls that monitor available daylight and respond as needed to decrease or increase electric lighting" .

As noted by Deru, et al. (2005, p.14), on the challenge of defining "effective daylighting," daylighting performance is often defined differently by different stakeholders in the design and use of the building. For example, a mechanical engineer may define performance in terms of electrical lighting energy reduction. Alternatively, an architect may define performance in terms of the aesthetic qualities of daylight distribution in the space.

The client may define daylighting performance based on whether or not the project complies with the requirements of sustainable building certification criteria for daylight sufficiency and views. Also building occupants may judge the daylighting performance of the building based on their perception of daylight sufficiency, visual comfort, and available views.

> "Daylight should always be the first choice for illuminating a space during the day, unless the function specifically excludes it. It is beneficial because of its zero energy consumption, directionality, variability, intensity and colour. None of these elements can be completely reproduced by electric lighting. People are tolerant of the variability of light levels if they know that the light is daylight. However, it can become a source of annoyance and/or give rise to a need for compensatory heating or cooling and therefore has to be balanced against excessive heat loss, or unwanted solar gain or glare. Natural light must therefore be considered alongside the view, the layout of spaces and the activities". (Halliday ,2008.p.226)

According to Halliday (2008, p.229), daylight if properly designed into a building and well controlled, also offsets the energy consumption associated with artificial lighting,

which is often a very significant proportion of the overall energy consumption of buildings.

When daylighting is well designed it is an aid to effective working and/or enjoyment of a space, and its directional qualities can assist occupants in discerning details. Promoting natural lighting will improve the life quality of the users of interior spaces in the building. Greater use of daylighting can also provide advantage for the environment by reducing power demand and the related pollution (Heshong Mahone Group, 1999).

Access to natural light by connection to the outdoors has many benficial aspects for both building and occupants . Exposure to natural light is very important to human health.

> "Daylighting throughout the year helps building occupants maintain bio-rhythms that mesh with diurnal and seasonal changes, resulting in greater well-being.Areas with natural light tend to be gathering places. Both indoor and outdoor relaxation areas with vegetation and views are likely to enhance social interactions and sense of belonging."

2.5. The Effects of Daylight on Human Behavior

According to Steffy (1990) lighting plays a significant role in the human behavior. Steffy (1990, p14) stated that lighting affects the human sensory response, desired impressions, expectations and subjective impressions (visual clarity, spaciousness, relaxation, and sense of privacy).Lighting also has the power to direct activity. Lam and William (1977, p62) explored the effect of lighting on the choice of which

passageway people would use. They found that the more brightly lit passage was the one that was used by most people.

As Dilouie (1995, p26) claims, the presence of daylight provides clues about three-dimensional form and orientation in addition to indicating the state of the weather. The author also suggested that effective lighting is capable of creating a safer environment. Lam and Wiliam (1977, p73) also studied on the effects of maximising sunshine as a light source in the customer service center of the Sacramento Municipal Utility District. One hundred and fifty six employees were surveyed or interviewed about their impressions and experiences with the lighting and they were generally quite satisfied with the appearance of the lighting in the open offices and more than half believed the lighting was better than similar workspaces in other buildings. This proves that higher usage of daylight evoked positive perceptions in human being.

There is no Perception of things without the Natural-light. We can realize the features of things throughout the Natural-light.

> "If we get into a dark room, we will not easily realize the shape, size, height or even the colour of this room. But as soon as a spot-light gets inside the room, its characteristics will appear for us clearly. Whenever the quantity of the Natural-light will increase these features will be realized more and more by us." (Carlson ,1984, p26).

Hence we can realize the space. As we change the quantity of the Natural-light entering inside the space, its direction or its colour we will not have the same impression about the shape of the space such as size, appearance, height and depth. Instead, we will get different impression about the space features which we are watching even after the

stability of the real shape of the space immediately after the change of the area or the direction of the windows through which the Natural-light penetrating, or even when the colour of the window glasses is changed (Carlson,1984, p28).

There have been several researches done in the field of education with regards to the aspect of light and how it affects students. In a study done by Innovative Design entitled analysis of the performance of students in daylit schools, (Heshong Mahone Group ,1999). libraries with superior light resulted in significantly lower noise levels.

Research done in three schools in California, Colorado and Washington used multivariate linear regression in gauging the performance of 21000 students (Heschong, 1999). The outcome of the research shows that classes with more daylight is 201% faster in solving mathematical papers, 26% faster in reading and understanding questions compared to other classes with less daylight usage. Among all three, the class with the most daylight is ahead of others in overall exam marks ranging from 7% to 18%. A research using light spectrum as a variable to differentiate students in a classroom with full light spectrum and a classroom with a conventional artificial lighting has been conducted for two years in Alberta, Canada shows that students from the classroom with the full light spectrum has the least absentees and an increase in the students well being (health) compared to students in classrooms lit with conventional artificial lighting.

Daylight also has the ability to encourage people to meet and gather in different ways (Guzowski, 2000, p.28). Human social connections can be achieved with the aid of daylight. The author wrote that people gather in places with distinct qualities of light; in a warm climate, people might pause under the dappled light of a tree-lined plaza; in a cold climate, they might sit in a pool of warm sunlight from a south-facing window. Architect Christopher Day as quoted by Guzowski (2000, p.28) argues that: "To quite a large extent how people meet is supported or hindered by the environment." This reflects back to the type of places and particularly what "places of light" you are drawn to for different types of social interactions. Professor J. Stephen Weeks of the University of Minnesota as quoted by Guzowski (2000, p.30) distinguishes between " the place for one, the few and the many." The place of light for one is an intimate experience such as the reading carrels at the Exeter Library designed by Louis Kahn. The places of light for the few refers to small communal activities that might contain pockets or pools of light and shadow that gather and hold several people such as Tadao Ando's Soseikan Tea House that uses low horizontal windows to define a space of light for the master of the tea ceremony and the seated participant.

Guzowski (2000,p.34) also suggest that daylighting supports or undermines social hierarchies and power structures. As quoted by Guzowski (2000,p.34) "daylight can be equated with power:The location of the secretarial office is routinely predictable: the boss occupies the outer office with the windows and views; the support staff is clustered in the interior". Daylighting also has the capability to encourage people to participate in and interact with their social, built and natural environment.

As Diane Ackerman explains in Guzowski (2000,p.34) on her book entitled A Natural History of the Senses: “Even people who have been blind since birth are greatly affected by light, because, although we need light too see, light also influences us in subtle ways. It affects our moods, it rallies our hormones, it triggers our circadian rhythms”.

2.5.1. Daylight and Human Psychology

Many research show that among other factors, daylight plays an important role in affecting and influencing human psychologically.

Katz (1998,p.24) in his research on indoor lighting design incorporating human psychology found that daylight affects the human being psychologically. In a study done by Innovative Design entitled analysis of the performance of students in daylit schools, full-spectrum lighting induced more positive moods in the students. Ruk (1989,p16) agreed that the illuminated environment acts as a vital role in shaping our mood, reactions and even psychological well being. Katz (2005) found that daylighting is capable of improving the human morale. According to Loveland (2002,p.69) on the topic of daylighting and sustainability, people feel happier in a space lit with daylight. Monotony and uniformity in the distribution of light in a building should be avoided for it would contribute to the perception of gloom (Shepherd, 1992,p39).

According to Flynn (1972,p.48) “lighting has the capability to influence ones subjective impression or perception”. In other words, light can be manipulated to control or direct peoples actions. The fact that human being responds to light might be due to the vast properties of light itself. The existence of light has been proven to project positive effects in human being.

According to Katz (1998,p.26), light plays a vital role in determining ones experience and perception. Negative effects such as depressive moods are related to the usage of balanced light and the interplay of shadow. The capabilities of light in influencing the human perception might suggest why people tend to gather in brightly lit spaces compared to dark spaces. “The ability of light in influencing occupant’s perception of appearance of a space” as stated by Shepherd (1992,p42) supports this idea.

Dark spaces have also been associated with crime. According to Flynn (1972,p.62) “muggers, vandals and burglars are attracted to dark buildings, and avoid those that are well-lit”. This suggests that dark spaces encourage negative human behaviour. Light is also known for its capability of creating different environment for a space in an instant as stated by Shepherd (1992).

Patients in windowless hospital rooms experience an increase in stress levels and exhibited a doubling post-operation delirium cases (Evans, 1981). According to IESNA (2000) Lighting handbook why people options for spaces with more light,is explored as: “ Light profoundly affects our feeling of well being, of awe and wonder, of mood,

of comfort and motivation.The ability of light in evoking positive effects in the human being might render the subconscious mind to respond to it; such as going to places with more light instead of vice-versa without realising the act".

2.5.1. Daylight and Human Physiology

The fact that human well being and light is interrelated could be a contributing factor to why the human being reacts and responses to light. For example, "radiant energy accepted through the eye or as it penetrates living tissue, stimulates glandular response, metabolism, hormone development and the entire autonomic system-respiration, heart action and even appetite" (Steffy, 1990,p. 27). The author stated that apart from vision, light is also capable of influencing hearing and thermal sensation.

Katz (2005) in his research on daylighting harvesting technologies pointed out that "daylighting helps satisfy the human needs for natural light which promotes various health and performance benefits". This statement is also supported by Loveland (2002,p.73) on his research of daylighting and sustainability where he pointed out that "spaces that are lit with daylight is capable of making people feel happier" and he agreed that "daylighting supports human health and activities". The author discovered that an increase in illumination level could increase hormone production, in particular, the stress hormone cortisol.

In a study done by Heshong Mahone Group (2003); study of student performance and the indoor environment analysis of the performance of students in daylit schools,

students exposed to a full spectrum of light were healthier and attended school 3.2 to 3.8 days more per year than comparative non daylit schools because of the additional vitamin D received by the students in full-spectrum light, students had nine times less dental decay and grew an average of 2.1 cm more over a two year period, than students attending school with average light. Heshong Mahone Group also did a study on the effects of types of light on children and found out that students under full spectrum fluorescent with ultraviolet supplements developed fewer dental cavities and had better attendance, achievement and growth and development than students under other lights (Heshong Mahone Group ,2003).

Birren (1988,p.81), stated that "haemoglobin in the blood could be increased by light and decreased under darkness that would lead to why people normally feel sleepy under a dimmer environment". The presence of light plays a significant role in determining human well being. "Lack of exposure to daylight and even sole dependency to artificial light could cause harm not only to human but even other living beings". (Loveland ,2002,p.47)

Veitch and Mcoll (2004,p11) do research on the impact of fluorescent light on endocrine, neurophysiological and subjective indices of well being and stress found out that fluorescent light of high illuminance may arouse the central nervous system and that this arousal will become accentuated if the lamps are of the 'daylight' type. They suggested that the practical implication might be that people should not be exposed to fluorescent light of high illuminance for a prolonged period of time. Artificial lighting

such as fluorescent lamps for example shouldn't be used commonly for it poses negative effects towards human well being and behavioural patterns.

According to Evans (1981,p.41), excessive brightness ratios in the field of view should be avoided which suggests that the best visual conditions are achieved in a uniform environment, but lack of change is inconsistent with the natural capabilities and tendencies of people. He stated that one of the strongest elements in the establishment of a sense of orientation and well-being is the presence of direct sunshine in buildings. Evans came to a point that changing nature of daylight automatically and naturally responds to the need of the body and mind for change of stimuli or mood. Evans also discussed on the need for human body to be able to relate to its natural surrounding both physically and mentally. He pointed out that aviators who lose contact with the horizon and the exterior surrounding in adverse weather are subject to vertigo and must use instruments to maintain level height.

Prolonged exposure to artificial lighting such as the fluorescent lamp could lead to diminished visual acuity occurring after lengthy periods of fatigue and stress, manifest in terms of eyestrain, opthalmalgia, eye fatigue and headache; also known as asthenopic(Evans,1981,p.46). Veitch and Mcoll (2004) studied asthenopic complaints associated with fluorescent lamp illumination and found out that it affects predominantly female, 20-30 years aged, and possess a higher than normal

psychovegetative ability, diminished power of concentration, enhanced light sensitivity in cases of flicker sensitivity and reduced binocular and stereoscopic vision.

The results derived as a relationship between overall evaluation of lighting and behavioural responses in the human well being suggests that one of the keys to designing a comfortable indoor lighting environment is to eliminate the darkness or the excessive brightness which occupants feel in interior building.

2.6. Significant Impacts of Daylighting

The proper introduction of natural light in buildings has many advantages and benefits, which range from the aesthetic to physiological and economic.

2.6.1. Daylight and Health

While daylight is often engaged as a means for interior illuminance it also plays a role for other qualitative aspects of occupant experience in buildings. Daylight sufficiency from the perspective of Indoor Environmental Quality (IEQ) is defined in regard to the human biological need for a circadian stimulus and for visual information enabling connection to the outdoors. A growing body of research in the disciplines of photochemistry, photobiology, and human physiology demonstrates that exposure to solar radiation (i.e. daylight), has a range of influences on human biology that are important for health and well-being. For example, daylight is known to control the circadian rhythm of hormone

secretions, with implications for sleep/wake states, alertness, mood and behavior (Steffy1990, p59).

Research has shown that disruption of the circadian system by shift work is associated with sleep-wake disorders, gastrointestinal pathology, and an increased risk of cardiovascular disease . Exposure of patients experiencing seasonal affective disorder (SAD) exposed to a bright light source that simulates daylight in intensity and spectral quality has been shown to reduce symptoms of depression. (Stevens and Rea ,2001,p.73)

According to Baker and Steemers (2002,p.148) the intensity of light is one of the most important aspects that effect humans. The author stated that the intensity of light entering the eyes activates a specific neural pathway, which regulates the arcadian rhythm. Because humans have evolved in natural light, a variety of body organs exhibit diurnal cycles of activity, which are linked to the production and release tuning during a 24hs cycle of melatonin hormone by the pineal gland The release of melatonin at night helps to redure stress, and facilitates sleep, and these effects are reversed during daytime when melatonin production is switched off (Baker and Steemers ,2002,p.148) .The sleep-wake cycle is the most obvious of the circadian rhythms: others include variations in body temperature, insulin production regulation of kidneys and sex organs as well as influencing mood and sense of well-being in humans .(Baker and Steemers,2002,p150).

Receiving adequate levels of intense light (daylight) each morning synchronizes the internal body clock to the Earths' 24hour rotational cycle (Stevens and Rea ,2001,p.79). At this time, people are usually at home or on their way to work. However, such pre-work exposure is not in itself sufficient and without adequate daylighting at the workplace, maintenance of the circadian 24 hour cycle is difficult to achieve, thus the importance of good daylighting design of commercial buildings is obvious (Baker and Steemers ,2002,p152).

When low levels of light are received, the circadian cycle in the body slows down and circadian resynchronization will be experienced. Melatonin will be released at the wrong times of day, resulting in lethargy, and drowsiness. Most seriously, disruptors of the melatonin rhythm may lead to chronic fatigue, depression reproductive anomalies, and perhaps even cancer (Stevens and Rea. 2001). Seasonal affective disorder (SAD), for example, is now a well-known disorder affecting people in countries at high latitudes that results from the lack of sunlight or reduced sunlight hours in winter (Baker and Steemers,2002).

However. many studies show that the proper use of daylighting decreases the occurrence of headaches, SAD, and eyestrain .Headaches and SAD are related to insufficient light levels. These ailments are reduced when the lighting level is improved by using proper spectral light. (Stevens and Rea. 2001).

2.6.2. The Role of Daylight in Enhancing Productivity

Probably, the most comprehensive studies on daylight in buildings and its influence in people's performance are the studies carried out by the Heshong-Mahone Group in schools, offices and retail buildings. The first study on schools was performed in three districts in the USA. Statistical data from approximately 100 elementary schools within these districts were gathered. The data included the standardized math and reading test results of the students and lighting conditions of the classrooms. The analysis showed that students with the most daylighting in their classrooms progressed 20% to 26% faster when compared with students in classrooms with no windows (Heshong Mahone Group, 2003).

However, these results could not be replicated in another study on the Fresno School District in California . The general conclusions were that where daylighting provides an even distribution and extensive view, limiting glare and thermal heat gain, the students' performance was likely to improve. In contrast, where windows increase the level of noise, glare, or contribute to the distraction of students from outside activity then the students learning progress is reduced .Heshong Mahone Group ,(2003).

Studies on retail buildings have investigated the relationships between good daylighting and sales. The performance data used was an l8-month gross sales average per store for the one chain retailer. The study found that those stores with skylights had a 40 %

increase in sales in comparison to those without natural light (Heshong Mahone Group, 2003). A more recent study examined a different retail chain to test these results. Although the daylight effect on sales was constrained by the amount of parking available on the site, this second study found that for stores with good parking and daylight, there was a similar increase in sales.

These various studies have shown that daylighting alone cannot dramatically improve sales or performance. It must be well-designed to avoid glare and heat gain, and it should be part of a holistic design that responds to the desired function of the building. Although not necessarily the primary aim of daylighting design, increased sales of retail stores or profits of companies are important benefits. People prefer daylight, and it is clear that daylight has a vital affect on the health and well-being. (Baker and Steemers, 2002).

These studies showed a relationship between good daylighting design in buildings and occupants increase in productivity.

With properly installed and maintained daylighting systems, natural light has proved to be beneficial for the health, productivity, and safety of building occupants.

> "Natural light helps maintain good health and can cure some medical ailments. The pleasant environment created by natural light decreases stress levels for office workers. Productivity increases with the improved health of workers, and with better productivity comes financial benefits for employers. Students also perform better with natural light". (Stevens and Rea. 2001,p.27)

However, the effects of natural light on bulding occupants should be well considered by the building designer because all the studies through the world on diffrent types of

buildings and in many diffrent environment has showon the strong influence of natural light on people.Finally, daylight can provide satisfcation for both building occupants and the building itself.

2.6.3. Daylight and Energy in Buildings

Daylighting is the practice of bringing light into a building interior and distributing it in a way that provides more desirable and better-quality illumination than artificial light sources. This reduces the need electrical light sources, thus cutting down on electricity use and its associated costs and pollution.As discussed before, studies substantiate that daylighting creates healthier and more stimulating work environments than artificial lighting systems and can increase productivity(Baker and Steemers,2000,p.33).In a procedure developed by the National Renewable Energy Laboratory (NREL) to measure indoor lighting energy performance daylighting is defined as:

"Indoor illumination provided by natural light entering the space through some type of fenestration that results in a reduction of necessary electrical lighting for ambient, accent, emergency, or task lighting". (Deru et. al.,2005,p.18)

In the NREL definition of daylighting, "necessary" refers to the standard workplane illuminance levels for commercial office buildings recommended by the IESNA Handbook (IESNA, 2000). Workplane illuminance refers to the amount of visible light measured at the workplane using a global illuminance meter. Performance is considered in terms of minimizing electrical lighting energy required to achieve recommended workplane illuminance levels (Deru et. al., 2005).

> "Daylighting significantly reduces energy consumption and operating costs. Energy used for lighting in buildings can account for 40 to 50 percent of total energy consumption. Properly designed and implemented daylighting strategies can save 50 to 80 percent of lighting energy". (Deru,2005,p.22).

According to Deru(2005,p.19) "The issue of the potential to save energy through effective daylighting design seems to be generally believed that good daylighting design will lead to reductions in electric lighting consumption, and also overall energy consumption".

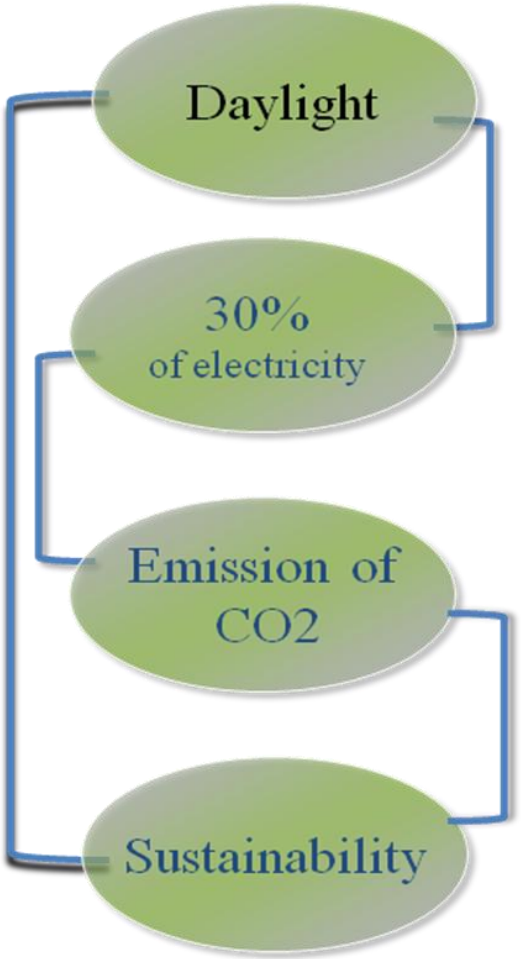
> 'When lighting electricity consumption is considered along with heating and cooling as part of a whole building energy equation, daylighting typically provides a net energy benefit. Daylight is intrinsically more efficient than any electric source because it provides more lumens per unit of heat content. Therefore, if appropriate daylighting techniques are used to displace electric illumination, the savings for both lighting and cooling can be dramatic".

According to Baker and Steemers (2000), the use of natural light in buildings has many implications for the energy use in buildings. A reduction in the energy consumption of a commercial building can be achieved by decreasing the need for, or use of artificial light. Natural light is more efficient than electrical light, by providing more light for less heat than artificial light. For example, at a given level of illumination, a tungsten light produces between 5 and 14 times more heat than daylight. As a consequence, daylight also lowers the cooling requirements of a building up to 15% (Baker and Steemers 2000, p.32).

By using daylight, the use of electric lighting is reduced. According to the IESNA Handbook, the use of daylight can reduce the amount of electricity used for interior

lighting by 30% thus lowering the emission of CO2 and in turn improving the sustainability in building as show in table 2.4 . At the present time, when energy is expensive and sustainable development is an important consideration in architectural design, daylight is once again seen as an important technique to help obtain energy savings (IESNA. 2000).Given these benefits, it is obvious that daylight should be utilized to its full potential to help creating a visually pleasant environment and sustainable architecture.

Table 2.4 The Role of Daylight in Sustainability



2.7. General Evaluation of Daylight towards Sustainability

Research in daylighting has recently received major attention for its valuable contribution to the sustainability of the built environment, thus research have been held upon the role of daylighting in energy efficiency, its regional qualities in relation to the façade configuration, and its contribution to the sense of visual comfort and to enhance indoor environment quality. Ann (2009) states that generally daylight variables in interior public spaces include a combination of sunlight, skylight and the reflected light from the facades and the ground. The Solar altitude, the geometry of sectional profiles, the reflectance of the opposing facades are aspect effecting the level illumination in spaces (Ann ,2009,p.12).

One of the significant strategies should be to evaluate in indoor environment quality, as one of the criteria of sustainable interior design is daylighting. Different aspects of daylight system can be examined to evaluate the building performance to guide building design step towards sustainability such as the impact of daylight in building energy efficiency and quality of design. Indoor environment quality covers many issues for air quality including ventilation and low-emitting materials as well as thermal comfort ,and daylight access. Thus implementing good daylighting in the interior public spaces specially of huge structure buildings can improve air quality and reduce the pollution levels towards achieving sustainable interior spaces (Reinhart and Galasiu, 2006,p2).

The work here may show the link between daylighting and sustainability concept through the version of sustainable building rating system LEED which is originally developed to provide a fram work for assessing building performance.

According to research in lighting and technology by Mardaljevic (2009); drive towards sustainable, low-energy buildings places increasing emphasis on the need for detailed daylight performance evaluation. This need ranges from useful guidance at the early design stage, to code compliance based on construction documents, and to post occupancy stage. The daylighting performance of a space, and its component parts, are potentially of concern to many stakeholders throughout the life of the building. Stakeholders and their concern for providing the acceptable level of daylighting in the building can be categorized as the following:

1- Building occupants feel more safe and active in day lit environment.

2- Owners of firms pay the salaries of the building occupants may wish for a pleasant day lit environment as a demonstration of concern for the occupants well being or productivity

3- Renters who bear the running cost of the building may wish to maximize daylight exploitation to reduce electric lighting and space conditioning costs. (Mardaljevic,2009.p.30).

4- Government and regulatory bodies may wish to encourage the same to reduce energy use or carbon emissions. Utilities may wish to curtail peak electricity demand to defer the need for more power generation capacity (Heshong Mahone Group,2003)

5- Manufacturers of materials, devices or systems where the provision or control of daylight is a key feature of the product or technology. Examples include: glazing in general, skylights, light- pipes, light re-direction materials (e.g. Serraglaze), light

modulating materials (e.g. electrochromic glazing), blinds, shading devices, etc. (Heshong Mahone Group, 2003).

6- Architectural team and designers who, in their drive to design better solutions, will compare and improve their designs based on performance data. (Ann, 2009).

Each one of these purposes and associated stakeholders has slightly different needs in terms of the level of detail and effect in terms of sustainability concept.The list is not complete. For example, some health professionals believe that daily exposure to high levels of daylight illuminance may have signicant, long-term health benets, and that should as well be a design consideration (Mardaljevic,2009.p.31).

According to US Green Building Council (2006), "Design professionals that concentrate on the architectural aspects of daylighting, strive for that 'interplay of natural light and building form' often rely on the daylight and views within the LEED and Indoor Environmental Quality section for a performance metric" By using daylight, the use of electric lighting is reduced. According to the IESNA Handbook (2000), the use of daylight can reduce the amount of electricity used for interior lighting by 30% thus lowering the emission of CO2 and in turn, the green house effect.

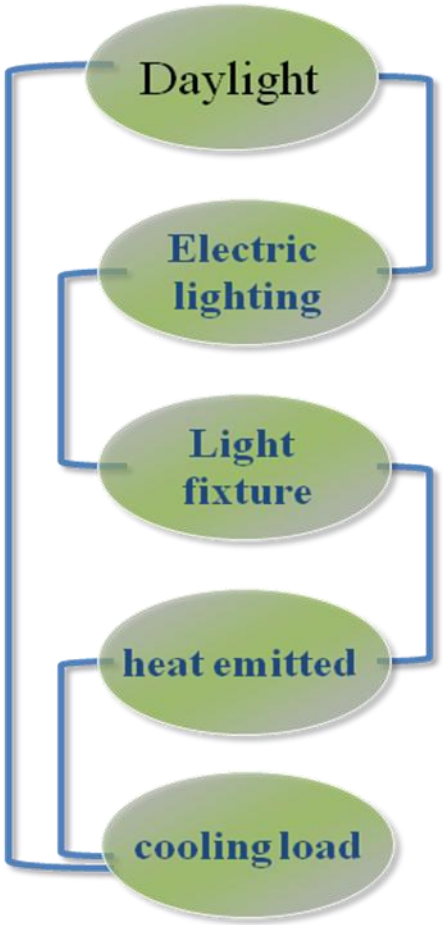
As mentioned before in the second chapter, according to Yaldiz and Magdi (2010,p.2) "Sustainability is a multi-dimensional concept that has environmental, social, political, economic, cultural and spiritual dimensions".However, the link between sustainability and daylight in buildings can be summarized by the following scheme:

Table 2.5 The Link Between Sustainability and Daylight

Sustainability	The Role of Daylight in Achieving Sustainability
Resource sustainability	Using daylight to affect the energy performance of the building.
Economic Sustainability	Using daylight to enhance indoor environment quality. Productivity increases with the improved health of workers, and with better productivity comes financial benefits for employers.
Human sustainability	The physiological effects of daylight on the human body and psychological effects as part of general human health.

When the concern of daylight is applied in shopping center interior spaces, aspects and dimension of sustainability such as human well-being, health and satsfaction can be mentioned as common features for all building types .To discuss these categories of sustainability in detail begining with “Resourcse sustainability” simply using daylight for energy efficiency can reduce the use of electric lighting power, such a reduction will reduce lighting density and then light fixture will be reduced and such a reduction can result in a lowered cooling load as there is less heat emitted by these fixtures as show in (table 2.6).

Table 2.6 The Role of Daylight in Sustainability Resource



The secound category is “Economic Sustainability” as mentioned before in the impacts of daylight (2.5.2 Enhance productivity) “Productivity increases with the improved health of workers, and with better productivity comes financial benefits for employers” (Stevens and Rea. 2001). Many studies on the role of daylight to enhance productivity prove that employees that have access to daylight will be happier in their work and will consequently complete their work more effectively. Daylight noy only impacts job satisfaction, but also daylight has been proven to contribute indirectly to lowerd stress levels for building occupants.Morever daylight has been shown to provide the effect of promoting a positive and comfortable indoor environment for the users.

Finally, “Human Sustainability” and daylight conection can easy appear through the link between the role of daylight on physiological dimension of human body. As mentioned before (in 3.2.1 The Effects of Daylight on Human Behavior), Steffy (1990, p59) stated that “daylight is known to control the circadian rhythm of hormone secretions, with implications for sleep/wake states, alertness, mood and behavior”. In addition to the emotional benefits of daylight circadian rhythm and mood is considered as human sustainability aspects. As a result from discussing the impacts of daylighting in building, it is important to understand the resons for bringing and introduce daylight in buildings.

CHAPTER 3

SYSTEMS OF BRINGING DAYLIGHT INTO INNER SPACES

In this chapter, ways of bringing daylight into deep plan and multistory buildings will be examined through providing the information about the available technologies and strategies to transport the natural light into innermost spaces. Examples and studies that have been done in different types of buildings will be demonstrated to make these strategies more explicit.

Reasons of bringing natural light into interior spaces of buildings has been made clear through the literature review in the second and third chapters of this research and it can summarized as following:

1) Quality of natural light, its spectral composition, and variability gives a better-illuminated environment than artificial light. The human eye has evolved to respond to natural light stimulus, and electrical light does not achieve the same stimulus.

2) Daylighting has psychological and physiological benefits that may improve the performance of people, which it is not obtainable with electric lighting.

3) Better energy efficiency is obtained when replacing the demand for electricity during the peak hours of the day by the use of natural light

4) An overall sustainable result can be achieved by reducing the dependence on non-renewable energy sources and this can enhance indoor environment quality as one of LEED (Leadership in Energy and Environmental Design) categories.

5) Workplace health can be improved, and in addition, a positive and comfortable indoor environment for the users can be promoted by the use of daylight.

Introduction of natural light into interior spaces of shopping center buildings is normally achieved through simple apertures such as windows or skylights. Side lighting (from windows) in buildings decreases rapidly with distance from the window and generally, this spaces require artificial lighting for illumination.

Top lighting (from skylights) is a very good solution to obtain good daylight distribution levels in the space, as long as the ceiling apertures are well designed and do not let direct sunlight in.

Figure 3.1 Daylighting from Skylights (Ankamall, in Ankara)

Figure 3.2 Daylighting from Skylights (Cepa mall and Gordion AVM , Ankara)

> "Illumination from skylights can only reach the top floor of a building. For multistory buildings with deep plans, atriums and light wells have been used to bring natural light deep into the building. Having an open space in the middle of the building, not only creates more facade but also diminishes the depth of the plan "(Northen,1977,p.52).

Electrical lighting has replaced daylighting as means of illumination as good daylighting is usually not possible in shopping center buildings. The building form and orientation, ,the building location and surroundings are important considerations with respect to utilizing daylight (Northen,1977, p.54).

In addition, using electrical lighting during midday hours has many reasons and depends on the level of natural illumination existing in these spaces. Using these, electrical lighting has several direct and indirect detrimental affects (i.e., energy

inefficiency, the use of non-renewable resources and production of greenhouse gases, and unhealthy and unproductive environments for the occupants of the building). The question in this chapter is how to bring natural light in to innermost spaces of shopping center buildings to improve energy efficiency and the appropriate indoor air quality for building occupants

Contemporary shopping malls are mostly considered as a deep plan and multistory buildings there is a reason to be so. According to Baker and Steemers (2002), there are two main reasons for the popularity of deep plan buildings in design for shopping mall buildings.

> "**First**, they provide good cost/benefit returns due to maximum site coverage. In cities, land cost is expensive, and individual lots are often small. For maximum return on investment, developers build upwards and more intensively on a given piece of land. **Secondly**, they satisfy the requirement of large quantities of space at the same level by building tenants." (Baker and Steemers ,2002, p.18)

Electrical lighting has promoted the growth in deep plan building design and construction. Electrical lighting has replaced daylighting as means of illumination as good daylighting is usually not possible in these buildings. As Aizenberg (2003,p.29) points, reasons for the use of artificial light in deep plan buildings include:

1) Large differences in illuminance levels between perimeter and central areas due to side lighting creating problems of bright and dark zones.

2) The placement of small shops along the perimeter that block light from side windows to the interior.

It is clear that to naturally illuminate a deep plan and multistory buildings such as shopping mall is not an easy task.

Generally, bringing natural light further into the interior zones of large buildings is possible with simple daylighting strategies such as windows or skylights. (Littlefair,1990,p 17)

Another strategy for bringing natural light into innermost spaces of deep plan buildings is light transport systems, collect and transport sunlight over long distances within a building, and are usually referred to as light pipes or light guides (Littlefair,1990, p.49).

According to Littlefair(1990, p.51) light transport systems generally have three elements:

1) A collection head, which tracks sun light, or simply redirects it inside the pipe.

2) The pipe itself that transports the light to where it is needed, with the method of transportation dependent on the material selected for the pipe (i.e. lenses, mirrored light pipes, prismatic pipes and solid core systems)". (Littlefair,1990, p.51)

3) A distribution system that includes extractor devices, which extract light from the pipe to the exterior, and diffusers that spread light uniformly across the space. (Baker and Steemers,2002).

For deep plan buildings such as shopping malls, with depths greater than 10m from the window, natural illumination can only be practically achieved by light transport systems. "Light transport or remote source systems are devices capable of channeling sunlight to areas in buildings that receive inadequate natural illuminance and usually remote from the building envelop. These systems consist of three major components

:light collection ,light transportation, and light distribution: (extraction and emission)".(Ayers and Carter. 1995,p.26)

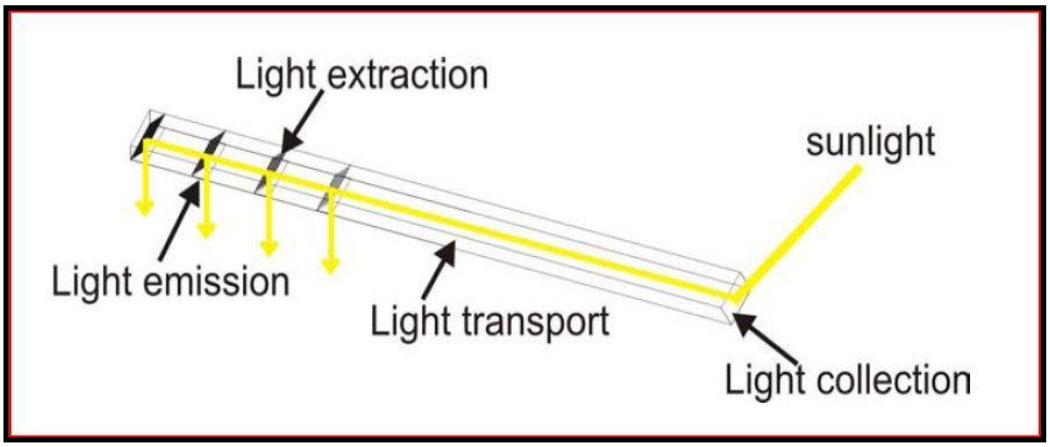


Figure 3.3 Light Piping System Diagram

3.1. Light Collection System

Collection systems generally consist of reflective or refracting devices. Their main objective is to capture sunlight and direct it through a small aperture into the interior. Collecting and conveying daylight to a specific location can be achieved by active or passive systems (Littlefair, 1990). "Light collection is achieved either by redirection of sunlight by, for example, flat minors, or by concentration of light (e.g. anidolic systems, fluorescent panels). Concentration describes the increase of illumination on a surface above the incident solar level". (Ayers and Carter. 1995, p.28)

Light collection system is consist of two way to collect sunlight : light concentrate system and light redirection system, collection of sunlight by concentrate sunlight can be achieved through using more than one system such as luminescent solar concentrator (LSC) , anidolic concentrators . In contrast to the light concentration collector systems, light redirection systems operate on aligning sunlight with the light transport system. The efficiency of light transportation in light pipes depends strongly on the angle at which sunlight enters the light pipe. (Aizenberg, 2003,p.48)

The main examples of light redirecting systems used with light transport systems are reflective device and laser cut panels (Aizenberg, 2003).

3.1.1. Light Concentrate System

3.1.1.1 . Reflective Devices

Reflective devices are made of high reflectance material and are designed to redirect the maximum amount of daylight falling on the collector to the light pipe aperture. These devices do not concentrate daylight, and can be flat or curved mirrors.

A representative working example is the Heliobus system developed for a school in St. Gallen. Switzerland (Aizenberg, 1997). The Heliobus (Figure 4.2) system consists of a concave minor (2.25m high. 1m diameter, and 95% reflectance) to collect natural light, a unit containing an artificial light source, a vertical hollow prismatic guide (9.1m high and 0.65m wide), and extractors (Aizenberg, 2003,p.50).

Figure 3.4 Heliobus Sun Collector

Figure 3.5 Light Pipe

A static, specially designed mirror gathers the light on top of the roof of the school building and directs it into a vertical light pipe. This pipe extends over three floors and reaches right down to the underground floor. The light pipe illuminates the various floors and fascinates observers through special optical effects. The bottom end of the light pipe diffiuses the light via an attached light dome and illuminates the entire basement floor.

Another example of light redirecting systems used with light transport systems is laser cut panels.

3.1.1.2. Laser Cut Panels (LCP)

Laser cut panels comprised another light redirection system that has been utilized for the improvement of daylight collection in domestic scale mirrored light pipes . Depending on their inclination, LCP helps to improve daylight collection when sun elevation is low in the sky, and can reject sun rays at high solar elevations to reduce problems of overheating .(Littlefair, 1990,p52)

Figure 4.6 illustrates how a Laser cut panels **(**LCP) redirects light more axially along a mirrored light pipe.

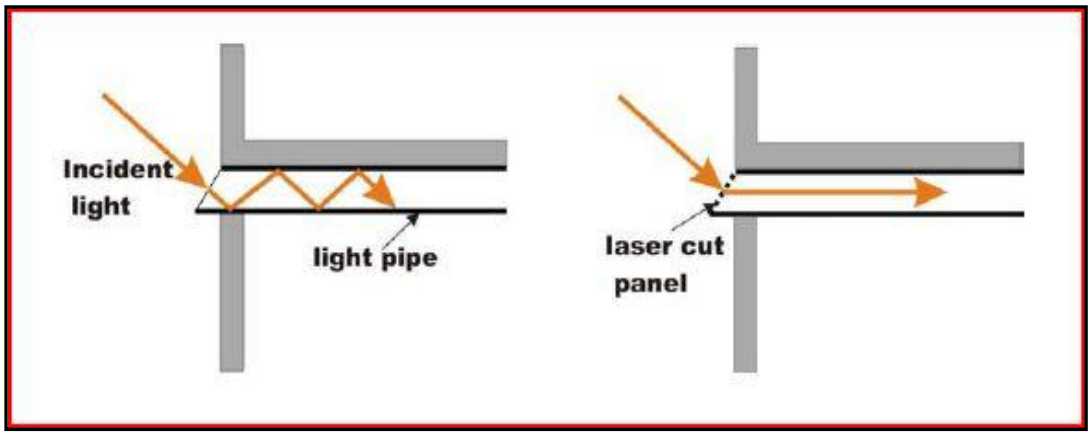


Figure 3.6 Left- Light pipe with clear glazing. Light at any angle coming into the pipe will be lost due multiple reflections. Right- Light pipe with

LCP. The LCP ideally redirects light along the pipe diminishing the number of reflections and therefore losses of light intensity.

" Benefits of this system are

1- Its relatively low cost.

2- The potential to collect light from the whole sky vault

3- The ability to deflect both direct and diffuse components of daylight".(Littlefair, 1990,p.53)

3.1.2. Light Redirection System

Heliostats are flat mirrors usually placed on the roofs of buildings that track the position of the sun and then redirect it into light transport devices to be guided to interior spaces in buildings. A mechanical system allows the minor to track the sun motions. The tracking is automatically controlled by software and hardware. Depending on the collector assembly, the optical axis may be designed for altitude or azimuth tracking, combined altitude azimuth tracking, or polar axis azimuth tracking. The light ray is redirected to a second reflector placed in a fixed position that then directs the light to the aperture of the light pipe. The second element can consist of lenses, curved mirrors or Fresnel lenses that concentrate or focus light into the light pipe aperture. Figure 4.6 shows a design of a heliostat comprising

Figure 3.7 Heliostat Appropriately Located and Oriented to Provide Sunlight on The Requested Surface

Figure 3.8 White Hologram Appropriately orientated at the suitable inclination in accordance with its optical properties deflects sunlight so that it flows vertically into the narrow light shaft reaching even the last windows

A working example of a heliostat (Figure 4.7) has been installed on the roof of the Semper lux headquarters, a three storey building in Berlin (Ayers and Carter. 1995). The heliostat is part of a light transport system used to illuminate the staircase of the building. The heliostat is a two-axis controlled flat mirror system with an area of 6.25m that follows the altitude and azimuth sun angle. The focusing devices are Fresnel lenses that focus the light into a curved reflector that then guides the light into a hollow prismatic light pipe. (Ayers and Carter. 1995,p.31).

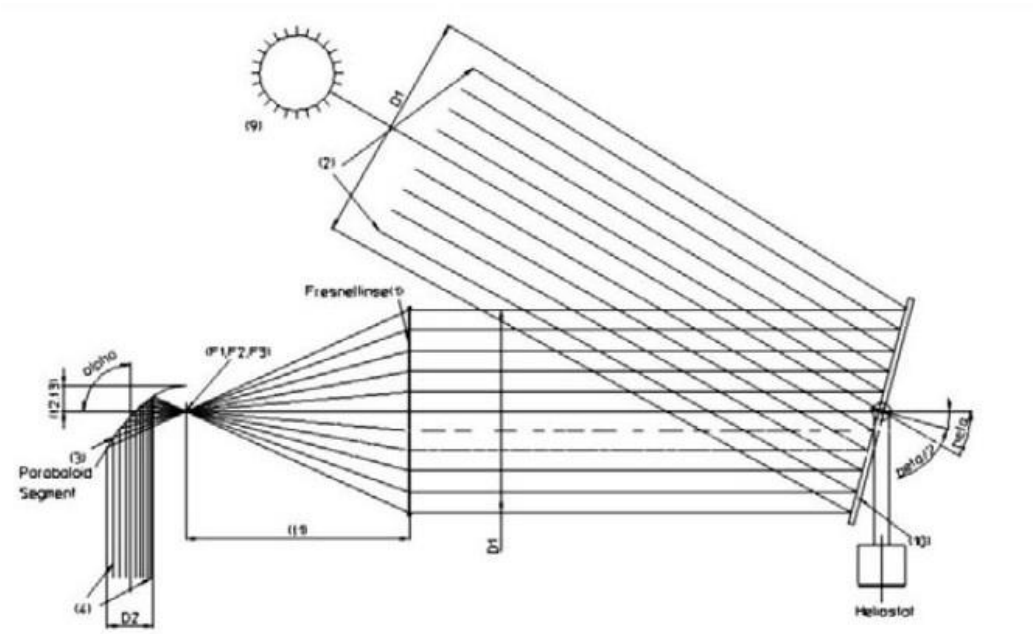


Figure 3.9 Schematic Design of Flat Heliostat, Focusing Fresnel Lenses and Curve Reflector

Figure 4.7 shows how the system looks on the building. Although the optical focusing devices are protected from the environment and integrated better with the building architecture, the heliostat mirror is unprotected and its performance will be reduced due to dirt pollution build-up. Regular cleaning and maintenance of the mirror is required to maintain optimal performance of the system. (Ayers and Carter. 1995).

Figure 3.10 The Heliostat on Top of The Semperlux Building in Berlin, Germany.

3.2. Light Transport Systems

Light can transported by three main strategies

3.2.1. Mirrored Light Pipes

In Mirrored Light Pipes, the light is transmitted inside the tube from the source to the output aperture by a number of multiple specular reflections at the inner wall surface of the pipe. (Aizenberg, 2003)

Mirrored light pipes of small-scale have been used quite successfully in domestic and commercial applications for the enhancement of natural light in rooms with poor illumination levels. (Aizenberg, 2003) .The technology is also being applied in buildings with a large floor to facade ratio that need to be illuminated through the roof such as supermarket, warehouses, etc (Figure 4.12).

Figure 3.11 Sunlight Tracker of Mirrored Light Pipes in The Roof.

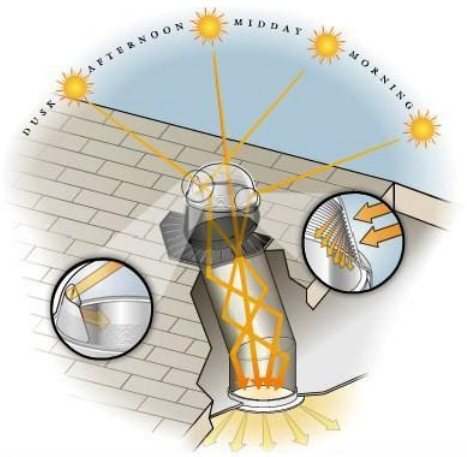


Figure 3.12 Mirrored Light Pipe.

Figure 3.13 Mirrored Light Pipes Use in Supermarket-South London

Figure 3.14 Mirrored Light Pipes in Showroom Roof San Diego

3.2.2. Horizontal Light Pipes (HLP)

“The inherent problem of distributing daylight with traditional windows is non-uniform floor illumination over the entire plan depth. This may result in a steep daylight profile so that under bright sky conditions the luminance near the window is much larger than that available at the far end of a deep plans”. The high brightness near the window may cause discomfort and glare to the occupants at the perimeter zone who may then activate sun shading devices, e.g. vertical blind, to reduce the excessive amount of daylight that penetrate through windows.(Smith,2001,p.17)

As smith (2001,p.17) states’ natural daylight illumination available in the far area is therefore further limited. The illumination of the internal environment unavoidably relies on artificial lighting. “The running out of fossil fuels and the recent unusual climate changes in some parts of the Earth indicate the need to conserve the environment and reduce the use of energy and global emission”(Littlefair, 1990). All these suggest the need to explore a new distribution method so that daylight can be delivered to a deep room effectively.

Horizontal light pipes (HLP) may help to enhance daylighting and improve the uniformity of daylight distribution even when the sun shading device inside the room is activated since HLP extracts light at the building facade. Sunlight and skylight can then travel through the HLP to the room area far away from windows where very little natural illumination is available through windows. A properly designed HLP

contributes to lighting energy saving by reducing the burden on the artificial lighting system. (Ayers and Carter. 1995, p.38)

A case study by the Architect Ken Yeang's examines development work on the application of horizontal light pipe technology in (Waterfront House) a high rise building in Kuala Lumpur, Malaysia (Figure 4.17)

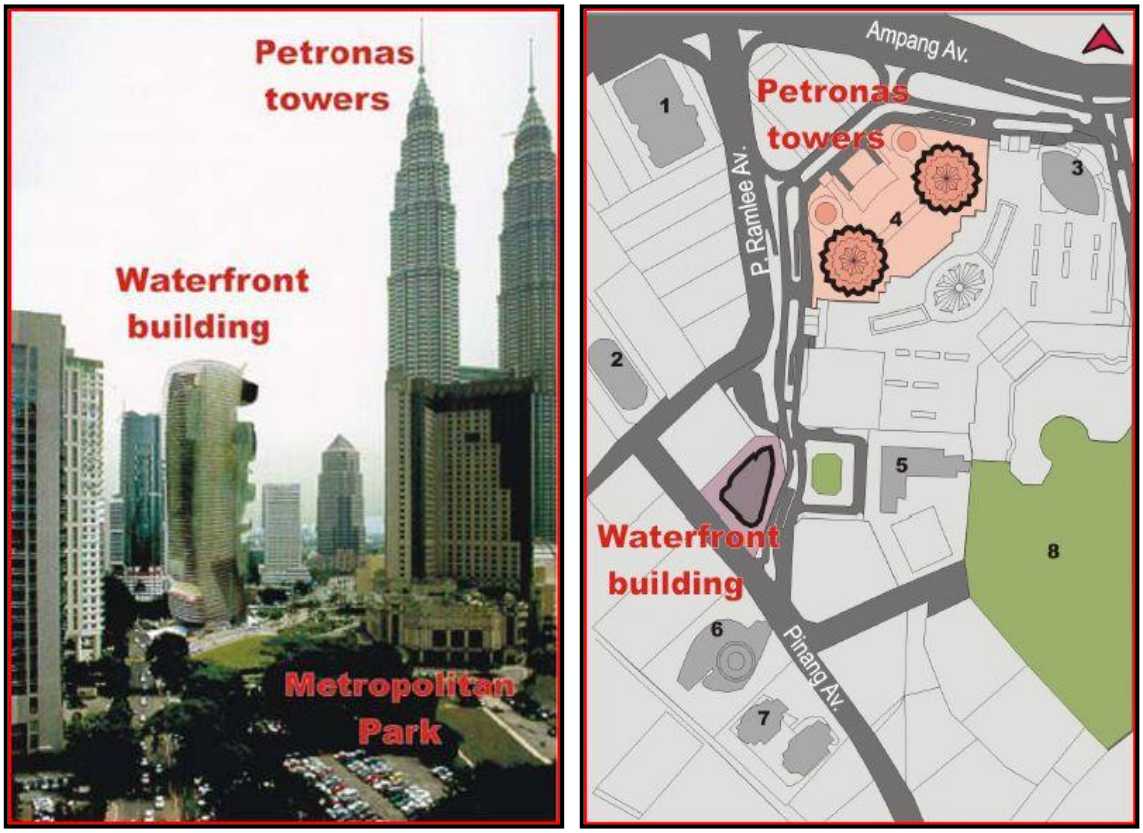


Figure 3.15 Waterfront House Building in Kuala Lumpur, Malaysia

The innovative device is the “light-pipe” as a passive low-energy device for transmitting natural daylight into buildings with deep plans.

The horizontal light pipe is a device that brings daylight into the inner parts of buildings without the use of any electrical or other sources of energy. The extraction and emission of daylight is transmitted horizontally and vertically using internal mirrored surfaced within a box-tube structure (hence the term “pipe”) coupled with laser-cut panels at the outer edge of the pipe as collectors. (Ayers and Carter. 1995, p.42)

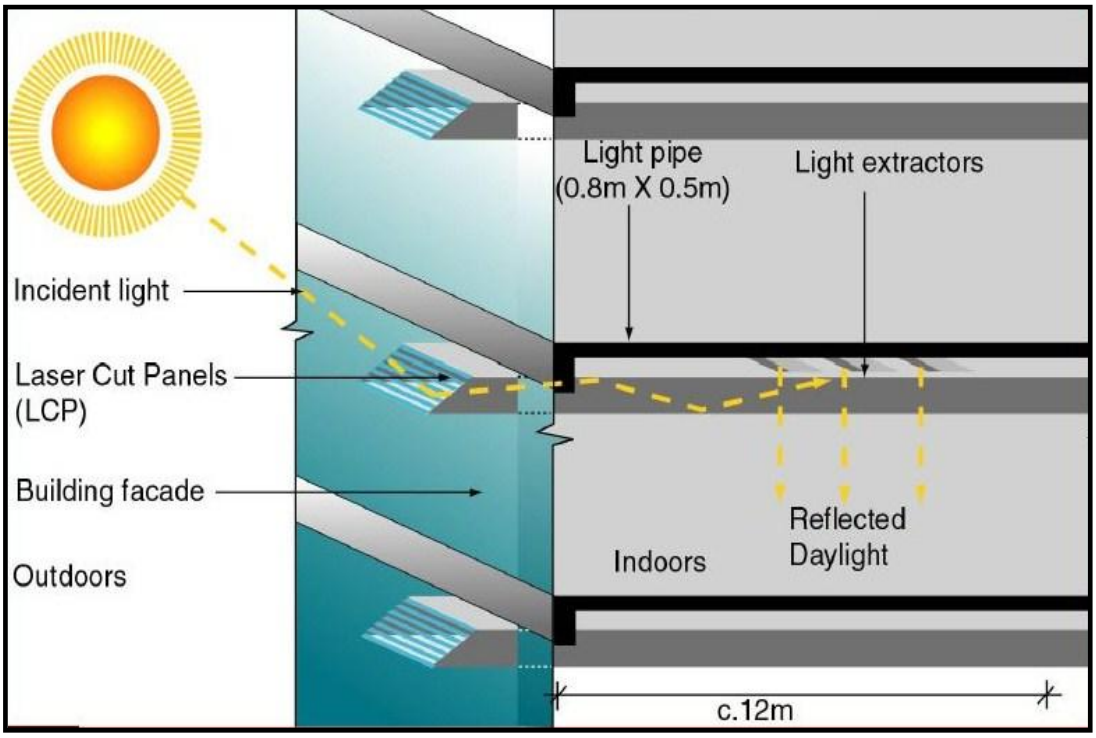


Figure 3.16 Diagram of Horizontal Light Pipe.

The horizontal light pipe comprises of a box (i.e. Like a duct, that has highly reflective interior mirrored surfaces and an arrangement of laser cut light deflecting panels (LCP) at the outside edge as sub-light collectors and extractors that redirect light along the

pipe to the interior spaces as required and with light emitters to spread the light uniformly around the space.

The Waterfront House building has a large floor plate .A 20 m deep plan floor is not susceptible to good natural lighting, and therefore four light pipes per floor, coupled with laser cut panels have been proposed to improve the daylighting performance of office space in the building (figure 4:22). The light pipes are designed to channel sunlight into the deep zone of the office plan as sunlight falls on the western facade of the building. (Baker and Steemers, 2000)

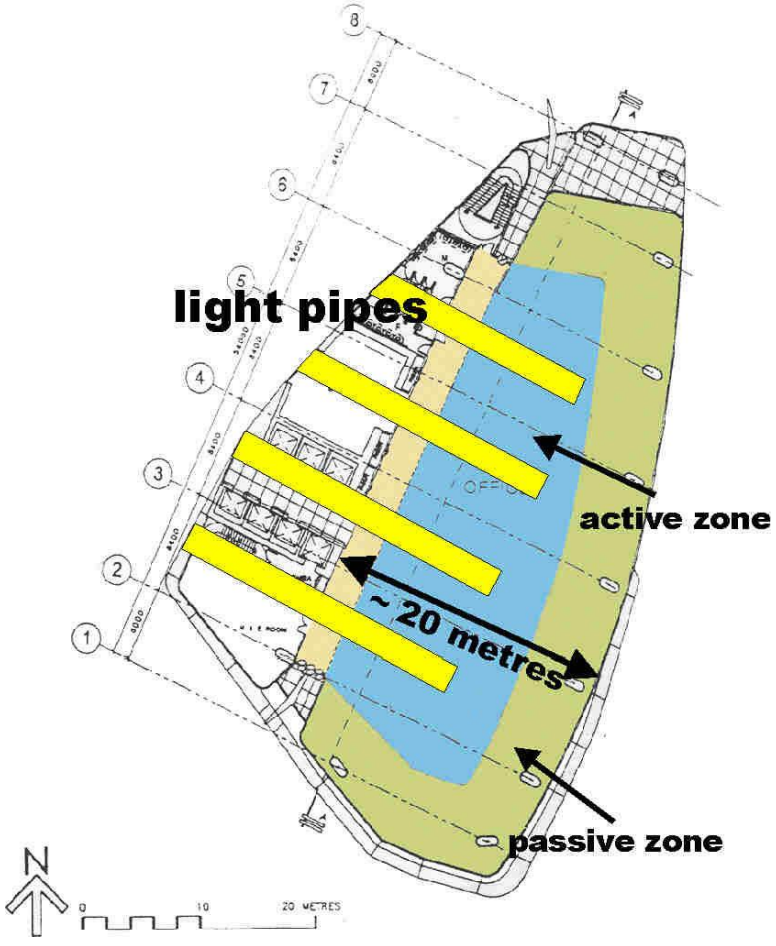


Figure 3.17 Light pipes in plan (yellow), aligned to come through the westerly core, Passive zone: spaces located on the perimeter that can benefit from the ambient environment.

The conclusion of this study has shown that horizontal orientated mirrored light pipe systems coupled with LCP (Laser Cut Panels) collectors provide a potential solution for the natural illumination of deep-plan office buildings, achieving an adequate spatial light distribution along the pipe. Illuminance values range from 100 to 400 lux for the horizontal light pipes over a period from noon to 4pm. (Baker and Steemers, 2000, p.87).

The study showed that light pipes coupled with laser cut panels have a good performance for deep plan buildings, reaching illuminance values ranging from 200 to 300 lux over a period from 12pm to 4pm thereby contributing to the 300 lux required for the Water Front House Building. (Baker and Steemers, 2000, p.87).

In time where energy consumption become exceeding high because of using the electrical lighting , in my belief shopping mall buildings will become more and more dependent on all passive (non use of renewable) sources of energy. Thus, use of light pipes will lower energy consumption, improve the quality of light in the inner parts of building and enable shopping center buildings to have a more natural light in the innermost spaces.

3.2.3. Vertical Light Pipes

A light pipe system is a simple daylighting device that allows the natural daylight to enter into interior spaces or underground spaces where access to windows or skylights

is restricted. The use of a light pipe system can enhance illuminance without the use of artificial lighting and thus would reduce energy consumption significantly. (Baker and Steemers, 2000, p.93).

A presents of a performance prediction method of a light pipe system based on the amount of daylight admitted and energy saved by not needing electric lighting.

The use of natural light has the potential for improving both the energy efficiency and indoor environmental quality in buildings and this is an important aspect in many sustainable building certification systems.

A study of vertical light pipes as means of natural illumination by the Architect Ken Yeang's and Wilson in Millennium Library in Brisbane, Australia The objective of this study was to determine the benefits and limitations of the technology as applied to illumination vertically through several floors of a building. This study has shown that vertical light pipes reach average lux values from 50 to 300 lux for different light collection strategies, under sunny sky conditions, with a good concordance between measured and calculated values.

This library has a serious problem in terms of daylight design solution for solve this problem was proposed by using vertical light pipe.

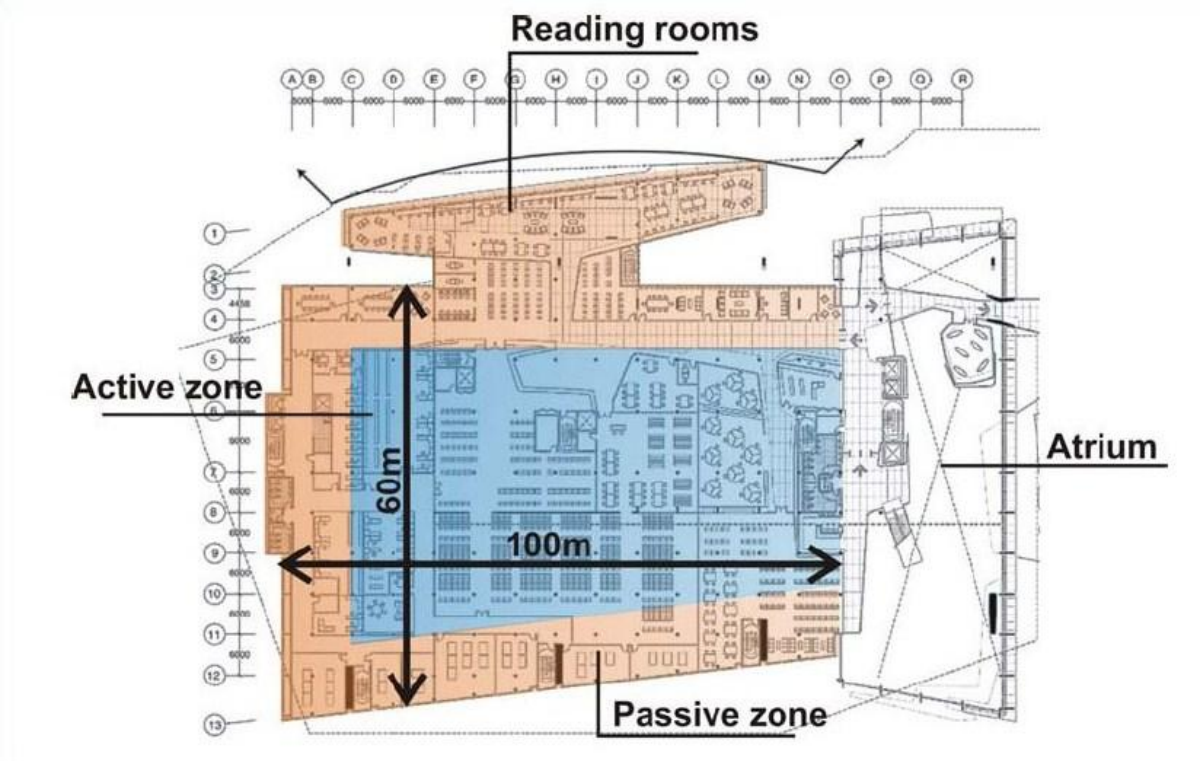


Figure 3.18 Plan of in Millennium Library

Due to wide floor plan of the Millennium library, the shortest distance to capture natural light and pipe inside the building was from the roof. The solution proposed to improve natural illumination of this building was 18 vertical mirrored light pipes coupled with laser cut panels that will capture natural light from the top of the building and will take it to where is needed (Figure 4.20). Each light pipe, with an estimated diameter of 2m and 18.5m in length, will serve area of 12m by 12m on each floor.(Ayers and Carter. 1995, p.63)

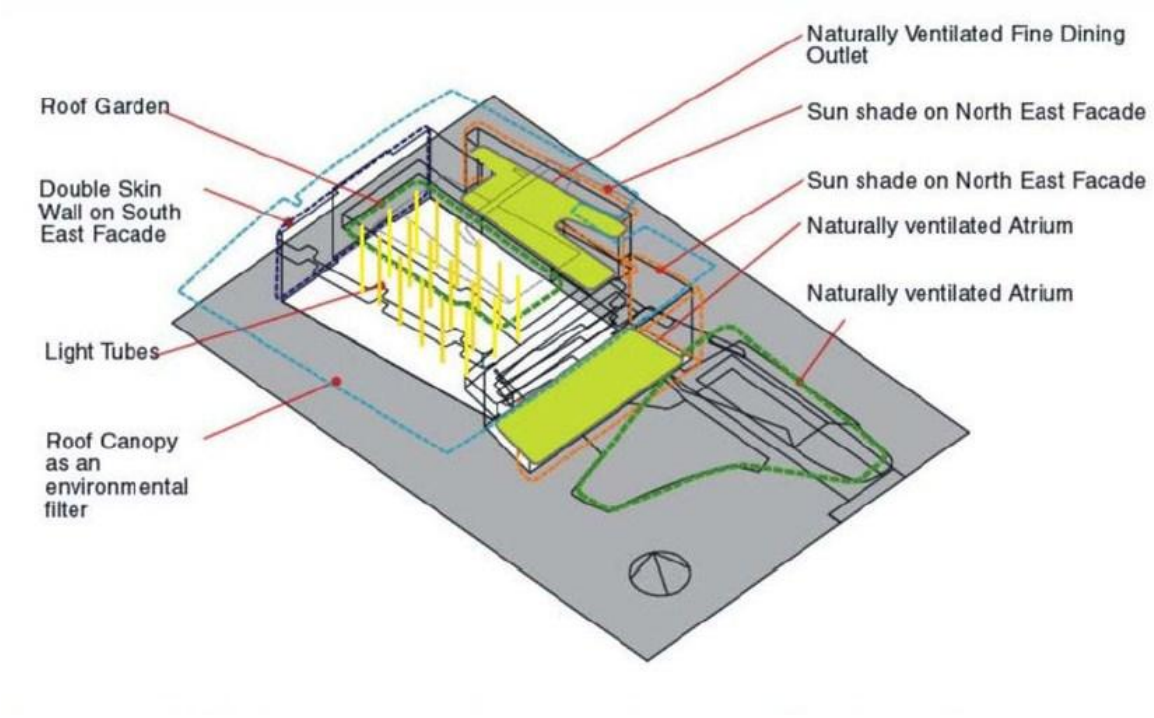


Figure 3.19 Location of Vertical Light Pipes in Millennium Library.

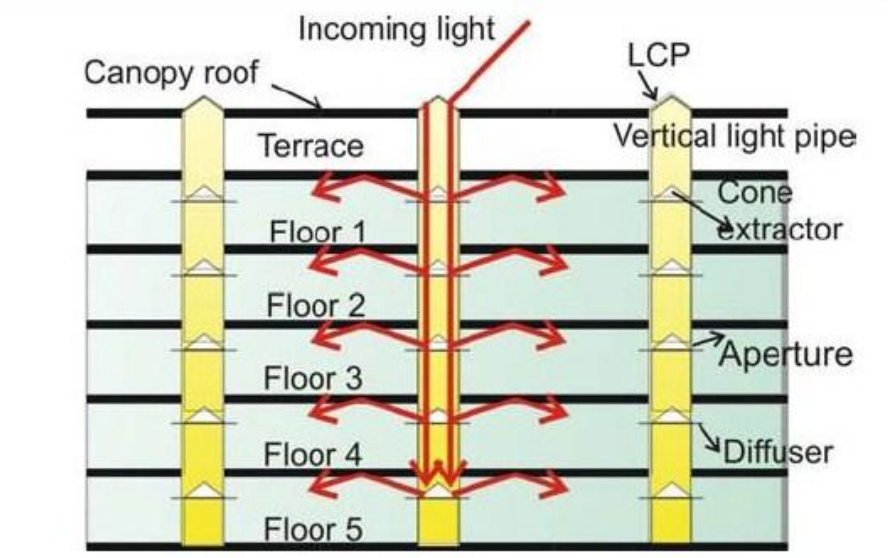


Figure 4.20 Section Show The Vertical Light Pipes

The design of the vertical light pipes follows the same principles as the design of the horizontal light pipes: “capturing light from the roof and redirecting it downwards creates a better illuminate interior zones. Light extraction design and theory is also

similar although for vertical light pipes the incoming light has to be extracted and then spread to the room in all directions". The difference in light collection for a vertical light pipe is that the system can see the whole sky vault. In comparison a horizontal light pipe can only see half of the sky vault. (Ayers and Carter. 1995, p.42)

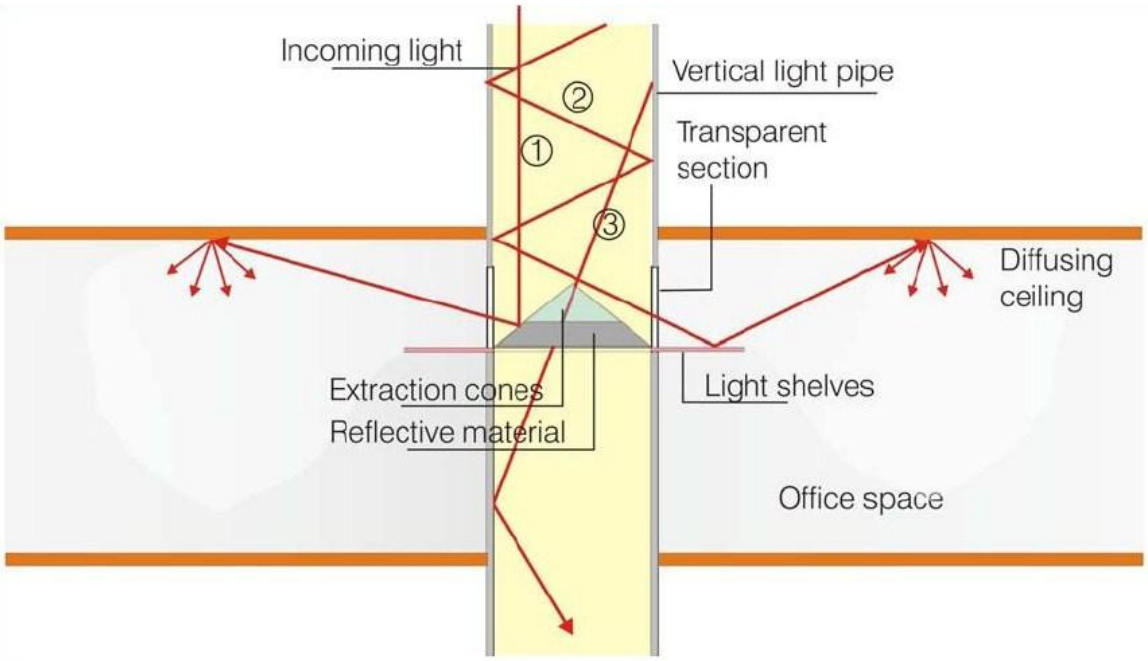


Figure 3.21 Light Distribution for The Vertical Light Pipes System.

Natural illumination of the working plane in the Millennium library is obtained by indirect lighting, responding to the needs of uniform distribution of natural light in the library space and avoidance of direct sunlight on computer screens, and book stacks. Indirect lighting was accomplished by the redirection of the extracted light to the ceiling, and the inclusion of light shelves to protect against any light reaching downwards. All light is therefore redirected to the ceiling as shown in Figure 4.21. (Ayers and Carter. 1995, p.67)

3.2. Light Distribution

Final component of light transport technology is the light distribution system that directs light from the guide to illuminate a space. Distribution of light requires extraction of light from the light guide and emission of light into the space. The type and complexity of the emitter or luminaries will depend on the type of pipe used for light transportation. The following section reviews some of the light distribution devices and technologies. (Aizenberg, 2003,p.52)

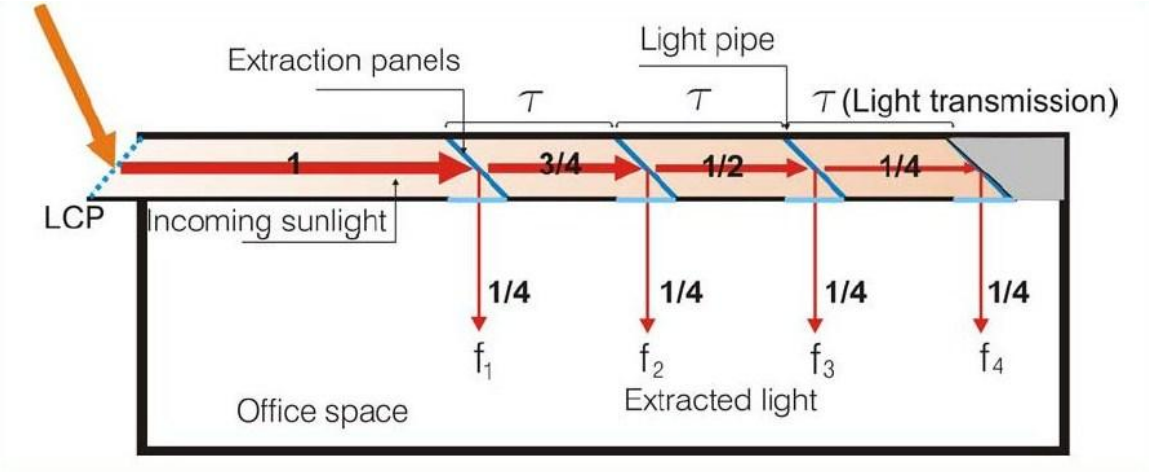


Figure 3.22 Theory of Light Extraction

A principle of a light extraction system was developed by Edmonds et al. (1997) and illustrated in Figure 4.22 In this example, the same amount of light is extracted at each aperture. To achieve this, the first extractor panel is made sufficiently reflecting to deflect one quarter of the light. The second deflects one third of the remaining light, the third panel deflects one-half and the final extractor deflects all of the remaining light. More complicated ratios may be derived to account for transmission loss in the pipe

that occurs between each extractor. Edmonds et al. (1997) developed this theory for the use of laser cut panels with different spacing cuts as extractors. (Aizenberg, 2003, p.58)

3.4. General Evaluation of Light Transport Systems and Possibilities for Shopping Malls

Numerous daylight systems have been developed to improve natural illumination in the deep plan and multistorey buildings. According to Baker and Steemers (2000,p.114).

"Innovative daylight systems can be generally divided in two groups:

1) light guiding systems, which redirect natural light (direct and diffuse) to the core of the building up to 8 to 10 meters, by means of reflection, refraction or deflection (e.g. light shelves, louvers), or

2) light transport systems, which can reach further distances than light guiding systems by means of channeling sunlight (generally the direct component of sunlight) through guides from the building exterior where it is collected, to the interior to be distributed (e.g. light pipes)."

Benefits of light transport systems include:

1) The potential of integrating artificial and natural light into one system

2) Providing a centralized lighting system in the building that pipes light to distribution system in the building that pipes light to distribution devices, thereby replacing many electrical fixtures and cabling.

3) Eliminating infrared and ultraviolet radiation from sunlight. (Ayers and Carter. 1995, p.74).

Examples of different building using the light transport system for bringing daylight into their interior spaces are as follows:

-Subterranean Train Station at Potsdamer Platz, Berlin

Figure 3.23 Light Pipes, Subterranean Train Station at Potsdamer Platz, Berlin

Figure 3.24 and **3.25** Light Pipes, Subterranean Train Station at Potsdamer Platz, Berlin

-Borusan Group Building in Instanbul

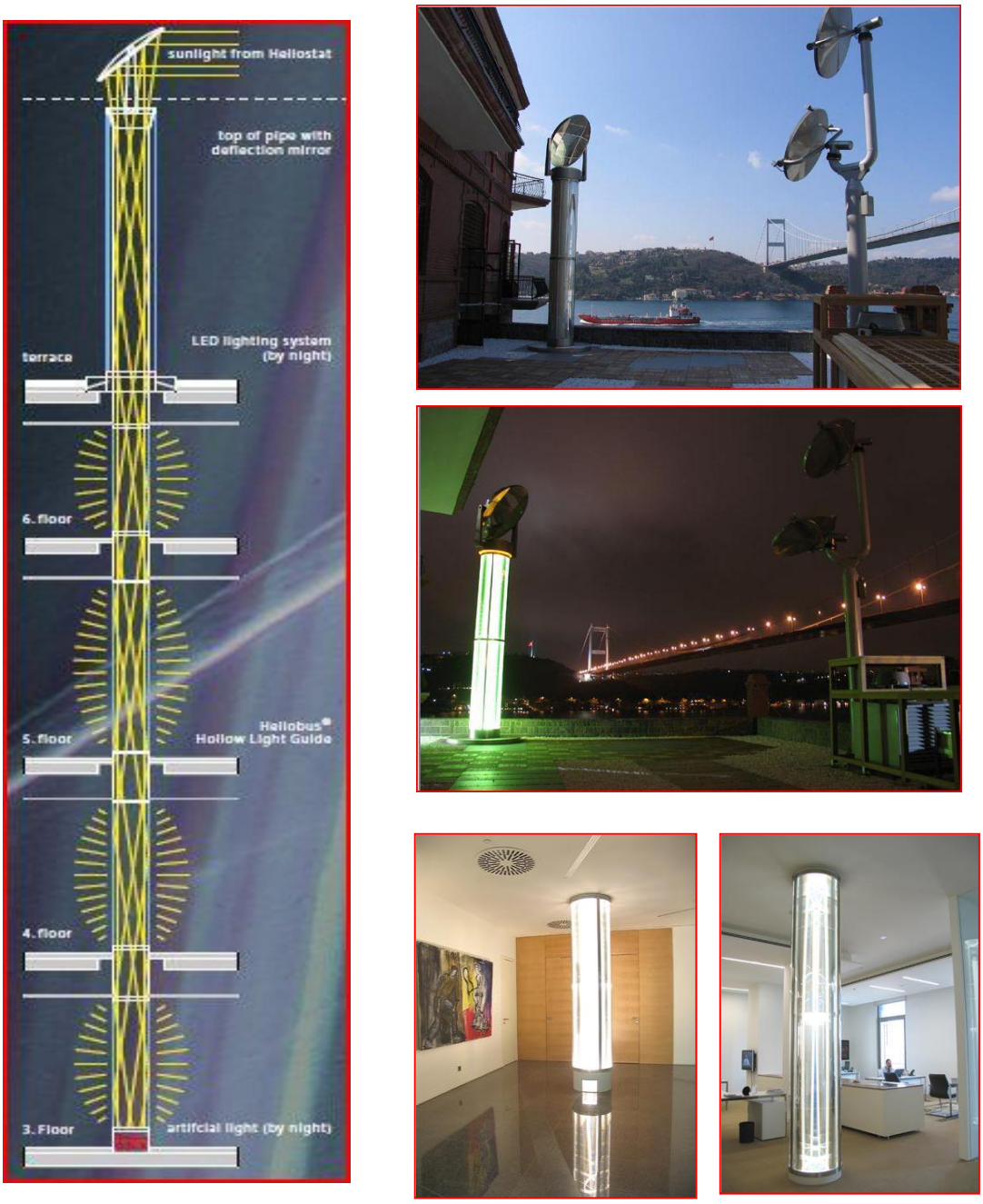


Figure 3.26 Light Pipe Serving Four Under Ground Floor of Borusan Group Building in Istanbul

-South Charnwood School in USA

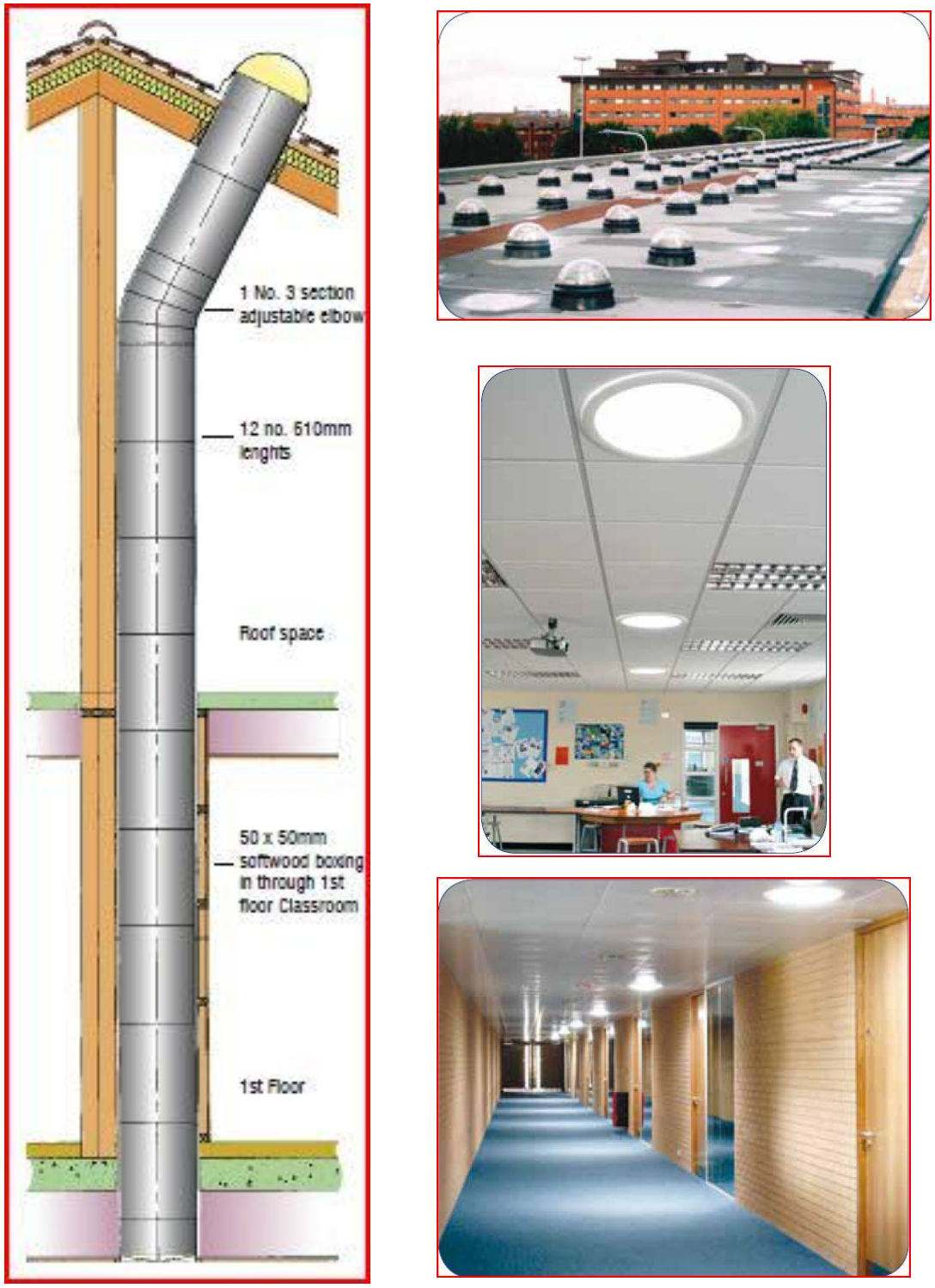


Figure 3.27 Light Pipe(7.6 m) Serving Ground Floor of South Charnwood School in USA

Figure 3.28 Supermarket in Germaine

Figure 3.29 Basement Store

Figure 3.30 Ontario Academy, CA

Figure 3.31 Business Center, UK

CHAPTER 4

DAYLIGHT IN INTERIOR SPACES OF SHOPPING MALLS

The literature review in this chapter is divided into three sections, which consist of general development and main approaches for defining shopping center, then the effect of daylight on the human being behavior and finally the general evaluation of daylight in shopping centers. The review on the effects of daylight on human behavior can be categorized into two groups, which consist of review about the role of daylight on human psychology and human physiology.

The literature review will address three main subjects that consist of the human being, light and shopping center buildings and discuss the relationship between. The selection of these subjects is based on the premise; if daylight affects human being in more than one way and if daylighting plays a significant role in shopping mall buildings that will enhance the aim of this study.

The review will show that human being behavior is affected by light and daylight is also discussed in the context of shopping mall buildings in the last section, which comprises the general evaluation of daylight in shopping malls. The problem of shopping mall buildings in introducing natural light in their interior spaces will be discussed and the most problematic interior spaces in this enclosed mall according to

daylight abundance will be determined.

4.1. Shopping Mall Definition

4.1.1. General Development and Main Approaches

The term “shopping center” has been evolving since the early 1950s. A shopping center has been defined by the ICSC (International Council of Shopping Centers, 2004.p.2) as:

> “A shopping center is a group of retail and other commercial establishments that is planned, developed, owned and managed as a single property, typically with on-site parking provided. The center's size and orientation are generally determined by the market characteristics of the trade area served by the center”.

After this definitions, it is important to observe the types and classification of shopping center buildings .Therefore, there are three main forms of shopping center according to ICSC (International Council of Shopping Centers, founded in 1957).

> “The first one is “Mall” the most common design mode often called as a “shopping mall”. The walkway or “Mall” is typically enclosed, climate-controlled and lighted, flanked on one or both sides by storefronts and entrances. On-site parking, usually provided around the perimeter of the center, may be surface or structured”.

Figure 4.1 Enclosed Mall, West Edmonton Mall

The second form of shopping center is an “Open Air Center” Which simply refers to that is not enclosed space. This form of shopping center is often “attached row of stores or service outlets managed as a unit, with on-site parking usually located in front of the stores with common areas that are not enclosed. Open canopies may connect the storefronts, but an open-air center does not have enclosed walkways linking the stores”.

Figure 4.2 Open Air Center, Westgate City Center

The last form of shopping center according to the same resource (ICSC ,2004) exhibit the characteristics of both the first and second forms which called “hybrid”.

Figure 4.3 Hybrid Shopping Center ,Bristol's Cabot, England

According to Oxford's dictionary there are three meaning of "Mall" as following:

1- Mall (also shopping mall) chiefly North American a large enclosed shopping area from which traffic is excluded.

2- A sheltered walk or promenade.

3-An alley used for pall-mall

The term "pall-mall" in the third definition may give an idea about the original of the term "Mall". According to the web sources the earliest usages of mall in English are derived from "pall-mall", a game played in 17th-century England and somewhat earlier in Italy and France. Pall-mall came into English through the French pallemaille,

meaning ball and mallet. The object of the game was to drive a boxwood ball through a suspended iron ring using a mallet.

According to Fong (2003, p. 10) shopping mall is a "simulation of the commercial live center' of cities which are built to replicate the retail offer in established city centers, providing comparison to shopping in a 'continuous' selling space on goods". Additionally, Shields (1994, p.203) defines the enclosed shopping mall as a micro-city with its street-like galleries and multi-level atria.

Today, according to Crawford (1999, p.95), an entire life can be lived inside a shopping mall .Existence of the different types of shopping centers can be seen in different cultures and locations. Shopping center has become the most significant and popular building where people spent a longer time because "contemporary shopping centers include not only the stores for shopping but also leisure areas such as cinemas, restaurants and playgrounds for social and cultural activity" (Klehs ,1983,p .8).More details on the classification of shopping center will not be given in this study, but it is important to mention the types of shopping mall after mentioning the classification of shopping centers.

According to the ICSC (International Council of Shopping Centers, 2004) the first form of shopping center, which was "Mall" has two types:

> **"Regional Center:** A typical regional center is usually enclosed with an inward orientation of the stores connected by a common walkway. Parking surrounds the outside perimeter.
>
> **Super-regional Center:** Similar to a regional center, but because of its larger size, a super-regional center has more anchors, a deeper selection of merchandise, and draws from a larger population base. As with regional centers, the typical configuration is an enclosed mall, frequently with multilevel. Parking may also be structured to accommodate the sheer size of the center."

Eventually, “contemporary shopping centers buildings became a fully enclosed and environmentally controlled space and became one of the large public spaces nowadays”.

(Crawford ,1999, p.98).Therefore, sustainability will play a significant role in their overall quality and especially the interior public spaces become more important. Then it is necessary to evaluate the role of daylight in their interior public spaces as well as the effect of daylight on other indoor environment aspects such as thermal performance, air pollution and materials in step towards achieving sustainable interior space. Limitation in this study is determined as the first types of shopping centers, which is shopping mall as an enclosed building type, to evaluate their indoor natural light concern in relation to sustainability. The enclosed shopping malls usually come out as deep-plan and multistory buildings illuminated by skylight from the top floor with huge areas of indoor spaces which usually lack sufficient daylight .

4.2. Daylight in Shopping Malls.

4.2.1. General Evaluation of Daylight in Shopping Malls

In today's society, most people spend a considerable amount of their time in shopping center buildings. As observed by Stevens and Rea (2001) “humans have moved from a terrestrial environment with dark nights and bright broad-spectrum days to a modern built environment with relatively dim. limited-spectrum days and nights”. One consequence of this move that has not yet been fully appreciated is the effect on people's health and well-being. In addition, the operation of these buildings consumes

large quantities of electricity and therefore fossil fuels for illumination and air-conditioning.

One of the principles of sustainable architecture is to increase the use of natural light for illumination, particularly in shopping center buildings, to reduce the dependence on electricity for illumination, thereby reducing the overall building energy consumption. Additional effects of using daylighting for illumination are improving the health and productivity of occupants of buildings, as well as enhancing the aesthetic qualities of buildings.

Numerous researches have been done to utilize and harvest the energy saving benefits of daylighting . "The depletion of fossil fuel which results to the increase in energy costs, results to the rise in research within the field of alternative energy". Some researchers turn to daylighting in hope of finding a solution (Veitch and Newsham,1997,p.18).

As Bouchey (2002,p.9) states, "Electric lighting in shopping center buildings costs ten percent of the electricity used in the United States each year" .Bouchey (2002) demonstrated that artificial lighting accounts for fifty percent of the energy consumption of commercial and industrial buildings. Claridge (1994) in his research on benefits of energy retrofits in commercial buildings; highlights on the potential of proper lighting in energy conservation. He manages to save seventy five percent in its electricity cost after applying daylighting in building. According to Claridge (1994,p.27), the America's Department of Energy has shifted their investment from photovoltaics to hybrid lighting

since it yielded higher energy gain. Sunlight collected from a parabolic mirror connected to optical fibres is used to light buildings in hybrid lighting system.

Daylit commercial buildings are also capable of reducing capital costs by cutting on glazing and minimizing solar heat gain by carefully designing windows (Loveland, 2002,p.49).The author point out that natural lighting also plays a very important role in increasing face value and adding aesthetic appeal. "natural lighting would make the building more attractive resulting to a more valuable building with more valuable renting space. In other words, the value of a building can be increased with the use of natural lighting." (Loveland, 2002,p.51)

The increase of research in daylighting strategies in commercial buildings also help in producing new and cheaper methods of daylighting in buildings . This is another contributing factor on the rise of researches in energy conservation through daylighting. Northen (1977,p.52)in his research on daylighting applications in commercial buildings found that lighting of buildings can be optimized and cooling loads can be minimized by using daylighting through proper design of the building envelope.

Another way to test the link between daylight and shopping center is to find out the affect of daylight to enhance indoor environment quality that will result to attract more customers and this idea agreed by reserch which has been done by the Heschong Mahone Group in California on the effects of daylight towards retail sales they found that "daylighting was found to boost sales by an average of 40 percent with a 99 percent degree of statistical certainty". (Claridge ,1994,p.28)

According to Birren (1988,p.93), through surveys, “many workers are still dissatisfied with the quality of their artificial lighting, despite the fact that in many cases, their lighting meets the basic requirements of the CIBS Code for interior design”. This suggests that higher degree of lighting doesn’t ensure human satisfaction.

Birren (1988,p.94) reveals the results of a study in California that “natural light boosts human productivity in retail sales and school performance with average increase is sales due to daylighting”. Increased level of lighting in a building doesn’t result to ultimate human satisfaction but the usage of daylighting has shown positive effects towards human performance. Research has shown that naturally lit buildings are more comfortable for human occupation and produce positive influence on operating income, resulting in increases in asset valuation (Katz, 2005).

Daylighting has been underscored as a factor in attracting and retaining workers.Daylight benefits such as increased workplace productivity and safety of building occupants. The pleasant environment created by natural light decreases stress levels for commercial office workers. Productivity increases with the improved health of workers, and with better productivity comes financial benefits for employers.(Stevens and Rea. 2001). The same can be vaild for shopping center workers.

4.2.2. The Problematic Spaces in Shopping Malls according to Daylight

Multistorey shopping mall can be easily described as a building having more than one storey (excluding car parking and service) and shops are arranged at these levels and connected horizontally and vertically by various circulation areas. Multistorey buildings are the most common mall type. There are different surface geometries, circulation plans and galleries in these buildings.

In this study, interior spaces of enclosed shopping mall types will be examined according to daylight abundance. By rendering multistorey shopping malls in Ankara I find that the most problematic interior spaces in terms of using daylight as below:

4.2.2.1. Circulation Areas

Shopping mall types can be easily divided into two groups according to their circulation areas as:

-*Circulation around Single Gallery*

-*Circulation around Multi Gallery*

-Circulation around Single Gallery

A single major gallery, circulation paths around it, shops that can be accessed from, and food-court at the basement or upper part of the gallery are the main features of such malls. The use of dome, vault, flat roof and different geometries in the roof of these buildings to allow natural light come in. Galleria Ankara, Ankuva and Gordion AVM can be given as examples belonging to this group.

Figure 4.4 Interior View of Galleria Ankar

Figure 4.5 Interior View of Ankuva Mall,Ankara

Figure 4.6 Interior View of Gordion AVM, Ankara

In this group, evaluate the performance of natural light that comes directly from the ceiling by using skylight is seems good because it's have a good presence of daylight in their circulation areas .However the problem of daylight presence in circulation areas are in the second group which is:

-Circulation around Multiple Galleries

Shopping malls having circulation areas connected with gallery spaces rather than their central galleries define this type of shopping malls. Circulation schemas designed in order to provide access to many shops, have different galleries, geometries and dimensions. Cepa, Ankamall and Armada Shopping Centers are some examples belonging to this group.

Figure 4.7 Circulation Gallery of Cepa AVM, Ankara

Figure 4.8 Circulation gallery of Ankamall, Ankara

Figure 4.9 Circulation Gallery of Armada Shopping Center, Ankara

Gallery ceilings are mostly finished as vaults ,dome or flat surfaces to allow natural light come in interior spaces of these shopping mall. The presence of natural light in circulation areas in this group has usually a good a quality of daylight in the upper floor. Natural lighting from the ceiling in this multi-storey buildings gradually lessen down to the ground floor and become dark spaces therefore the use of electric light will be higher than the upper floor.

4.2.2.2. Under Ground Spaces

The function in this storey changes according to the plan layout need. However, big spaces usually exist in this level such as closed parking car areas or big supermarket spaces. These spaces are completely using electric lights to illuminate the whole spaces and this will lead to the consumption of huge amount of electrical energy.

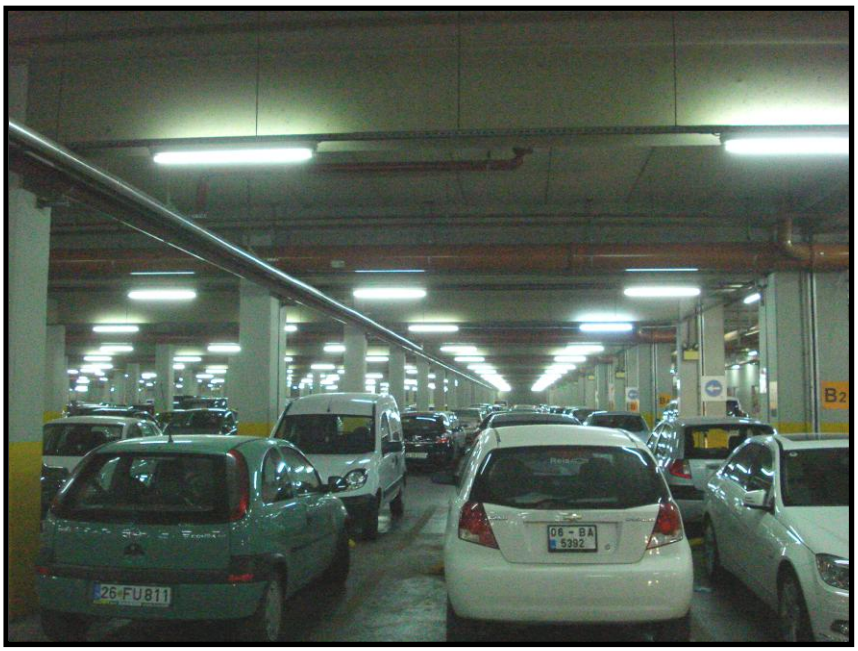


Figure 4.10 Underground Spaces, Car Park Ankamall, Ankara

Figure 4.11 Underground Spaces, Supermarket Ankamall, Ankara

4.2.2.3 Shop Spaces

Shops can have different sizes individually, but in the overall shopping mall building size they take the biggest amount of areas and in my beliefe they have a largest problem in term of using natural light. They are completely reliant on electrical lighting that has several direct and indirect detrimental effects (i.e. energy inefficiency, the use of non-renewable resources and production of greenhouse gases, and unhealthy and unproductive environments for the occupants of the building). The question is how to bring natural light in to these deep plan and multistorey buildings to improve energy efficiency and the workplace conditions for building occupants.

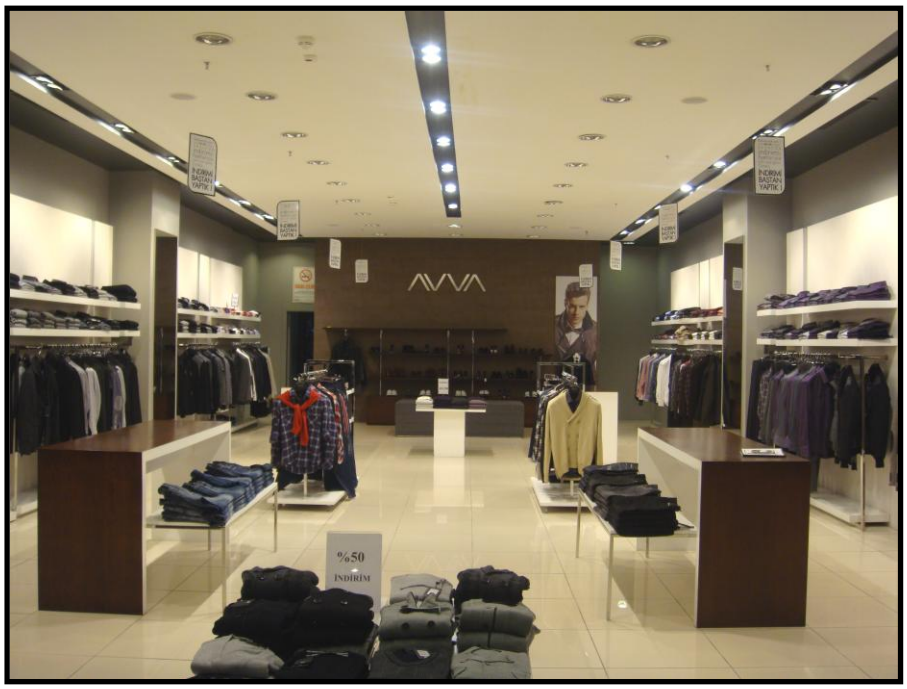


Figure 4.12 Interior View in Gordion Mall Shop During Day Hours.

Figure 4.13 Interior View in Ankamall Shows The Use of Electric Light During Day Hours.

CHAPTER 5

CONCLUSION

5.1. Overall Outcomes of the Study

Results from this study may provide useful insight and a basis for a larger, more comprehensive study including other types of buildings which have the same problematic in terms of using daylight as a main illumination source in interior spaces during day hours. The research has demonstrated that the natural light has a significant role to determine people's performance in interior spaces of shopping mall in terms of both physical and psychological concerns. This study, found that for sustainable interior spaces and successful integration of energy efficiency there must be a balance in enhancing indoor environment quality by providing a good daylight in interior spaces of shopping mall buildings. Shopping mall buildings have a potential opportunity to reduce electrical energy consumption for illumination by using the new strategies of providing natural light into their innermost spaces.

Designing shopping mall plans for the performance of daylight and the openings to provide a better natural light in innermost spaces must be one of the primary concerns of

architects. Yet many shopping malls have not been designed with enough concern for daylight. Thus, interior architects should also be aware of the advantages of innovative daylight systems; and may use this technology in interior design of shopping malls for bringing daylight into their inner spaces.

Based on the review of chapter three it is easy to conclude that research has shown that daylight affects the human being and lighting plays a significant role in shopping mall buildings and other buildings as well. Also the research regarding lighting and commercial buildings is more concentrated on energy conservation and energy efficiency. In addition, it is possible to conclude that light can affect the users of shopping mall buildings and light has a significant effect on physiological, psychological and behavioural aspects of these building occupants.

Applying the technology of providing daylight in two buildings which were mentioned in Chapter 3 (Waterfront House Building in Kuala Lumpur and Millennium Library in Brisbane), by using mirrored vertical light pipes or horizontal light pipes coupled with LCP, has shown that the technology is a potential solution for the problem of middle high deep plan buildings. The studies have shown that the system achieved an adequate spatial light distribution along the pipe. The average lighting values from design for the areas to be illuminated were set as a range from 150 to 300 lux for clear (sunny) sky conditions (Ayers and Carter. 1995). Finally, it is believed that such a technology can provide a better understanding and more accurate design method of daylight systems for architects and interior architects.

There is need to establish tools to ensure the accepted available level of daylight that can influence the users of interior spaces of this huge structural buildings because of the serious role of daylight to impact on the health of this building occupants. Research in similar context will enhance the key of sustainability challenges because of the common perception is that it costs more by using artificial lighting to illuminate indoor environment and there is no real awareness to use daylight as a main source to achieve sustainable interior spaces .

5.2. Further Studies

The objective of this research was to provide interior designers with a framework for the role of natural light in enhancing the LEED categories which is indoor environment quality for going towards achieveing sustainable interior spaces. From this, additional questions have been raised. Future investigation into the effects of daylight in interior spaces for such a huge building is required. Further studies in this method of bringing daylight in shopping malls should be the focus of the researchers who are interested in sustainability to make the building friendly to the environment.

Research into daylighting and light pipe technology should include psychological studies to determine people performance for illumination by using light pipe and if this way are realy do effect the human behavior inside the building. Further research can be carried in economic and cost benefits to determine what the energy saving of this system would be. Further research in light pipe technology (shape, lenght, materials, instalation) is considered the next important step in developing this way of bringing

daylight by test the performance of light pipe and test it in order to provide the best natural light.

Additional research in this area will provide interior designers with more knowledge and awareness that will assist them as they address sustainable design issues specific to the shopping mall interior spaces. Additional research, focusing on the use of bringing daylight strateigies in the design of the buildings interior that highlight their economic and environmental advantages will illustrate the impact that better sustainable design choices can have on the shopping malls interior environment. More study of how interior designers concern in his education toward sustainable interior design practices in step to be useful in the interior design profession.

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