The Evaluation of Office Buildings in terms of Shading Devices

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ABSTRACT

With the energy crisis of 1973, most architects, engineers, and building owners rekindled their interest in energy efficient building designs. Since then, the implementation of energy efficient designs has dramatically reduced the growth of non-renewable energy consumption in buildings. However, to successfully create these energy efficient designs, architects must consider energy efficient design strategies during the early design stage. After a building is designed, it becomes significantly more difficult to reduce its energy use. To design buildings, many architects tend to rely on simplified analyses and synthesis techniques. A considerable energy conservation chance exists within the building. Energy is needed in a building for room lighting, cooling, air heating, ventilation, etc. However, the utmost energy is used in buildings for air conditioning of rooms. The building energy demand may be reduced to a nice extent if correct passive solar options are used within the building throughout the design level. The employment of passive building concept to achieve comfort within a building could be a growing interest for the building energy conservation. The essential principle in passive solar architecture is to be able to take advantage of climatic conditions through proper location, orientation and sizing of building parts with less mechanical or artificial thermal control measures.

In this regard shading devices as examples of passive elements, with different types and orientation prevent direct radiation and through an outward reflection in order that no energy transfer, owing to direct radiation, is taking place. Their position would be most likely outside spaces to supply shadow over the glazed spaces.

Openings as the most important parts of a building in terms of thermal control should be taken into consideration at the design stage of a building. There is therefore a need to introduce measures for controlling heat gain into the interior of buildings in order to reduce the cost of cooling of interior spaces. Although shading devices can be considered as very good alternative for reducing heat gain into buildings and day light control in interior spaces, there is still an inadequate application (in terms of type and orientation of shading devices) by construction companies.

This study emphasizes on the role of shading element in direct solar energy gain with an enquiry into shading devices and how they can affect users in office buildings. The two cases (Italian and Spanish office buildings) were chosen to highlight the advantages of using proper shading devices. A comparison between the mentioned case studies and Emu Rectorate Office Building in Eastern Mediterranean University, Famagusta/North Cyprus, has been done assessing the correct shading devices deficiencies which reduce the energy efficiency in the case.

The study was finalized with a series of suggestions to improve the energy efficiency in the mentioned Cyprus case, Emu Rectorate Office Building.

Keywords: Energy efficiency, Thermal Comfort, Office Buildings, Shading Devices

ÖZ

Enerji Krizi ile birlikte ,1973 yılında birçok mimar, mühendisler ve bina sahipleri tekrar enerji verimliliği ile alakalı yapı tasarımları konusu ile ilgilendiler.Etkili enerji uygulamasını tasarlama sürecinden sonra ise binalarda yenilenemeyen enerji tüketimini dramatik bir şekilde düşürdü. Bu durumla birlikte başarılı olarak verimli enerji tasarlama durumunu mimarlar yarattı. Mimarlar erken tasarım evresi süresince verimli enerjiyi tarsarlama stratejilerini önemsediler. Binalar tasarlandıktan sonra enerji kullanımlarını düşürmek çok zordur. Birçok mühendis binalar tasarlanırken daha çok basitleştirilmiş analiz ve sentez tekniğine güvenmektedir.Binaların içinde ciddi bir enerji tasarrufu değişimi bulunmaktadır.Enerjiye en çok binalarda; oda ışıkları, soğutma, hava ısıtma, vantilatör ve sair durumlarda ihtiyaç duyulmaktadır .Bununla birlikte en fazla enerji binaların içindeki odalardaki klimalarda kullanılır. Binalardaki enerji talebini iyi bir şekilde uzun vadede düşürülebilir, Eger ki doğru pasif güneş seçenekleri kullanılır ve binaları tasarlama aşaması süresince uygulanırsa. Pasif bina konseptinde istihdam süresince binaların içerisinde konfor sağlanırsa binalarda enerji tasarrufu artacaktır. Pasif güneş mimarisindeki temel ilke iklim koşullarına avantaj sağlanabilir. Bu doğrultuda uygun konum, oryantasyon ve yapı parçaları boyutlandırma ile birlikte daha az mekanik veya yapay kontrol önlemleri getirir. Bu konuda gölgeleme cihazlarını pasif elemanlar olarak örnek gösterebiliriz, yine değişik model ve oryantasyon direk radyasyonu önler ve dışa yansımasısonucunda enerji transferi olmaz, doğrudan radyasyon yerini almaktadır. Onların pozisyonu büyük bir olasılıkla dış alanlarda kaynaklanan gölgeler üzerindeki gizli alanlarda olur.

Açık olarak binaların dizayn aşamasında en önemli göz önünde bulundurulması gerekli bölüm ise ‘Termal Kontrol’dür’.Bu sebeple Binaların içindeki tanıtım ölçüleriyle ısı kazancını kontrol etmek için mekanların soğutma maliyetlerini düşürmek gerekir.Yine gölgeleme cihazları çok iyi bir alternatif olarak göz önünde bulundurulabilir.Bu da ısı kazancını düşürebilir ve gün ışığı kontrolü iç mekanlarda uygulanabilir. Hala daha inşaat şirketlerinde bu konuda yetrsiz bir uygulama bulunmaktadır (şartlar yönünden gölgeleme cihazlara yönelme).

Bu çalışma gölge elemanların direk güneş enerjisini Gülge Cihazlarla kazandırılmasını vurgulamaktadır ve bu konu da büyük bir ölçüde ofis binalarını kullananları etkilemektedir.İki olayda da (İtalyan ve İspanyol ofis binaları) Yüksek ışık avantajı kullanılarak doğru gölge cihazları seçilmektedir. Doğu Akdeniz Üniveristesi ,Magosa/Kuzey Kıbrıs’taki rektör ofis binaları ve Çalışma binaları arasında karşılaştırma yapılırsa, doğru gölgeleme cihazların eksiklikleri değerlendirildiğinde, bu da enerji verimliliğini düşüren bir olaydır .

Bu çalışma bir seri öneri geliştirmek açısından Kıbrıstaki rektör binaları enerji verimliliği ile sonuçlanabilir.

Anahtar Kelimler: Enerji Verimliliği, Isı Konforu, Ofis Binaları,Gölge Cihazlar.

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INTRODUCTION

With the intense energy tension worldwide, the use of energy has become a significant issue and also the conservation of energy has gained a prime importance. A considerable energy protection opportunity exists within the building. The energy is needed in a building for cooling, lighting, ventilation, heating, etc. However, the utmost energy is used in buildings for area air conditioning. The office building's energy demands for heating and cooling are often decreased to great measure if appropriate passive solar specifications are incorporated within the building throughout the design level. The employment of passive building concept for attaining thermal comfort inside a building is a growing concern for the building energy protection. The fundamental principle is to provide shading devices as part of location, size and orientation to require most advantage of the surroundings and indoor thermal (Chan, Riffat et al. 2010) .

Although, solar energy could be a free, clean and environmental friendly supply of energy, the use of solar energy shouldn't overheat interior spaces in hot summer season. There are apparent issues faced within the buildings as a results of overexposure of facades to direct daylight (Duffie, 2013). Built environment is a mean for providing a suitable shelter for people, needed for fulfilling the requirements of comfort, both physically and psychologically. This was a real motivation for mankind to seek out the most suitable indoor environmental conditions that meet his needs satisfactorily. After this achievement, people experimented different themes trying to pursue further development in their environment through acceptable improved environmental conditions. Human beings have always the motivation and eagerness to improve their environment and make it more suitable for living, and that was the reason behind the success of human beings in early time to control the surrounding with which they were in direct contact (Smith 2013) .

The amount of shading systems, prevent the direct of radiation and filter it out in order that no energy transfer, owing to direct radiation, is taking place. They eliminate the main issue conducive to the ample heat gain inside. Their position would be most likely outside spaces to supply shadow over the glazed spaces.(Schittich 2003)

1.1 Problem Statement

Openings as the most important parts of a building in terms of thermal control should be taken into consideration at the design stage of a building. There is therefore a need to introduce measures for controlling heat gain into the interior of buildings in order to reduce the cost of cooling of interior spaces. Although shading devices can be considered as very good alternative for reducing heat gain into buildings and day light control in interior spaces, there is still an inadequate application (in terms of type and orientation of shading devices) by construction companies.

1.2 Aim of the Study and Research Questions

This study aims to emphasize the role of shading element in direct solar energy gain and find out which type of shading devices and how they effect on user's in case of office buildings. To achieve the objectives, the main question is:

- What is the role of shading devices in case studies energy efficiency?

Also for supporting the main question, following question are important:

- What is the appropriate shading type of shading devices?
- Which orientation of shading devices is impotent based on solar radiation?
- How energy efficiency can be improved by utilization of proper shading devices?

1.3 Research Objective

This study, categorizing the most appropriate shading devices based on type and orientation. Further, after comparative between two successful cases (Italy an Spanish office building) with Emu Rectorate Office Building, investigated of shading devices impact on energy efficiency of specified case studies to find appropriate explanations with or without shading devices. Finally based on explanations, suggest appropriate shading devices by means of energy efficiency in the case of Emu Rectorate Office Building based on orientation and type.

1.4 Methodology of Research

This study could be a problem determination analysis with the focus and analyzing the type and orientation of shading devices. Therefore, to have the assessment of the solar energy advantages through appropriate shading device in office buildings, two office buildings nearly in the similar climate zone will be selected. Data collection is based on analysis and comparative method, which related literature review by both comparison and qualitative approach.

Comparative analysis regarding information derived from observation and qualitative research class and has been performed to attain facilitate and outcomes discussion concerning the case studies.

1.5 Organization of the Research

This study comprises four chapters:

The first chapter is the introduction which describes the aim of study, research objective, and scope of the study.

The second chapter covers the literature review .The universal information to be offered in this report will be the incorporation of a conceptual analysis and comprehensive study of literature, principles, and concepts achieved from numerous references such as papers, technical themes, periodicals, and textbooks.

The third chapter is the study and analysis part from selected case studies from three different countries (North Cyprus, Italy, and Spain) which are located in the similar main climate zone (hot-climate).

The fourth chapter includes the conclusion of the thesis and the references.

1.6 Limitation and Scope of the Study

In this study, the limitation and scope is to know about shading devices in direct gain and its effect on thermal comfort .For this reason the number of three case studies have been evaluated in terms of shading devices which directly effect on indoor thermal comfort and energy efficiency.

The two cases of Italian and Spanish office buildings has been chosen to highlight the advantages of using proper shading devices. The comparison between mentioned case studies and Emu Rectorate Office Building has been done to assess which type and orientation of shading devices reduced the level of thermal comfort and energy efficiency in each case.

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INTRODUCTION

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Chapter 2

LITERATURE REVIEW

2.1Thermal Comfort

Atmospheric and thermal conditions in an enclosed area are generally controlled in order to ensure the comfort and health and of the occupants or the suitable functioning of susceptible electronic equipment, such as certain manufacturing processes or computers that have a limited range of humidity and temperature tolerance (Law, 2013).

In addition, the human surroundings should provide air, light and thermal comfort. Comfort is best determined as the lack of discomfort. People feel uncomfortable when they are too cold or too hot, or when the air is stale and smelly. Affirmative comfort conditions are those that do not distract by causing unbecoming sensations of drafts, humidity, temperature or other sights of the environment. Ideally, in a suitable qualified area, people should not be aware of equipment heat, noise or air motion (Gaitani, 2007).

The feeling of comfort is relying on a network of sense organs: the ears, eyes, heat sensors, tactile sensors, nose and brain. Thermal comfort is that state of mind that is acquiescent with the thermal surroundings; it is the condition of minimal instigation of the heat-sensing portion of the brain and the heat sensors of skin (Baker 2001).

For efficiency and comfort, the human body needs a fairly thin range of environmental situations contrast with the full area of those found in nature. Furthermore the human body tries to keep its temperature around 37°C. It achieves this through several mechanisms: Increasing blood flow and sweating can be used to lower the temperature in warm conditions while blood flow is reduced and goose bumps may develop to keep the body warm in colder conditions. The latter provides extra insulation of the skin. Blood flow regulates the surface temperature and thus the heat losses from the skin to the environment. If the body does not manage to raise the temperature due to decreased blood flow and goose bumps, the body will increase its heating activities by shivering. To maintain a balance at 37°C clothes are also used to regulate the insulation of the skin (Epstein, 2006).

2.1.1 Thermal Conditions of the Environment

To create thermal comfort, we tend to perceive not solely the warmth dissipation mechanisms of the human body but the four environmental conditions that let the heat to be lost. These four conditions are:

1. Mean radiant temperature (MRT)
2. Air velocity (cm/min)
3. Relative Humidity (%)
4. Air temperature (°C)

All of those conditions have an effect on the body at the same time.

1. *Mean radiant temperature*: When the MRT differs greatly from the air temperature, its result should be thought of. As an example, when you sit in front of a south-facing window within the winter you would possibly truly feel too hot, despite the fact that the air temperature is a comfortable 24°C. This can be as a result of the sun's rays

raised the MRT to a level too high for comfort. As soon as the sun sets, however, you will most likely feel cold despite the fact that the air temperature in the room is still 24°C. This time the cold window glass lowered the MRT too far, and you experience a net radiant loss. It is vital to comprehend that the average clothing and skin temperature is around 30°C, and this temperature specifies the radiant interchange with the environment. In general, the goal is to maintain the MRT close to the ambient air temperature (Huizenga, 2006).

2. *Air velocity:* Air movement affects the heat-loss rate by each evaporation and convection. Consequently, air velocity contains a terribly pronounced result on heat loss. Within the summer, it is an excellent quality and within the winter a liability. The comfortable range is from about 20 to about 60 cm/min.(Huizenga, 2006)

3. *Relative humidity:* Evaporation of skin moisture is basically a function of air humidity. Dry air can readily absorb the moisture from the skin, and also the ensuing speedy evaporation can effectively cool the body. On the other hand, when the relative humidity (RH) reaches 100 percent, the air is holding all the water vapor it can and cooling by evaporation stops. For comfort the RH ought to be higher than 20 percent all year, below 80 percent within the winter and below 60 percent within the summer. These boundaries are not very exact, however at terribly low humidity levels there will be complaints of dry noses, skin, eyes, and mouths, and will increase metabolic process sicknesses (Krishan, 2001).

   High humidity not only decreases the evaporative cooling rate, however also encourages the formation of skin moisture (sweat), that the body senses as uncomfortable.

4. *Air temperature:* the air temperature can determine the speed so that the heat is lost to the air, principally by convection. Above 37°C, the heat flow and also the body can

gain heat from the air. The comfort range for many people (80 percent) extends from 20°C in winter to 25.5°C in summer (Fiala, 2007).

2.1.2 Shading System and Thermal Comfort

Comfort span is relied on kind of cloth, activity, health, and body metabolism rate. Commonly people are diverse in body and health sorts and their activities additionally penetration on the thermal comfort. Thermal mass, windows, interior walls, and applicable shading devices in summer time and winter period are necessary to confirm the human comfort (Bainbridge 2011).

The important functions of shading systems is to decrease overheating to improve thermal comfort (Lechner 2009). Furthermore, shading devices minimize the glare to provide visual comfort. Since solar shading systems decrease the cooling requirement in warm seasons, a good level of solar conservation is necessary in green buildings. Shading systems are not just important for energy reduce of a building but also for improvement of indoor thermal comfort (Lin, 2010).

An optimum shading device demonstrates a system providing maximum shading for a special period throughout the year (summer), while allowing maximum solar radiation in winter (Bader 2013).

2.2 Tilt of the Earth's Axis

Because the tilt of the earth's axis is constant, the northern hemisphere faces the sun more directly in June and also the southern hemisphere faces the sun more directly in December (Figure 1). The intense situations happen on June 21when the North Pole is facing the sun more directly and on December 21 once the North Pole is farthest away from the sun (Abdallah, 2004).

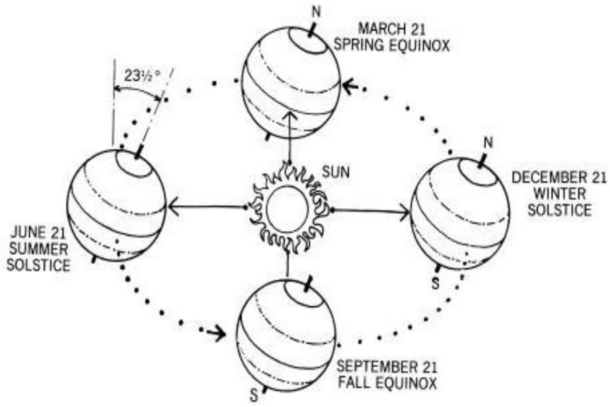


Figure 1: The seasons of the tilt of the earth's axis of rotation (Abdallah, 2004)

It is important to know that on June 21, north of the Arctic Circle will have twenty-four hours of sunlight (Figure 2). This can be the longest day within the hemisphere, and is termed the summer solstice. Additionally on that day, the sun's rays are perpendicular to the earth's surface along the Tropic of Cancer, which is, not by coincidence, at latitude 23.5 North's degrees.

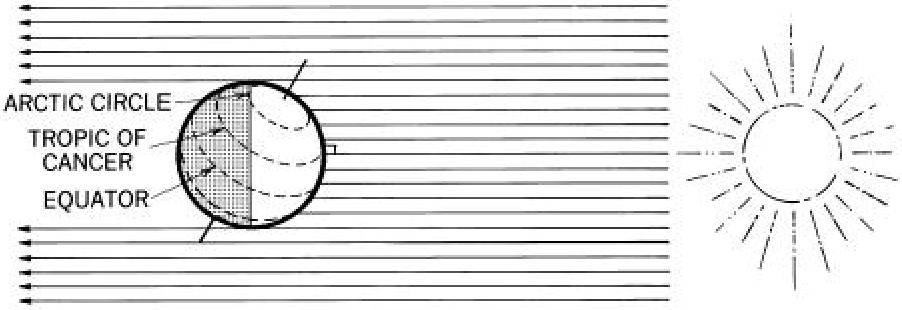


Figure 2: Tropic of Cancer during the summer solstice (June 21) (Smith 2013)

Six months afterward December 21, at the alternative finish of the earth's orbit round the sun, the North Pole points up to faraway from the sun that is higher than the Arctic Circle experiences twenty-four hours of darkness (Figure 3). 21 December in the northern hemisphere is known as the winter solstice. On this day, the sun is perpendicular to the southern hemisphere along the Tropic of Capricorn, which, of course, is at latitude 23.5 degrees south. Meanwhile, the sun ray's fall on the northern hemisphere in a much lower sun angles (altitude angles see below) than those striking the southern hemisphere (Brown and DeKay 2001).

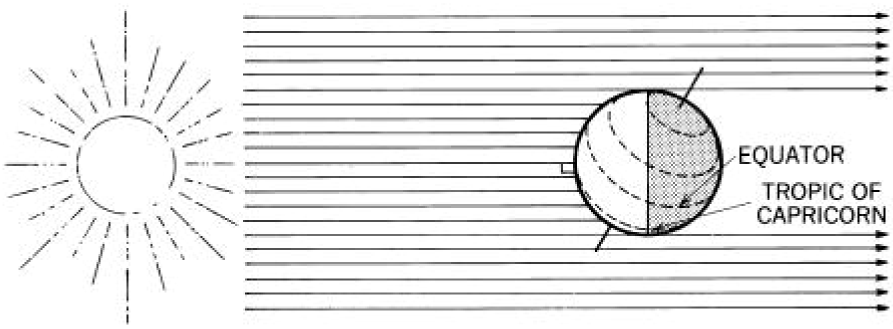


Figure 3: Tropic of Capricorn during the winter solstice (December 21) (Brown and DeKay 2001)

2.1.2 Determining Altitude and Azimuth Angle

By far the easiest way to work with the compound angle of the sun's rays is to use component angles. The most useful components are the altitude angle, which is measured in a vertical plane, and the azimuth angle, which is measured in a horizontal plane. Figure 4 shows a sun ray which enters the sky dome at 2 P.M. on the equinox. The horizontal projection of this sun ray lies in the ground plane. The vertical angle from this projection to the sun ray is called the altitude. It tells us how high the sun is in the sky. The horizontal angle, which is measured from a north-south line, is called the azimuth (Diaconescu, 2007).

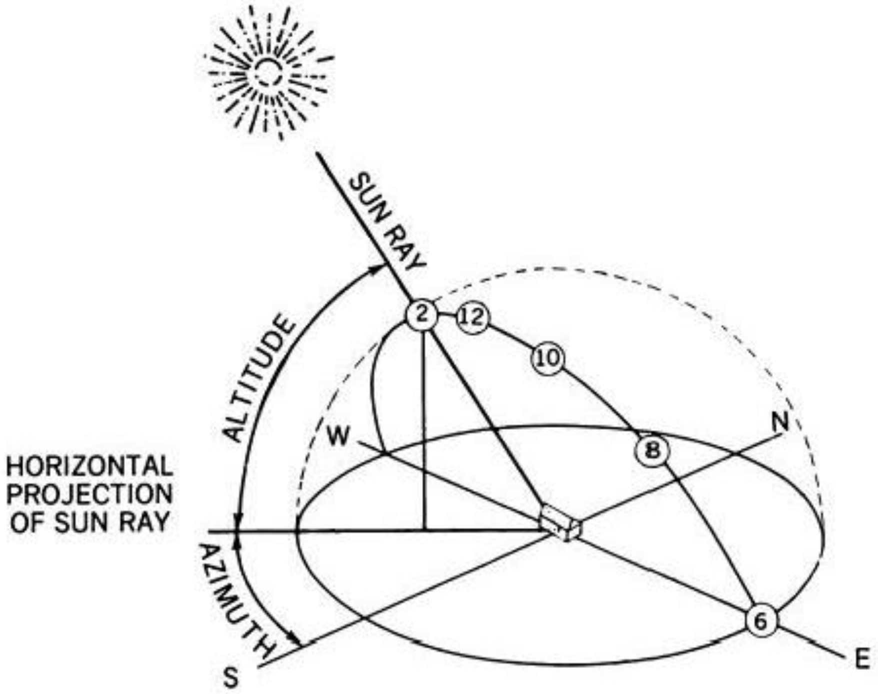


Figure 4: Definition of Altitude and Azimuth Angles (Sun, 2012)

2.2.2 Sun Path Diagram

Sun path diagrams are a convenient way of representing the annual changes in the path of the sun through the sky on a single 2D diagram. Their most immediate use is that the solar azimuth and altitude can be read off directly for any time of the day and month of the year. They also provide a unique summary of solar position that the architect can refer to when considering shading requirements and design options.

2.2.2.1 Horizontal and Vertical Sun Path Diagrams

However azimuth and altitude angles may be readily procured from tables, it's usually a lot of informative and convenient to get the knowledge from sun-path diagrams. Figure 5 represents the sky dome, but this time it has a grid of azimuth and altitude lines drawn on that even as a globe of the world has longitude and latitude lines. Even as there are maps of the world that are typically either polar or Mercator projections, so there are also horizontal or vertical projections of the sky dome (Figure 5). This image additionally shows however the sky dome's vertical projection is developed. Howsoever, that the apex purpose of the sky dome is projected as a line (Diaconescu, 2007).

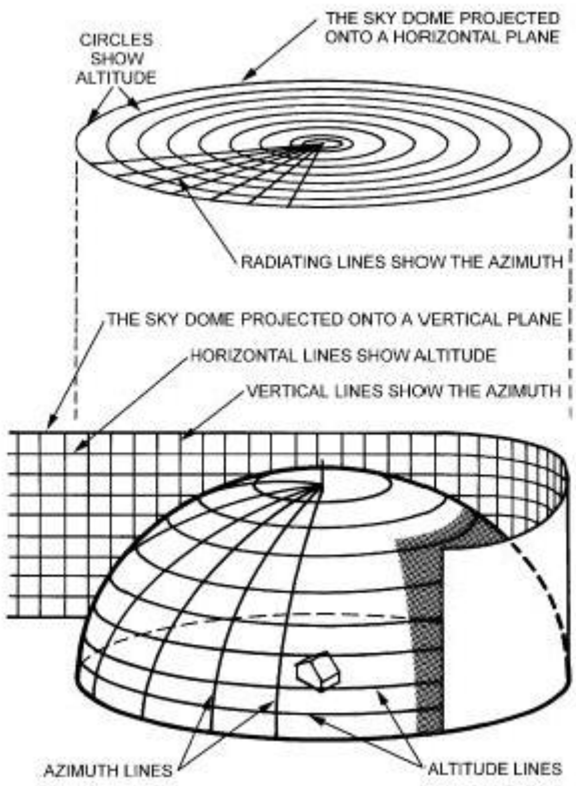


Figure 5: Derivation of the Horizontal and Vertical Sun Path Diagrams (Diaconescu, 2007)

2.2.2.2 The Stereographic Sun Path Diagram

Stereographic diagrams are used to represent the sun's changing position in the sky throughout the day and year. In form, they can be likened to a photograph of the sky, taken looking straight up towards the zenith, with a 180° fish eye lens. The paths of the sun as the different time of the year can then be projected onto this flattened hemisphere for any location on Earth (Szokolay, 2014).

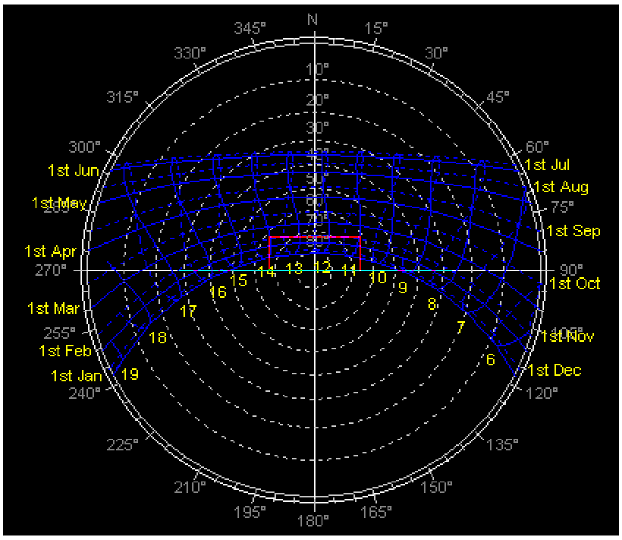


Figure 6: A basic full stereographic diagram (URL1: www.squ1.com/solar/sun-path-diagrams.html)

2.2.2.2.1 Azimuth Lines and Altitude Lines

Azimuth angles run around the edge of the diagram in 15° increments. A point's azimuth from the reference position is measured in a clockwise direction from True North on the horizontal plane. True North on the stereographic diagram is the positive Y axis (straight up) and is marked with an N. Altitude angles are represented as concentric circular dotted lines that run from the center of the diagram out, in 10° increments from 90 to 0. A point's altitude from the reference position is measured from the horizontal plane up (Diaconescu, 2007).

2.2.2.2.2 Date Lines and Hour Lines

Date lines represent the path of the sun through the sky on one particular day of the year. They start on the eastern side of the graph and run to the western side. There are twelve of these lines shown, for the 1st day of each month. The first six months are shown as solid lines (Jan-Jun) whilst the last six months are shown as dotted (Jul-Dec), to allow a clear distinction even though the path of the Sun is cyclical. Hour lines represent the position of the sun at a specific hour of the day, throughout the year. They are shown as figure-8 type lines (Analemma) that intersect the date lines.

The intersection points between the date and hour lines give the position of the sun. Half of each hour line is shown as dotted, to indicate that this is during the latter six months of the year (Szokolay, 2014).

2.2.2.3 The Cylindrical Sun Path Diagram

The main aim of the sun path diagram is the evaluation of solar access. Cylindrical sun path diagram is one of the most useful diagrams to evaluate the buildings based on sun path in specific time precisely. It is also one of the most often used diagrams for solar architects due to design and develop effective solar buildings. A Cylindrical sun path diagram, the bearing is marked at the base, and the altitudes on the vertical axis. The location of the sun can be determined by intersection of the altitudes and the azimuths. A very important use of this rectangular chart is that surrounding buildings can be plotted at define exactly when the sun would go behind those obstructions. Moreover in this diagram, the azimuth is plotted along the horizontal axis whilst the altitude is plotted vertically. The date and time values are first located in exactly the same way as in the Polar sun-path diagram. Once the date-hour intersection point is found, reading off positions is simply a matter of projecting vertically and then horizontally onto the two axis (Figure 7) (Baker, 2014).

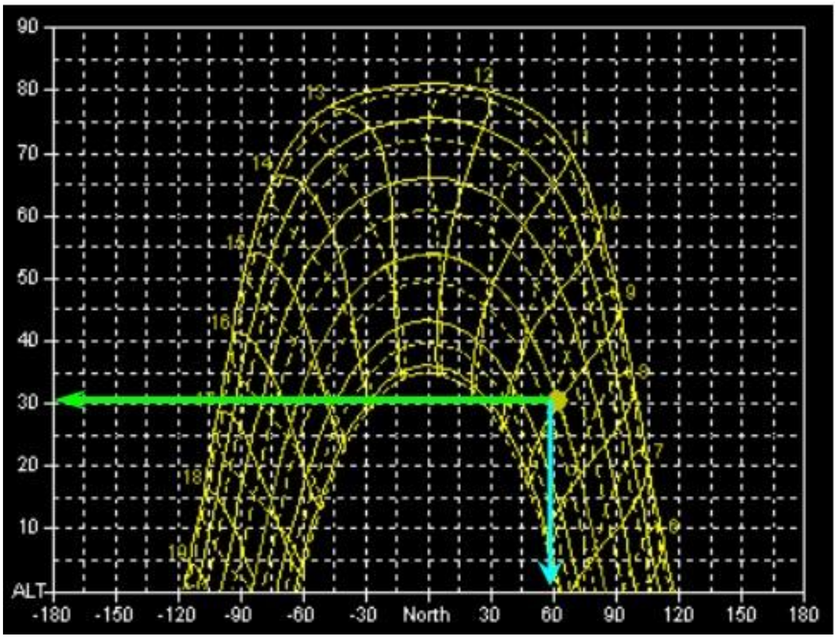


Figure 7: Example of Cylindrical Diagrams (URL2: www.squl.com/solar/sun-path-diagrams.html)

2.3 Passive Solar energy

Solar increment refers to the rise in temperature that happens once the sun's energy crossing via windows or doors. It may be prejudices or effective depending on the climate of the seasons. Technologies and new building materials can manipulate solar heat gain to maximize the comfort and reduce the energy prices of offices and homes. In active solar use the method happens with a form of energy transformation from heat to electricity, and passive ways are additional affiliate to passive components associated with light and harness heat (Duffie, 2013).

In colder climates solar gain are often helpful, to assist to diminish the costs of heating and it can even procreate heat for water heating. In warm climates the excessive solar energy can procreate a thermal load that needs to be diminished by the utilization of shading devices. The worth of solar energy getting into a building are often accomplished by using appropriate materials for windows, skylights, and doors (Boyle, 2004).

Furthermore solar energy are often used and offered in two alternative ways:

• Active solar energy

• Passive solar energy

In this regard, the use of shading devices is a part of sun control of passive solar energy use.

"Passive solar" refers to a system that stores, redistributes and collects solar energy without utilization of pumps, abstruse controllers or fans. It functions by relying on the integrated approach to building design, wherever the fundamental building parts, like floors, walls and windows have as many alternative functions as possible. For instance, the walls not solely impediment the roof and keep the weather however also work as heat-radiating and heat-storage parts. This means, the varied elements of a building at the same time satisfy structural, architectural and aesthetical needs. Each passive solar heating system will have a minimum of two parts: a collector consisting of an energy-storage parts and south-facing glazing that typically contains of thermal mass, like water or rock (Due, 2006).

Relating on the relationship of these two parts, there are three various kinds of passive solar energy systems:

- Direct Gain
- Indirect gain
- Isolated Gain

A passive solar method consist of five steps. These points are associated with direct gain and every of them has discrete performance. Even so, all the things should work along to realize a prosperous passive solar energy gain. These aspects will exemplified below:

- Aperture (collector): this can be regarding as exploitation of massive glass space which is used as collector of solar power and it shouldn't be shaded through alternative buildings throughout sunny periods.
- Absorber: absorbent may be floor, wall, or the other dark surfaces. Daylight hits absorbent and energy is absorbed as heat.
- Thermal mass: substances which reserve heat from sunshine as thermal mass. An absorbent is an exposed surface; but, materials as thermal mass are settled behind or below the surfaces.
- Distribution: may be a main technique during this system that delivers solar energy from storage points to all or any areas in home.
- Control: each prospering system ought to be controlled to work properly. During this regard, an overhang for aperture space will act like controller for optimum solar gain (Mingfang, 2002).

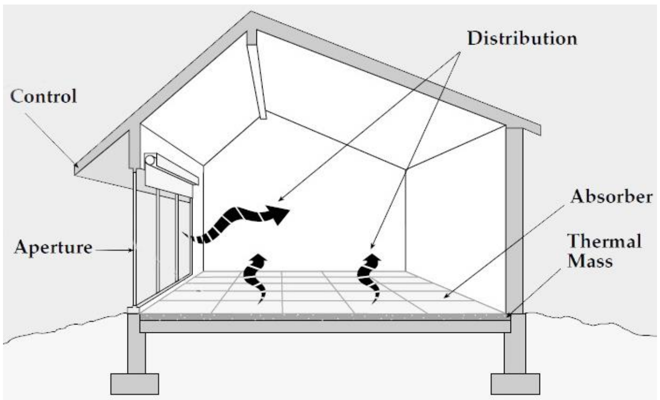


Figure 8: Five Elements in an Entire Passive Solar System (Paul, 2001)

2.3.1 Shading

The benefits of shading are so great and obvious which are visible in its application throughout history and across cultures. Its effect on classical architecture as well as on unrefined vernacular buildings (Sadler, 2005).

Many of the larger shading elements had the dual purpose of shading both the building and an outdoor living space (Lechner, 2009).

In hot and humid regions, large windows are required to maximize natural ventilation, but at the same time any sunlight that enters through these large windows increases the discomfort. For instance the overheating of interior spaces will lead to high indoor temperatures, which makes a negative impact on human's body. Large overhangs that are supported by columns can resolve this conflict (Figure 9). In any sensible design, building parts are sometimes multifunctional. The fact that the Greek porch conjointly protects against the rain does not negate its importance for solar control. It only makes the concept of a porch more valuable in wet and hot regions wherever rain is common and the sun is oppressive (Lechner, 2009).

Figure9: The Hermitage, Andrew Jackson's home near Nashville, TN(Lechner, 2009)

Shading is a key strategy of achieving thermal comfort in summer. Shading, as part of heat avoidance, is level one of the three-level design approach to cool a building (Figure 10). The second level consists of passive cooling, and the third uses mechanical equipment to cool whatever the architectural strategies of tiers one and two could not accomplish (Lechner, 2009).

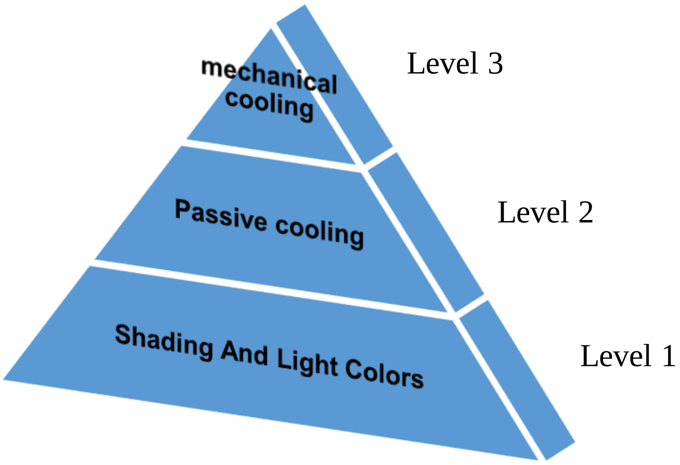


Figure 10: Logical and sustainable method for achieving thermal comfort in summer (Illustration drawn by author)

The graphic in figure 11 shows that on 21st of June, a window (horizontal glazing) collects regarding five times a big amount of solar radiation in comparison to a south window. Particularly, skylights won't be an effective shading or better should be avoided. Additionally figure 11 shows that east or west glazing collects virtually three times more solar radiation in comparison to south windows. Thus, the shading of east and west windows is also more efficient than the shading elements in south windows (Duffie, 2013).

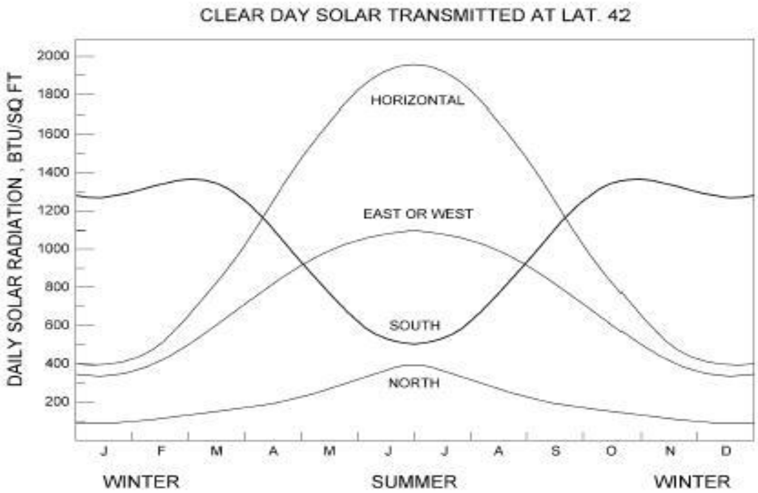


Figure 11: Amount of solar radiation in season (Duffie, 2013)

The total solar load consists of three components: direct, diffuse, and reflected radiation. To prevent passive solar heating when it is not wanted, one must always shade a window from the direct solar component and often also from the diffuse sky and reflected components. In sunny humid regions, like the Southeast, the diffuse-sky radiation can be very significant. Sunny areas with much dust or pollution can also create much diffuse radiation. (Figure 12). Reflected radiation, on the other hand, can be a large problem in such areas as the Southwest, where intense sunlight and high-reflectance surfaces often coexist. The problem also occurs in urban areas where highly reflective surfaces can be quite common. Concrete paving, white walls, and reflective glazing can all reflect intense solar radiation into a window. There are cases where the north facade of a building experiences the solar load of a south orientation because a large building with reflective glazing was built toward the north (Figure 13) (Lechner, 2009).

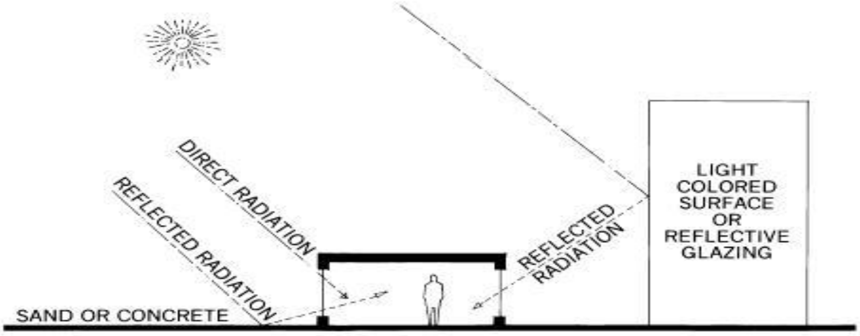


Figure 12: In humid and dusty regions, the diffuse-sky component is a large part of the total solar load(Lechner, 2009)

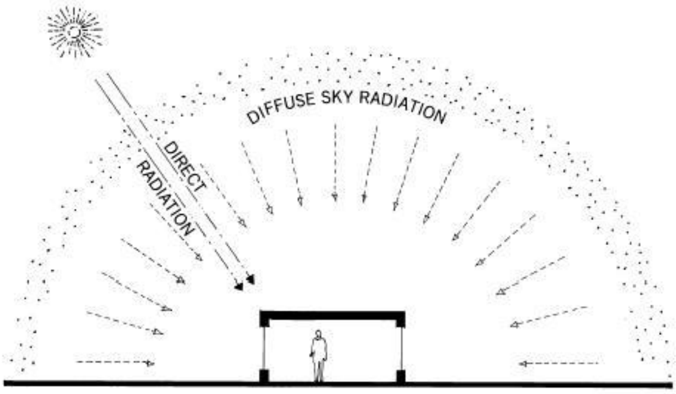


Figure 13: In dry regions, the solar load consists mainly on the direct and reflected components.(Lechner, 2009)

The size, location and type of a shading device can, therefore, rely partly on the size of the direct, diffuse, and reflected parts of the total solar load. The reflected part is sometimes best controlled by the reduction of solar reflection on the offending surfaces. Typically, this can be achieved by vegetation such as trees. The diffuse-sky part is, however, a much harder problem as a result of radiation, which comes from a great exposure angle. It is, therefore, sometimes controlled by additional indoor shading devices or shading within the glazing. The direct solar part is effectively controlled by outdoor shading devices(Lechner, 2009) .

Fortunately, when solar energy is brought into a building in a very controlled manner, it can supply high-quality lighting as well as reduce the heat gain. This is accomplished by allowing just enough light to enter so that the electric lights can be turned off.

When it is not used for day lighting, solar radiation should be blocked during the overheated period of the year. A residence in the north would experience an overheated period that was only a few months long. That same residence in the south or a large office building in the north could experience overheated periods that are two to three times as long. Thus, the required shading period for any building depends on both the climate and the nature of the building (Armaroli, 2011).

2.3.2 Orientation of Shading Devices

The horizontal overhang is extremely effective throughout the summer on south-facing windows as a result of the sun altitude. Though less effective, the horizontal overhang is additionally the most effective on the southwest, west, east, southeast and similar orientations. In hot climates, north windows conjointly have to be compelled to be shaded as a result of the sun that rises north of east and sets north of west (Throughout the summer). Since the sun is low within the sky at these times, the horizontal overhang is not very effective and tinny vertical fins work best on the north view (Figure 14) (Lechner, 2009).

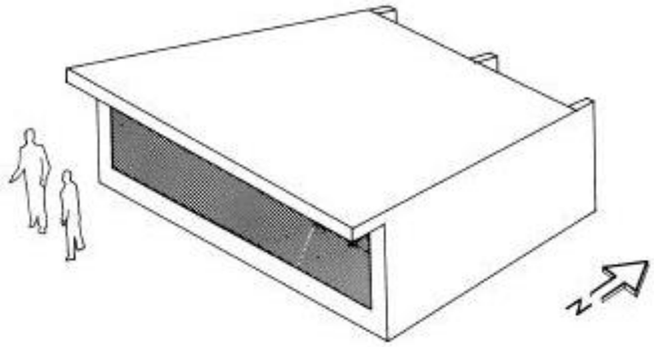


Figure 14: Each orientation requires a different shading strategy (Lechner, 2009)

West and east-facing windows create a tough problem attributable to the low-altitude angle of the sun in the afternoon and morning. The most effective resolution by far is to avoid using east and particularly west windows as far as possible. The best solution is to have the windows on the west and east views which should face to south or to north as representation (Figure 15). If that is also not conceivable, then vertical fins and/or horizontal overhangs ought to be used, however it should be understood that if they are to be very efficient, they will severely restrict the view (Schittich, 2003).

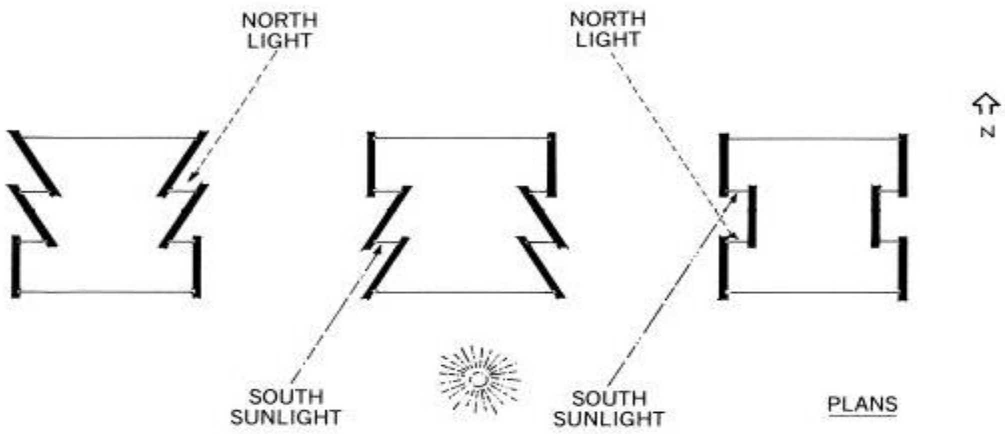


Figure 15: Window orientation (Lechner, 2009)

For more effective fixed shading devices, a mix of horizontal and vertical parts should be utilized, as represented in figure 16. When these horizontal and vertical parts are closely distanced, the system is termed an egg crate. This device is most applicable on west and east views in hot climates and on the southwest and southeast facades in extraordinarily hot climates (Loutzenhiser, 2007).

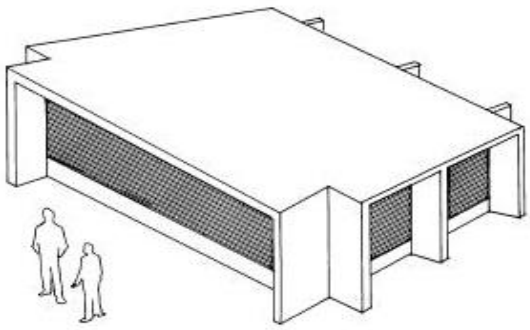


Figure 16: Combination of vertical and horizontal shading elements is used (Loutzenhiser, 2007)

Since the matter of shading is one of obstructing the sun at certain angles, several small devices will have constant impact as some massive ones, as represented in figure 17. In every case, the quantitative relation of length of overhang to the vertical portion of window shaded is the same. There are screens obtainable that encompass miniature louvers that are very efficient in obstruction the sun and nevertheless they are nearly as transparent as insect screens (Kotey, 2009).

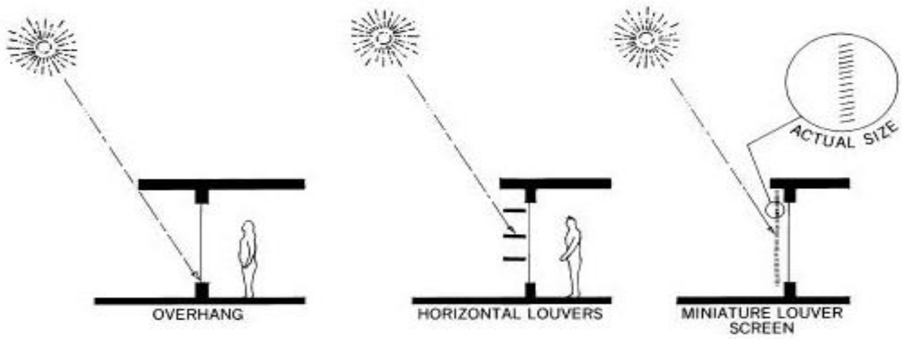


Figure 17: Shading effect with many small elements (Sun, 2012)

Skylights (horizontal glazing systems) produce a tough shading system because they are facing the sun most directly throughout the worst part of the year, summer at noon (Figure 18). So that skylights, such as west and east windows, should be avoided. A far higher resolution for rental daylight and winter sun while enter via the roof is the use of clerestory windows (Figure19)(Lechner, 2009).

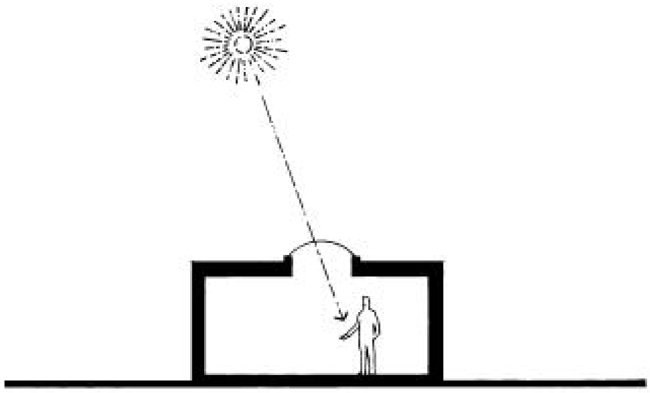


Figure 18: Skylights (horizontal glazing) in appropriate shading element (Lechner, 2009)

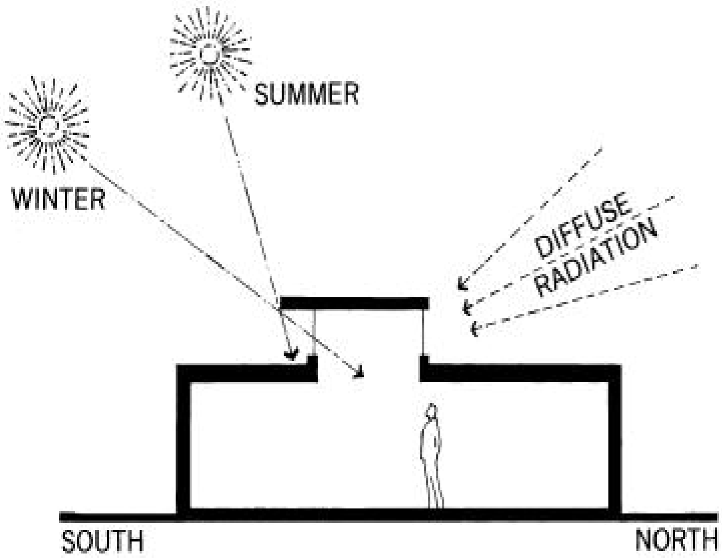


Figure 19: Clerestory windows as appropriate shading element (Lechner, 2009)

Fixed, instead of movable shading devices are typically used because of their simplicity, low maintenance, and low cost.

2.3.2.1 Exterior Shading Devices

Exterior shading devices such as overhangs and vertical fins incorporated in the building facade to limit the internal heat gain resulting from solar radiation. The have a number of advantages that contribute to a more sustainable building. First, exterior shading devices result in energy savings by reducing direct solar gain through windows. By using exterior shading devices with less expensive glazing, it is sometimes possible to obtain performance equivalent to unshaded higher performance glazing. A second benefit is that peak electricity demand is also reduced by exterior shading devices resulting in lower peak demand charges from utilities and reduced mechanical equipment costs. Finally, exterior shading devices have the ability to reduce glare in an interior space without the need to lower shades or close blinds. This means that daylight and view are not diminished by dark tinted glazing or blocked by interior shades. With exterior shading devices, glare control does not depend on user operation (Figure 20). (Carmody, 2007)

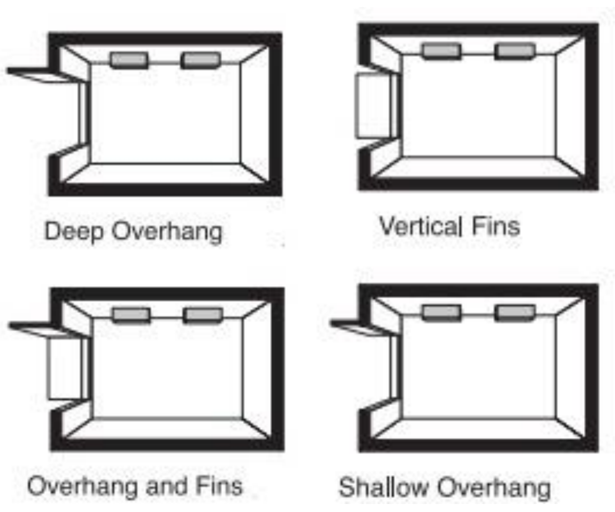


Figure 20: Example of Exterior Shading Device (Grondzik et al., 2011)

2.3.2.2 Interior Shading Devices

From an energy-rejection point of view, the external shading devices are by far the most effective. But for a number of practical reasons, the interior devices, such as curtains, roller shades, Venetian blinds, and shutters, are also very important (Figure 21). Interior devices are often less expensive than external shading devices, since they do not have to resist the elements. They are also very adjustable and movable, which enables them to easily respond to changing requirements. Besides shading, these devices provide numerous other benefits, such as privacy, glare control, insulation, and interior aesthetics. At night, they also prevent the "black hole" effect created by exposed windows (Galloway, 2004).

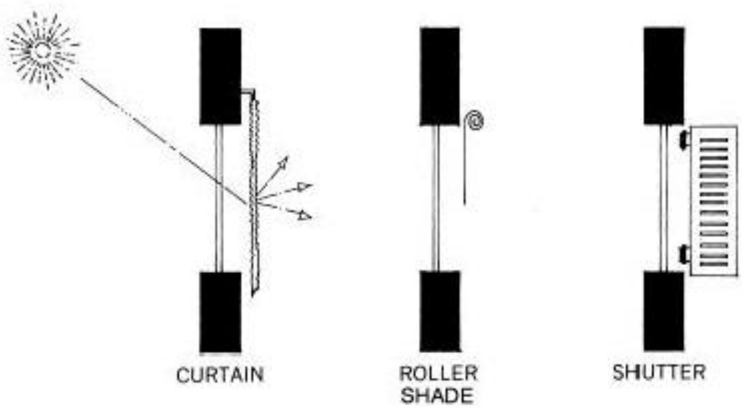


Figure 21: Interior Shading Devices for Solar Control(Lechner, 2009)

Since internal devices are usually included if external devices are supplied or not, internal devices should be used as advantage. They should be used to stop the sun when it outflanks the exterior shading devices. They are also useful for those exceptionally hot days during the transition or under heated periods of the year, when exterior shading is not used as Venetian blinds or light shelves (Figure 22) (Grondzik et al., 2011).

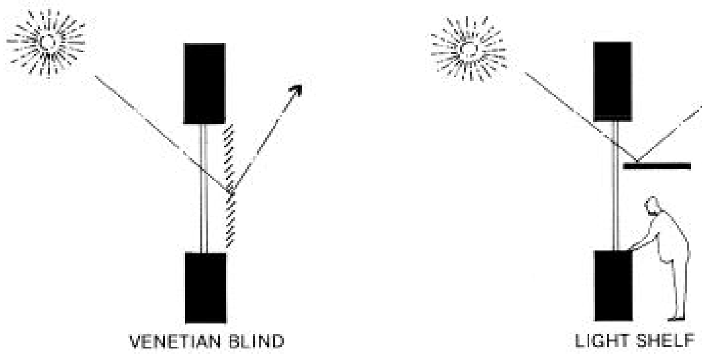


Figure 22: Interior Shading Devices (Grondzik et al., 2011)

One of the most drawbacks of interior devices is that they are not continually discerning. They cannot block the sun whereas admitting the view, one thing that may be effectively through with an external overhang. Since they block the solar radiation within the glazing, a lot of the heat remains inside. The side of the shade facing to glass should be as light as possible (white) in order to reflect solar radiation back out through the glass before it is regenerated to heat (absorption).

When indoor shades are utilized in conjunction with overhangs, the shades should move up from the window sill instead of down from the window head (Figure 23). The lower portion of a window always wants a lot of shade than the upper. Hence, some view, privacy, and day lighting can be maintained while shading function is required (Palmero-Marrero, 2010).

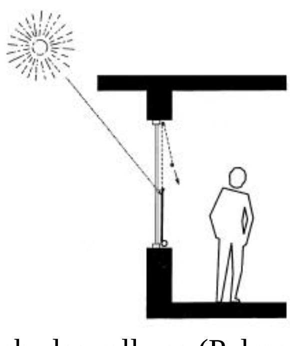


Figure 23: Roller shades roll use (Palmero-Marrero, 2010)

2.3.3 Type of Shading Devices

2.3.3.1 Horizontal shading devices

All shading devices accommodates of either vertical fins, horizontal overhangs, or both combinations. The horizontal overhang types are the best alternative for the south facade. As a result they are directionally selective, they will let the low winter sun into the interior spaces whereas absolutely shade the high summer sun with minimum occlusion of the view. They are usually also the best choice for east, southeast, southwest, and west orientations. Horizontal louvers have variety of benefits over solid overhangs. Horizontal louvers in a very horizontal plane decrease structural loads by permitting snow and wind to pass right throughout. Within the summer, they additionally minimize the gathering of hot air next to the windows under the overhang (Figure 24) (Galloway, 2004).

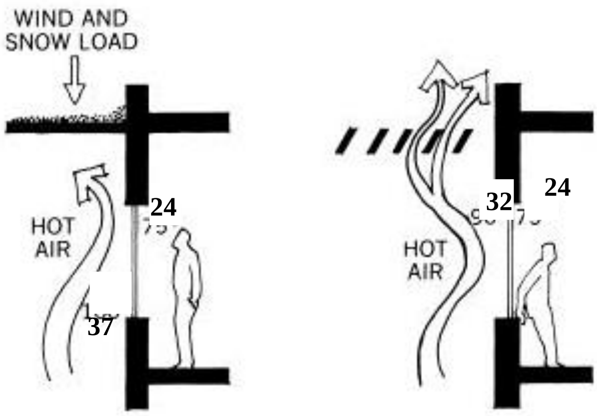


Figure 24: Horizontal louvered overhangs both vent hot air and minimize snow and wind loads(Galloway, 2004)

Horizontal louvers in a vertical plane are applicable once the protruding distance from the wall should be restricted. This might be vital if a building is on or close to the borderline. Louvers may also be helpful once the design incorporate small-scale components and a rich texture.

When designing an overhang for the south facade, one should keep in mind that the sun comes from the southeast before noon and from the southwest afternoon. Thus, the sun can outflank an overhang a similar breadth as a window. Thin windows want either a really wide overhang or vertical fins additionally to the overhang (Figure 25). Wide strip windows are affected less by this drawback as visible in figure 26 (Maurya, 2011).

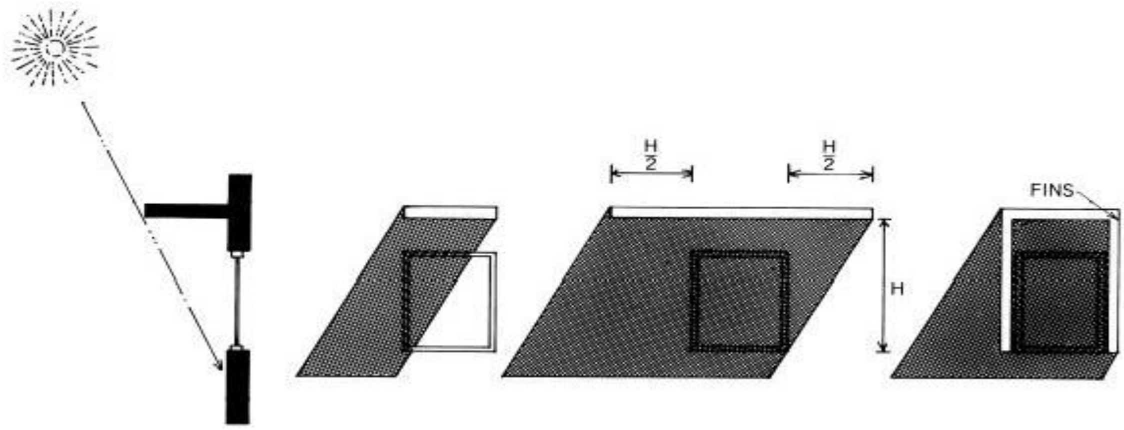


Figure 25: Use a wider overhang or vertical fins on each side of the window. (Maurya, 2011)

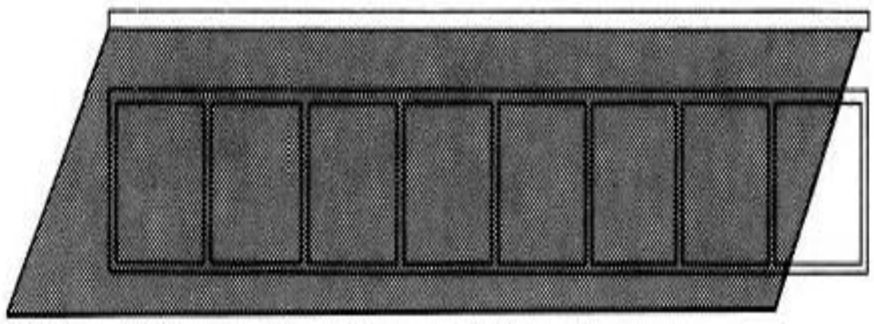


Figure 26: Long strip windows make efficient use of the horizontal overhang (Maurya, 2011)

The following illustration represents variety of basic shading devices, classified as horizontal. (Figure 27)

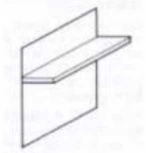
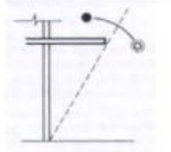
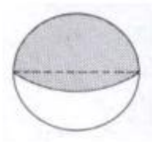
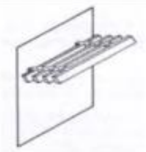
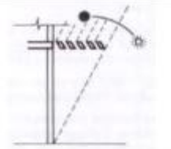
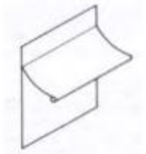
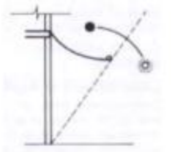
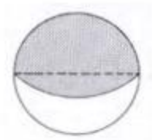
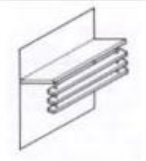
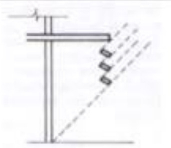
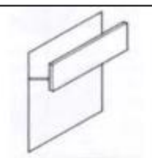
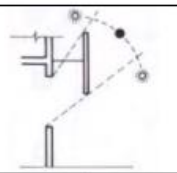
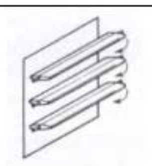
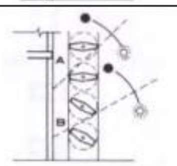
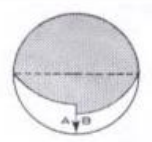
Horizontal Types			
Shading Device	Side View	Shading Masks	Comments
			Straight overhangs are most effective on southern exposure.
			Louvers parallel to wall allows hot air to escape and are most effective on southern exposure.
			Awnings are fully adjustable for seasonal conditions and most effective on southern exposure.
			Horizontal louvers hung from solid overhangs cuts out the lower rays of the sun. Effective on south, east and west exposures.
			Vertical strip parallel to wall cuts out the lower rays of the sun. Effective on south, east and west exposures.
			Rotating horizontal louvers are adjustable for daily and seasonal conditions. Effective on south, east and west exposures.

Figure 27 :Horizontal Shading Devices(Galloway, 2004)

2.3.3.2 Vertical Shading Devices

The vertical shading devices, are primarily helpful for west and east exposures. These devices additionally improve the insulation value of enclose winter months by acting as a shelterbelt. Furthermore vertical components can be designed to vary angle according to the sun's position (Brown & DeKay, 2001).

The following illustration represents variety of basic shading devices, classified as vertical: (Figure 28)

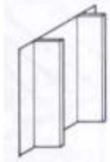
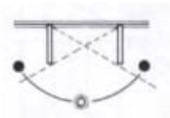
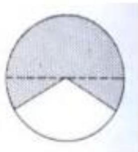
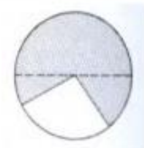
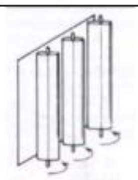
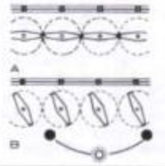
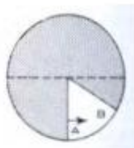
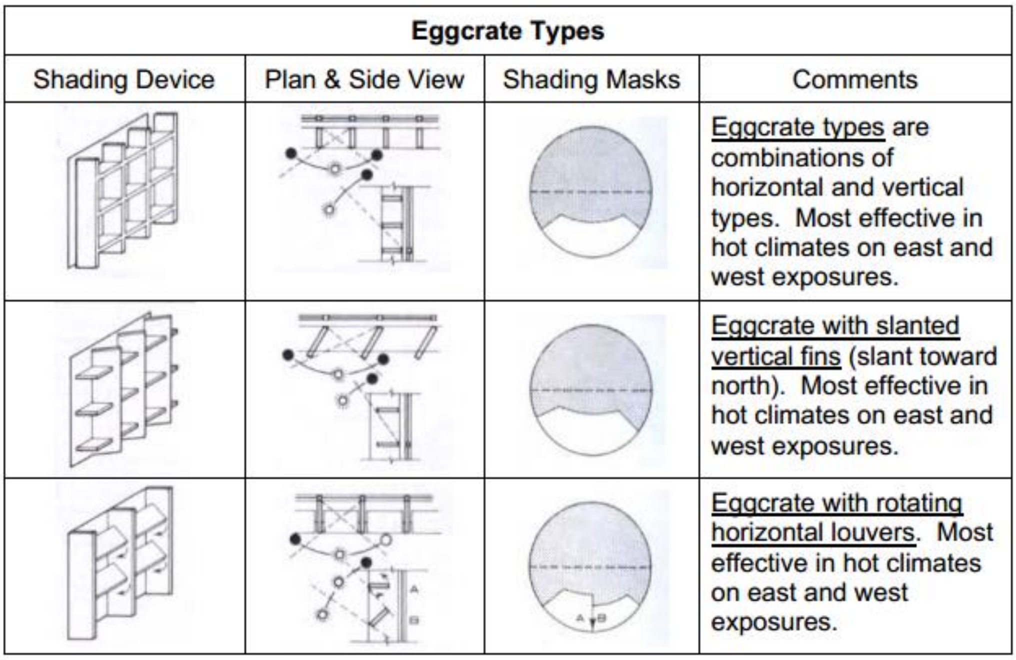
Vertical Types			
Shading Device	Plan View	Shading Masks	Comments
			Vertical fins are most effective on the near-east, near-west and north exposures.
			Slanted vertical fins are most effective on east and west exposures. Slant toward north and separation from wall minimizes heat transmission.
			Rotating vertical fins are the most flexible and adjustable for daily and seasonal conditions. Most effective on east and west exposures.

Figure 28:Vertical Shading Devices (Brown & DeKay, 2001)

2.3.3.3 Egg Crate Shading Devices

Egg crate shading devices are principally for west and east windows in hot climates and for the extra southwest and southeast orientations in very hot climates. An egg crate is a combination of vertical fins and horizontal overhangs (louvers). By dominant sun penetration by both the azimuth and altitude angle of the sun, extremely impressive shading of windows can be attained.

The following illustration represents variety of basic shading devices, classified as egg crate. (Figure 29)



Eggcrate Types			
Shading Device	Plan & Side View	Shading Masks	Comments
			Eggcrate types are combinations of horizontal and vertical types. Most effective in hot climates on east and west exposures.
			Eggcrate with slanted vertical fins (slant toward north). Most effective in hot climates on east and west exposures.
			Eggcrate with rotating horizontal louvers. Most effective in hot climates on east and west exposures.

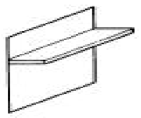
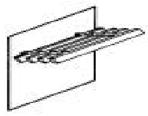
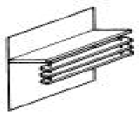
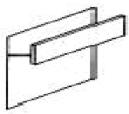
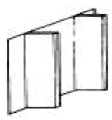
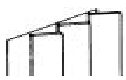
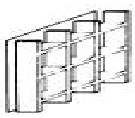
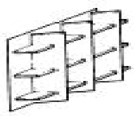
Figure 29: Egg Crate Shading Devices (Brown & DeKay, 2001)

Figure 30: Egg Crate Shading Device made of Masonry Units(Lechner, 2009)

2.3.3.4 Fixed Shading Devices

Fixed shading devices are typically utilized on the external view of glazing since they lower direct radiation from reaching the internal ambient, blocked the solar radiation. Table 1 displays some of the most popular fixed external shading devices. They are all alterations of either the egg crate (which is the combination of the vertical and horizontal), the vertical fin, or the horizontal overhang. The fins and louvers can be angled for additional solar control (Van Moeseke, 2007).

Table 1: Examples of fixed shading devices (Van Moeseke, 2007)

	Descriptive name	**Best orientation**	**Comments**
	Overhang Horizontal panel	South, east, west	Traps hot air Can be loaded by snow and wind
	Overhang Horizontal louvers in horizontal plane	South, east, west	Free air movement Snow or wind load is small Small scale
	Overhang Horizontal louvers in vertical plane	South, east, west	Reduces length of overhang View restricted Also available with miniature louvers
	Overhang Vertical panel	South, east, west	Free air movement No snow load View restricted
	Vertical fin	East, west, north	Restricts view For north facades in hot climates only
	Vertical fin slanted	East, West	Slant toward north Restricts view significantly
	Eggcrate	East, west W	For very hot climates View very restricted Traps hot air
	Eggcrate with slanted fins	East, west	Slant toward north View very restricted Traps hot air For very hot climates

2.3.3.5 Movable Shading Devices

It is not surprising that movable shading devices respond better to the dynamic nature of weather than static devices. Since we need shade during the overheated periods and solar radiation during the under heated periods, a shading device must be in phase with the thermal conditions. With a fixed shading device, the period of solar exposure to the window is not a function of temperature but rather of sun position (Figure 31). Unfortunately, sun angles and temperature are not completely in phase. For one, daily weather patterns vary widely, especially in spring and fall when one day might be too hot while the next might be too cold. A fixed device that is wide enough to block the sun in late April cannot make adjustments for a cold April day. The other additional vital reason for the discrepancy between temperature and sun angles is that the thermal year and solar year are out of phase. Due to its great mass, the world heats up slowly in spring and does not reach its most summer temperature till one or two months after the summer solstice (21 June). Equally within the winter, there is a one-or two-month time lag within the cooling cycle of the world. The minimum heating impact from the sun comes on 21 December, whereas the coldest days are in January or February. A fixed shading device can shade for equal time periods after and before 21June. For example, 21August and 21April will receive the same shade, even although August is considerably hotter (Crawley, 2004).

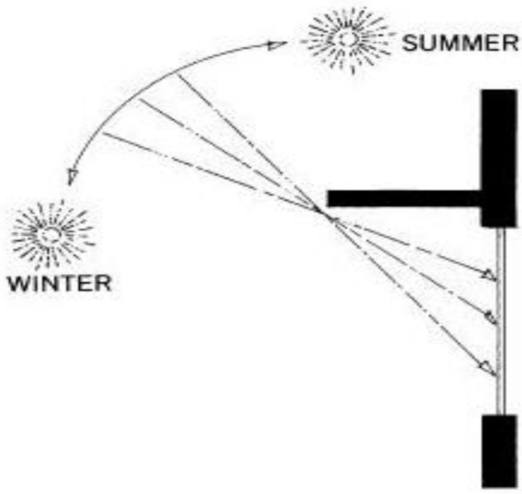


Figure 31: Function of the time of year and not of the temperature (Crawley, 2004)

To get full shading, would attempt a fixed shading device (Figure 32), that is sized to produce shade through the top of the hot amount. Though currently have shade throughout the complete overheated period, additionally shade the windows throughout a part of the underheated period. Solely a movable shading device, as represented in figure 33, will overcome this matter moreover because the problem of daily changes. The exception is in those buildings while passive solar heating is not needed. Here, a fixed shading device would be more applicable (Schittich, 2003).

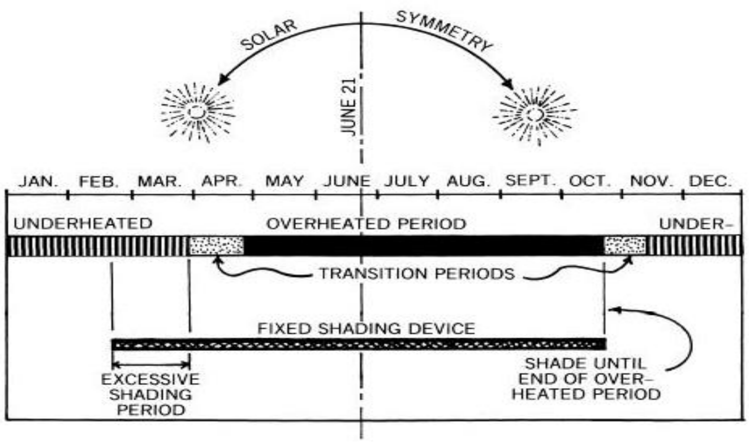


Figure 32: for a fixed shading device, excessive shading accurs in late winter (Schittich, 2003)

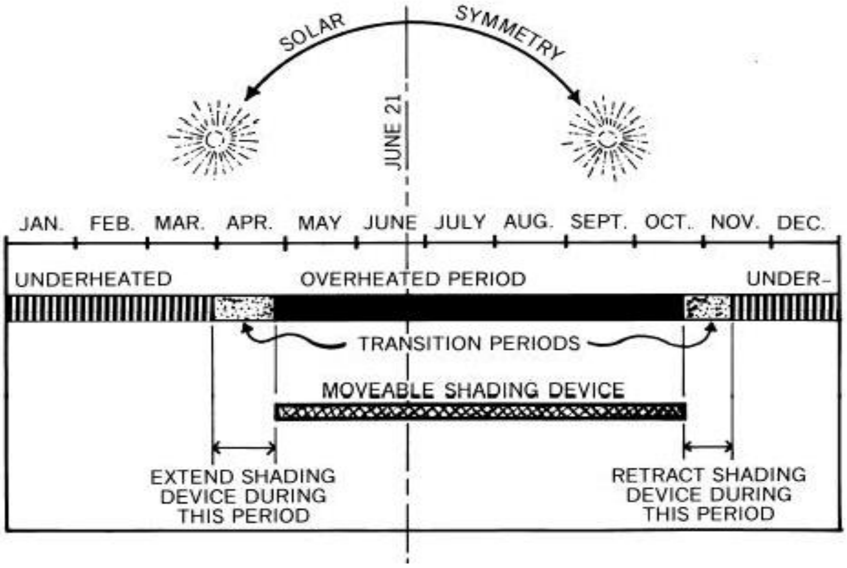


Figure 33: A movable shading device enables the shading to be in phase with the thermal year(Schittich, 2003)

The movement of shading devices is terribly easy or terribly advanced. An adjustment twice a year can be totally impressive and yet simple. Late in spring, at the beginning of the over-heated period, the shading device would be manually extended. At the end of the overheated period in late fall, the device would be retracted for full solar disposal (Figure 34) (Wen, Steller Chiang, Shapiro, & Clifford).

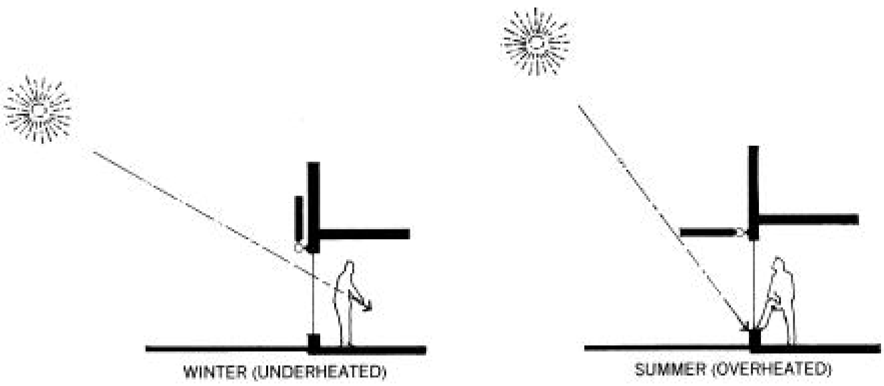


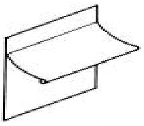
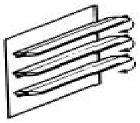
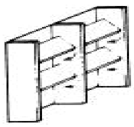
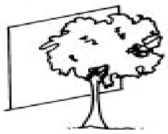
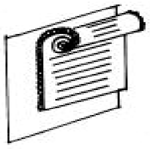
Figure 34: Movable shading device with just two simple adjustments per year (Wen et al.)

Before air conditioning became available, awnings were used to effectively shade windows in summer. Awnings were used on many buildings but were particularly common on luxury buildings, such as major hotels (Figure 35). In winter, the awnings were removed to let more sun and light could enter into the building. Modern awnings are excellent shading devices. They can be durable, attractive, and easily adjustable to meet requirements on a daily and even hourly basis. Movable shading devices, which adjust to the sun on a daily basis, are often automated, while those that need to be adjusted only twice a year are usually manually operated. Table 2 shows a variety of movable shading devices (Wienold, 2007).

Figure 35: Awnings element on many buildings during the first half of the twentieth century (Wienold, 2007)

Table 2: Examples of Movable Shading Devices (Lechner, 2009)

Descriptive name

IX 	Overhang Awning	South, east, west	Fully adjustable for annual, daily, or storm conditions Traps hot air Good for view
X 	Overhang Rotating horizontal louvers	South, east, west	Will block some view and winter sun
XI 	Fin Rotating fins	East, west	Much more effective than fixed Less restricted view than slanted fixed fins
XII 	Eggcrate Rotating horizontal louvers	East, west	View very obstructed but less than fixed eggcrate For very hot climates only
XIII 	Deciduous plants Trees Vines	East, west, southeast, southwest	View restricted but attractive for low-canopy trees Air cooled
XIV 	Exterior roller shade	East, west, southeast, southwest	Very flexible from completely open to completely closed View is restricted when shield is used

In many ways, the simplest shading devices are the plants, most of that are in part with the thermal year as a result of they lose and gain their leaves in response to temperature changes. Different benefits of deciduous plants include visual privacy, low cost, ability to reduce glare, aesthetically pleasing quality and ability to cool the air by evaporation from the leaves.

The basic disadvantage of mistreatment plants is the proven fact that leafless plants still produce some shade with some varieties far more than the others (Figure 36). Other disadvantages include restricted height, slow growth and therefore the possibility of illness destroying the plant. However, vines growing on a trellis or hanging from a planter will overcome several of those issues (Figure 37 and 38) other effective movable shading device is that the exterior roller shade. These types of shading devices are particularly suitable on those difficult west and east exposures, wherever for half a day almost no shading is critical and for the other half almost full shading is needed. (Baldinelli, 2009)

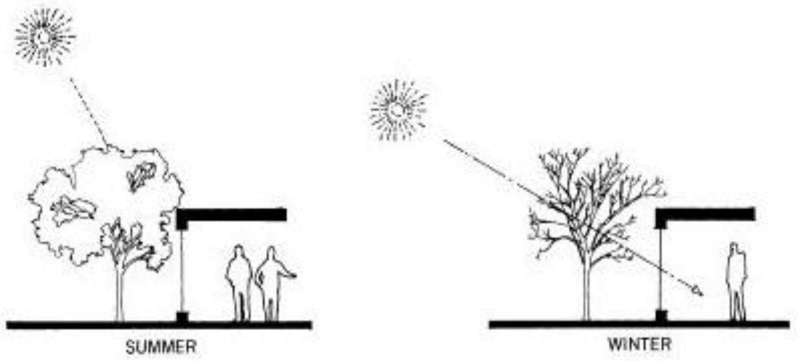


Figure 36: The shading from trees (Baldinelli, 2009)

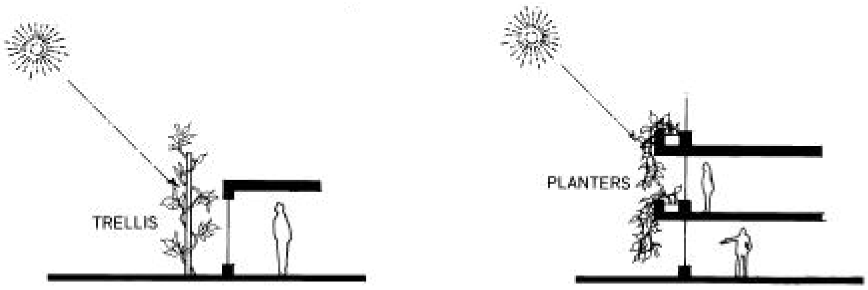


Figure 37: Vines as effective sun shading element (Lechner, 2009)

Figure 38:Trees as shading element for multistory buildings (Lechner, 2009)

2.3.4 Shading design

Solar radiation incident on a window consists of three components: beam-(direct-) radiation, diffuse-(sky-) and reflected radiation. External shading devices can eliminate the beam component (which is normally the largest) and reduce the diffuse component. The design of such shading devices employs two shadow angles: HAS (horizontal shadow angel) and VSA (vertical shadow angel).

2.3.4.1 Shadow angles

Shadow angles express the sun's position in relation to a building face of given orientation and can be used either to describe the performance of a given device or to specify a device. Horizontal shadow angle (HSA) is the difference in azimuth between the sun's position and the orientation of the building face considered, when the edge of the shadow falls on the point considered (Figure 39):

HSA = AZI - ORI[1]

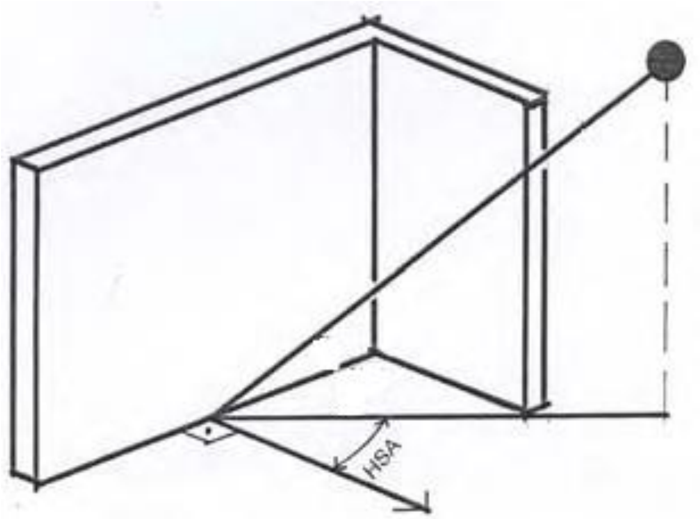


Figure 39: Horizontal shadow angle (Grondzik, 2011)

By convention, this is positive when the sun is clockwise from the orientation (when AZI > ORI) and negative when the sun is anticlockwise (when AZI < ORI). When the HSA is between +/- 90o and 270o, then the sun is behind the facade, the facade is in shade, there is no HSA. Section in Appendix A gives two further checks for results beyond 270o. The horizontal shadow angle describes the performance of a vertical shading device. Figure 40 shows that many combinations of vertical elements can give the same shading performance. (Grondzik, 2011)

[1] Orientation (building face azimuth)

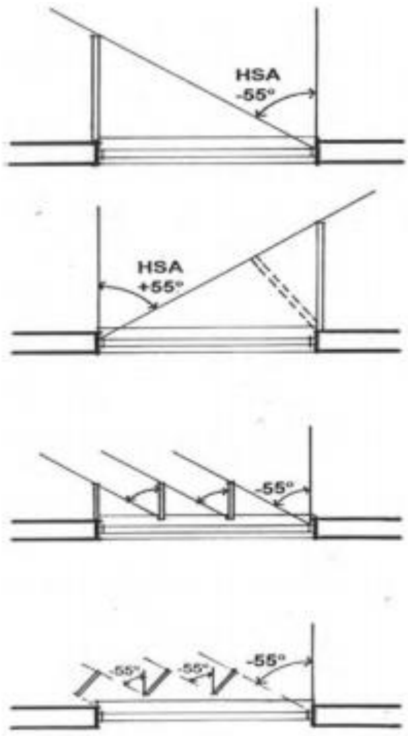


Figure 40: Vertical shading devices giving the same horizontal shadow angle (Maurya, 2011)

The vertical shadow angle (VSA) (or 'profile angle' for some authors) is measured on a plane perpendicular to the building face. VSA can exist only when the HSA is between -90o and +90o, i.e. when the sun reaches the building face considered. When the sun is directly opposite, i.e. when AZI = ORI (HSA = 0o), the VSA is the same as the solar altitude angle (VSA = ALT). When the sun is sideways, its altitude angle will be projected, parallel with the building face, onto the perpendicular plane and the VSA will be larger than the ALT (Figure 41). Alternatively, VSA can be considered as the angle between two planes meeting along a horizontal line on the building face and which contains the point considered, i.e. between the horizontal plane and a tilted plane which contains the sun or the edge of the a shading device (Figure 42) (Maurya, 2011) .

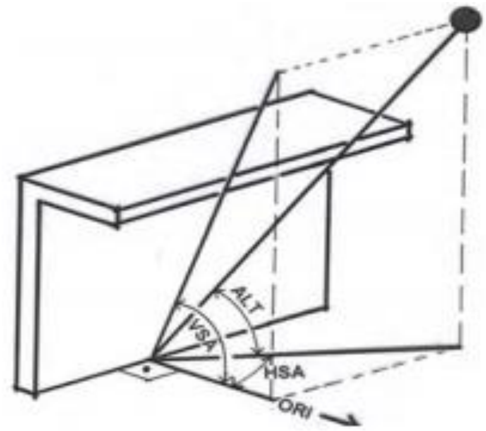


Figure 41: Relationship of VSA and ALT (Maurya, 2011)

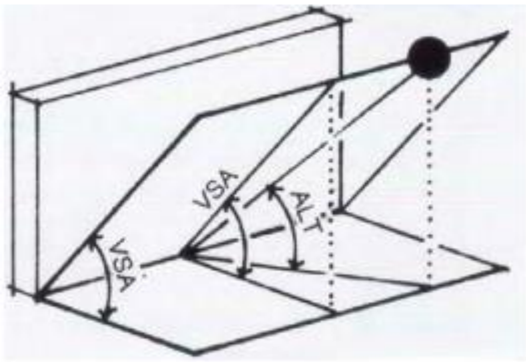


Figure42: Relationship of VSA and ALT (Maurya, 2011)

2.3.4.2 Design Guidelines for Fixed South Overhangs

A fixed horizontal overhang is utmost applicable when passive solar heating is not needed. The purpose, then, is to search out the length of overhang that may shade the south windows throughout most of the overheated time. Figure 43 displays the sun angle at the top of the overheated time. Since the sun is higher within the sky throughout the remainder of the overheated period, any overhang that extends to the line represented can totally shade the window for the complete overheated time. This full shade line is outlined by angle "A" and is drawn from the sill (Orsi, 2009).

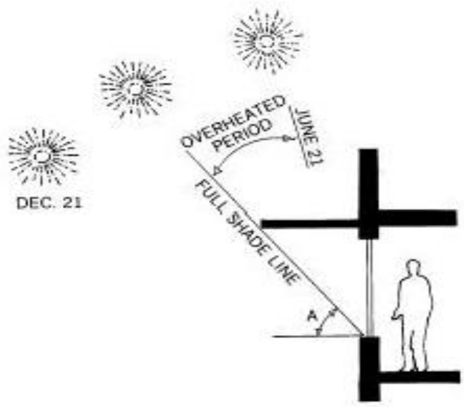


Figure 43:The "full shade line" determines the length of overhang (Lechner, 2009)

Overhangs that are higher on the wall, which reach “full shade line" can yet block the direct radiation and nevertheless provides a larger view of the sky. However, this might not be fascinating in regions with vital diffuse radiation since each visual glare and inflated over-heating can result from the increased exposure to the intense sky (Figure 44). Even the overhang, which is shown in figure 43 might not be enough in very humid regions where over 50 percent of the whole radiation can come from the diffuse sky. Instead of increasing the length of the overhang, it would be fascinating to use alternative devices, like plants or curtains, to dam the diffuse radiation from the low sky (Orsi, 2009).

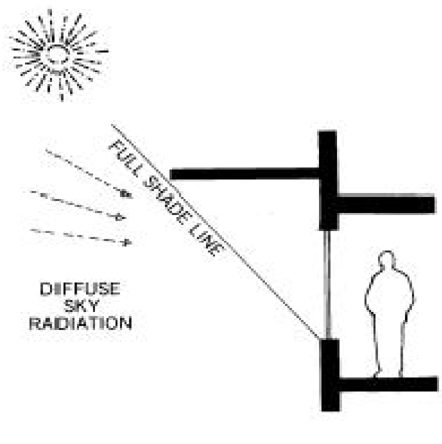


Figure 44: Fixed overhangs placed higher on the wall are not desirable in humid climates(Lechner, 2009)

As the sun slope under the "full shade line" later within the year, the window can bit by bit receive some radiation. However, the higher part of the window is in shade even at the winter solstice (Figure 45). Furthermore, an overhang extending to the complete shade line may end up in an exceedingly wholly dark interior.(Carmody, Selkowitz, Lee, Arasteh, & Willmert, 2004)

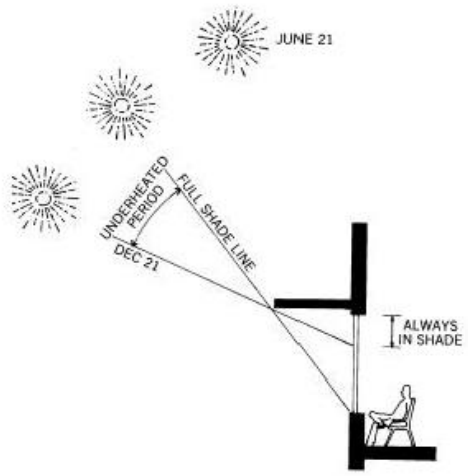


Figure 45: A fixed overhang designed to shade a window during the whole overheated period (Lechner, 2009)

Method for Designing fixed south overhangs:

- Confirm the climate area of the building.
- On a part of the window draw the "full shade line" from the window sill.
- Any overhang that extends to the current line can provide full shade throughout most of the overheated period of the year.
- Shorter overhangs would still be helpful, despite the fact that they would shade less in the overheated period(Lechner, 2009).

3.1.1.2.1 Design Guidelines for Moveable South Overhangs

The design of movable overhang is similar as for fixed overhang for the overheated period of the year. However, to create impressive use of passive solar heating, the overhang should avoid shading of windows throughout the underheated amount.

To ensure full-sun exposure of a window during the underheated period (winter), two points must be addressed. The first is to determine at which times of year the overhang must be retracted, and the second is to determine how far it must be retracted (Duffie, 2013).

The sun angle at the end of the under heated period (winter) determines the "full sun line" (Figure 46). Since the sun is lower than this position during the rest of winter, any overhang short of this line will not block the sun when it is needed. This "full sun line" is defined by angle "B" and is drawn from the window's head.(Galloway, 2004)

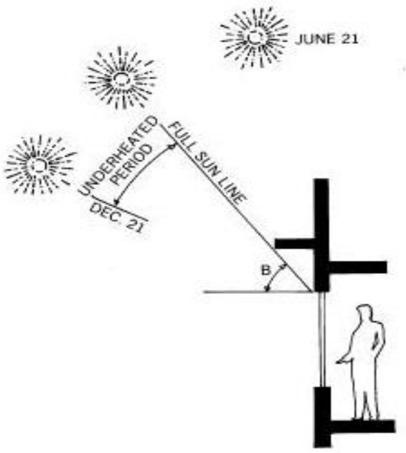


Figure 46: The "full sun line" determines the maximum allowable projection of an overhang.(Lechner, 2009)

Method for designing Movable South Overhangs:

- Confirm the climate area of the building

- On a district of the window, draw the "full shade line" (angle "A") from the window sill, and draw the "full sun line" (angle "B") from the window head (Figure 47).

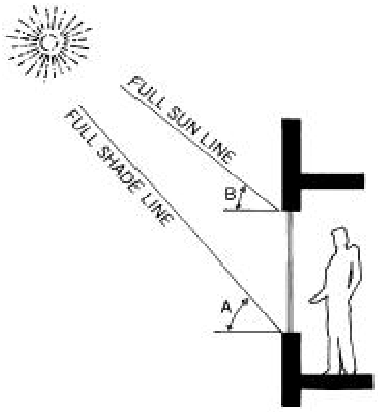


Figure 47: A fixed overhang, unlike a movable overhang (Duffie, 2013)

- A movable overhang must touch the "full shade line" throughout the hot period of the year and be retracted past the "full sun line" throughout the underheated amount of the year. See figure 48 as typical solutions:

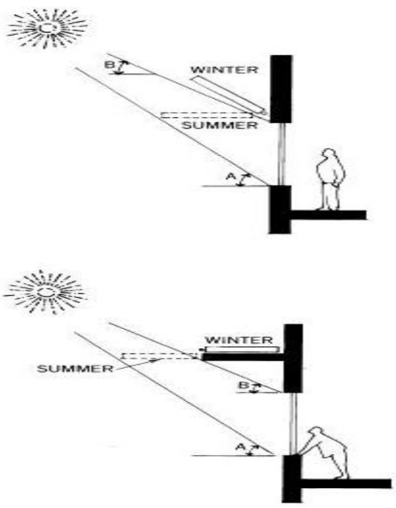


Figure 48: Alternative movable overhangs shown in both winter (under heated) and summer (overheated) positions. (Herzog, 2008)

- The overhang ought to be extended throughout the spring transition amount and backward throughout the autumn transition period (Herzog, 2008).

2.3.4.4 Shading for East and West Windows

On east and west orientations, unlike the south, it is not possible to fully shade the summer sun with a fixed overhang. The figure 49 represents how futile it would be to try to completely shade east or west windows with a horizontal overhang. Even though the direct sun rays cannot be shaded for the whole overheated period, it is nevertheless worthwhile to shade the windows part of the time(Grondzik, Kwok, Stein, & Reynolds, 2011).

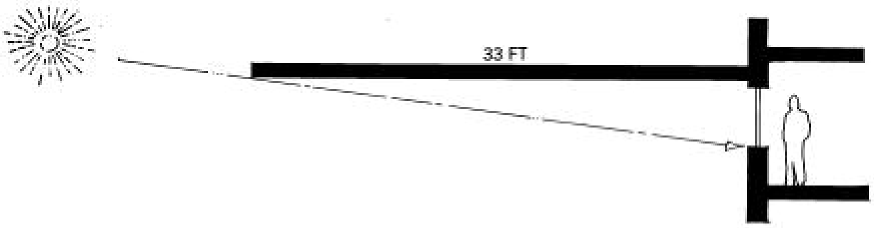


Figure 49: Shade east and west
windows with horizontal overhangs (Grondzik et al., 2011)

Since every little winter, heating is expected from west and east windows, shading devices on those orientations should be designed strictly on the idea of the summer demand.

No shading device can absolutely shade the west or east windows and permit a decent read because the low sun are going to be a part of the view. Since the view may be a high preference for windows, a horizontal overhang offers the simplest combination of shade and view on the west and east. These overhangs should be for much longer than the one on the south and will be protected by another device, like Venetian blinds.

Vertical fins are usually presented because as alternative shading device for west and east. In fact, they impede the view much more, and they shade no higher than the horizontal overhang. Figure 50 represents the fact, that there is a time each afternoon and morning when the sun shines directly on west and east facades of a building throughout the summer (six months of the year, 21 March to 21 September). Hence, vertical fins that face directly west or east can enable some sun penetration each day throughout the worst six months of the year. To minimize this solar penetration, we need to minimize the "exposure angle (Figure 51). Accomplish this by decreasing the distancing of the fins, by creating the fins deeper, or a number of each. To be extremely effective, the fins should be thus deep and then closely distanced that a view through them becomes nearly not possible (Ching, 2011).

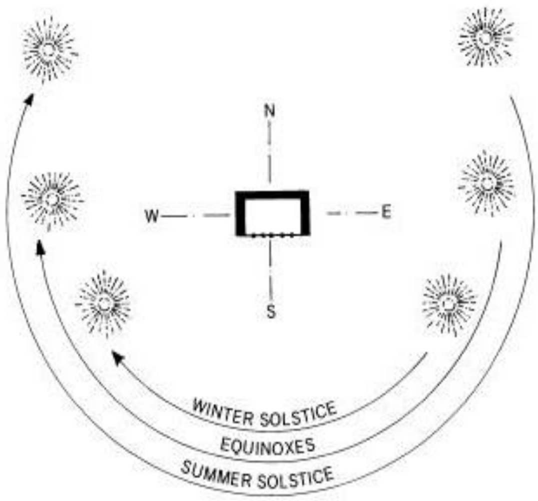


Figure 50: Illustrates the sweep of the sun's azimuth angle
at different times of the year from sunrise to sunset (Herzog, 2008)

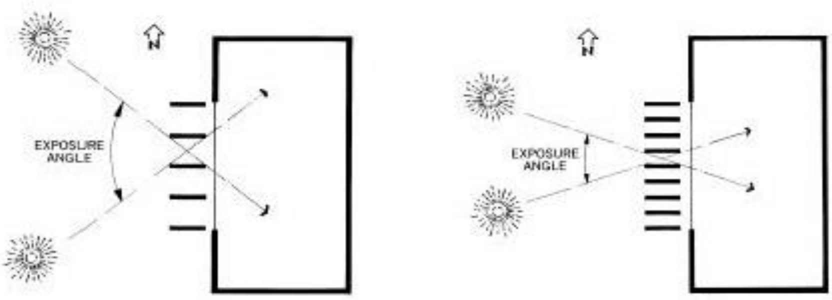


Figure 51: A plan view of vertical fins on a west (east) facade (Ching, 2011)

Vertical fins can be appropriate either when there is a desire to control the direction of view (e.g., slant fins to the northeast to block the view to the west and southwest) or when the view is not important. In that case, the fins could be slanted either to the south for more winter sun or to the north for more cool daylight (Figure 52) or both if the fins are movable (Duffie, 2006).

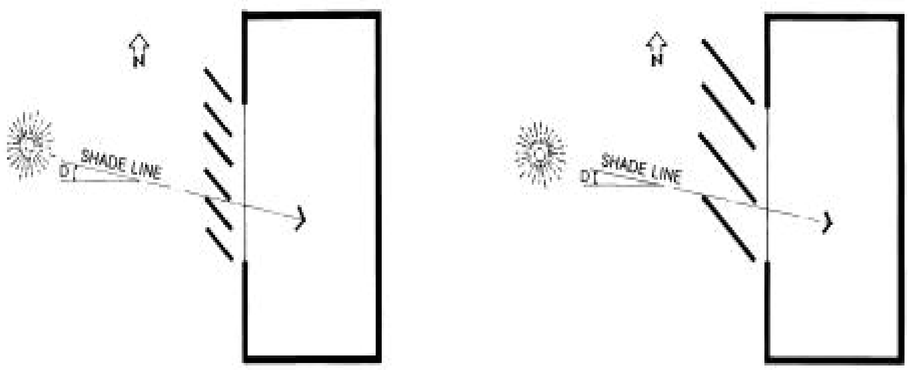


Figure 52: Combination of fin spacing, fin depth,
and fin slant on east and west windows (Duffie, 2006)

By moving in response to the daily cycle of the sun, movable fins allow somewhat unobstructed views for most of the day and yet block the sun when necessary. For example, movable fins on a west window would be held in the perpendicular position until the afternoon when the sun threatened to outflank them (Figure 53) (DeKay & Brown, 2013).

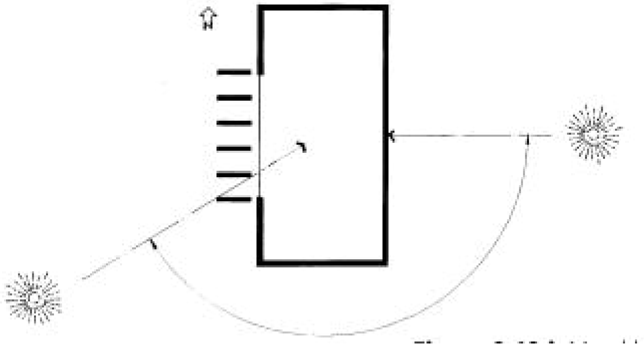


Figure 53: West movable fins in their maximum open position (DeKay & Brown, 2013)

Movable fins on the east windows would, of course, work similarly. Thus, if both effective shading and views to the east and west are desirable, then movable rather than fixed vertical fins should be considered (Figure 54) (DeKay & Brown, 2013).

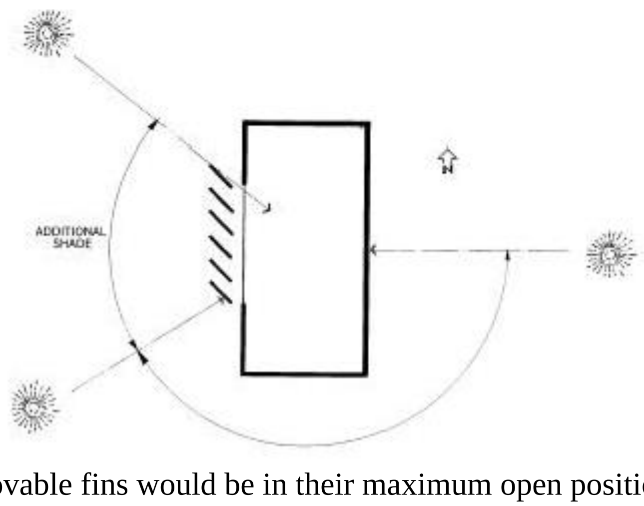


Figure 54 :East movable fins would be in their maximum open position (DeKay & Brown, 2013)

2.3.5 Shading Periods of the Year

Windows need shading during the overheated period of the year, which is both a function of climate and building type. From an energy point of view, buildings can be divided into two main types: envelope-dominated and internally dominated.

The internally dominated building tends to own a tiny low surface-area-to-volume ratio and large internal heat gains from such sources as people, machines and lights. The envelope-dominated building, on the other hand, suffers greatly from the climate as a result of its large surface-area-to-volume ratio and because it has solely modest internal heat sources. See table 3 for a comparison of the two types of buildings(Lechner, 2009).

Buildings do not require heating until the outside temperature is barely slightly under the comfort zone because the presence of internal heat sources (machine, people, slights, etc.) and since the skin of the building slows the loss of warmth. Therefore, the larger the inner heat sources and therefore the lot of impressively the building skin will retain heat, the lower are the outside temperature before heating are needed. The BPT[2] is that outside temperature below that heating is needed. It is a result of building design and performance and not climate. The BPT for generic inner dominated buildings is regarding 50°F (10°C); for typical envelope-dominated buildings it is 60°F (15.56°C) (DeKay & Brown, 2013).

[2] Balance point temperature

The overheated period of the year starts at regarding 10°C on top of the BPT of any building, Since the comfort zone has a range of about -12°C wide (20°C to 25°C). For instance, for an internally dominated building (BPT = 10°C) the hot amount would begin once the typical daily outside temperature attained regarding 15°C. Therefore, the longer will be its overheated period (cooling season) throughout which period shading is needed and therefore the lower the BPT of a specific building, the shorter will be the underheated period (heating season) (Duffie, 2013) .

Table 3:A comparison of the Two Type of Buildings (Lechner, 2009)

Characteristic	Envelope Dominated	Internally Dominated
Building form	Spread out	Compact
Surface-area-to-volume ratio	High	Low
Internal heat gain	Low	High
Internal rooms	Very few	Many
Number of exterior walls of typical room	2 to 3	0 to 1
Use of passive solar heating	Yes, except in very hot climates	No, except in very cold climates
Typical examples	Residences, small office buildings	Large office and school buildings, auditoriums, theaters, factories

Chapter 3

THE EVALUATION OF OFFICE BUILDINGS IN TERMS OF SHADING DEVICES

It is clear that heat gain from radiation is the most vital issue affecting the buildup interior temperature. This can be caused by direct daylight falling upon the glazed space of a building, which could additionally produce a glare drawback. A reality is that glare and heat gain from radiation will be controlled with preventing direct daylight from falling upon the glazed spaces of the building facade. Shading device is the instrumentation to remove the incident radiation to supply thermally comfortable surroundings whereas decreasing the cooling load considerably. That is, shading devices reject the direct radiation and permit the diffuse element solely to be admitted through in (Duffie, 2013).

From useful purpose of view, shading devices are supposed to supply an appropriate thermally comfortable climate also their contribution to glare and solar heat gain control when they are well designed. Supported by their materials, color, and geometry, shading devices decrease contrast between glazed areas and filter light, pass breezes, permit controlled views, bright sky. Of those characteristics, management of solar heat gain (thermal control) constitutes the principle function of shading devices, since their effectiveness should be appreciated from economic, thermal comfort, and efficiency purpose.

The methodology in this study has been considered qualitative and comparative. The three specified case studies were analyzed in term of advantage and disadvantage and eventually the successful ones was introduced as well as unsuccessful one. In this comparison by introducing advantage of the Italy and Spanish cases as a successful cases, some criteria were debated by means of Emu Rectorate office building shading devices improvement.

Therefore, this chapter investigates shading devices performance to control the direct sunlight, in accordance with the actual fact conferred in chapter two, that shading devices indeed control and decrease solar radiant heat admitted in interior spaces.

3.1 Case studies

3.1.1 Milan City in Italy

Italy is located in Southern Europe and contains the boot-shaped peninsula and variety of islands together with the two largest islands, Sardinia and Sicily. It is situated between latitudes 35° and 47° N, and longitudes 6° and 19° E. In addition, Milan is found within the northwestern section of the Po valley, just about halfway between the watercourse Po to the south, and therefore the initial reliefs of range of mountains with the nice lakes to the north, the Adda to the east and therefore the Ticino River to the west. The municipal territory is entirely flat, the best purpose being at 122 m on top of water level. The executive commune covers a locality of regarding 181 square kilometers. (Della Porta, 2006)

Figure55: Location of Milan/ Italy (Illustration taken from URL 3: http://www.tu-chemnitz.de/phil/english/chairs/englit/milan.php, (2014))

3.1.1.1 Weather information of Milan at a Glance

Milan contains a massive vary of temperatures and a humid subtropical climate with four distinct seasons. The sum up Milan's weather is generally Mediterranean (Della Porta, 2006).

Figure 56: Average monthly hours of sunshine over the year (Illustration taken from URL 4: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-fahrenheit,milan,italy, (2014))

Figure 57: Average percent of sunshine over the year (Illustration taken from URL 5: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-fahrenheit,milan,italy, (2014))

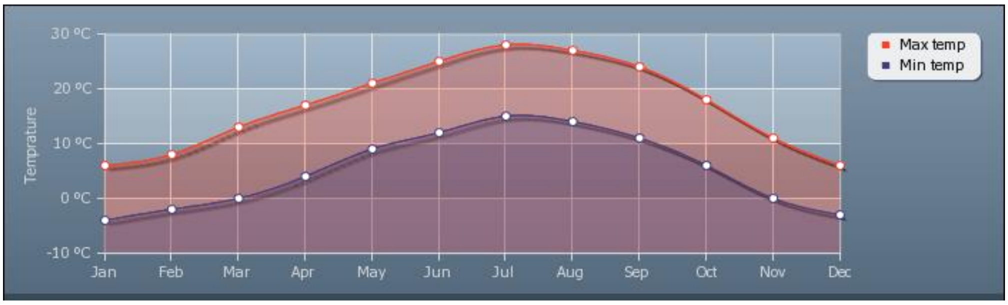


Figure 58: Average minimum and maximum temperature over the year (Illustration taken from URL6: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-fahrenheit,milan,italy, (2014)

3.1.1.2 The 3M Headquarters in Milan/Italy

Figure 59: The 3M Headquarters in Milan (Illustration taken from URL 7: http://www.archdaily.com, (2014))

The office building of 3M is located in the Eastern part of Milan, Italy. The building is designed by Mario Cucinella Architects in 2010. The buildup area of the linear building is 10,300 m^2 (105m long and 21m wide). (Plan, section and elevation in appendix C)

Figure 60: Site plan of the 3M Headquarters in Milan (Google earth. Illustration edited by author, 2014)

3.1.1.2.1 Analysis of Sun Path Diagrams of 3M Headquarters in Milan/Italy

According to the Milan 3M heard quarter geographical information, the longitude is 9.39 and the latitude is 45.5. Stereographical diagram shows that wall azimuth angel of this building is between 90 -270 (W-E). Based on this diagram and climatic condition it will be realized that the overheated period in this city are 21st of June, 21st of July and 21st August. Also it accordingly shows that in 21st of December this building has the maximum solar optimum depth since sun radiation height is less and oblique. Consequently the most involved façade with sun radiation is south façade while east and west are somehow involved. Therefore for south orientation in the overheated period which can be covered by vertical shadow angels, it needs only horizontal shading devices. Also for east and west orientation in this period (Figure 61, 62 and 63).

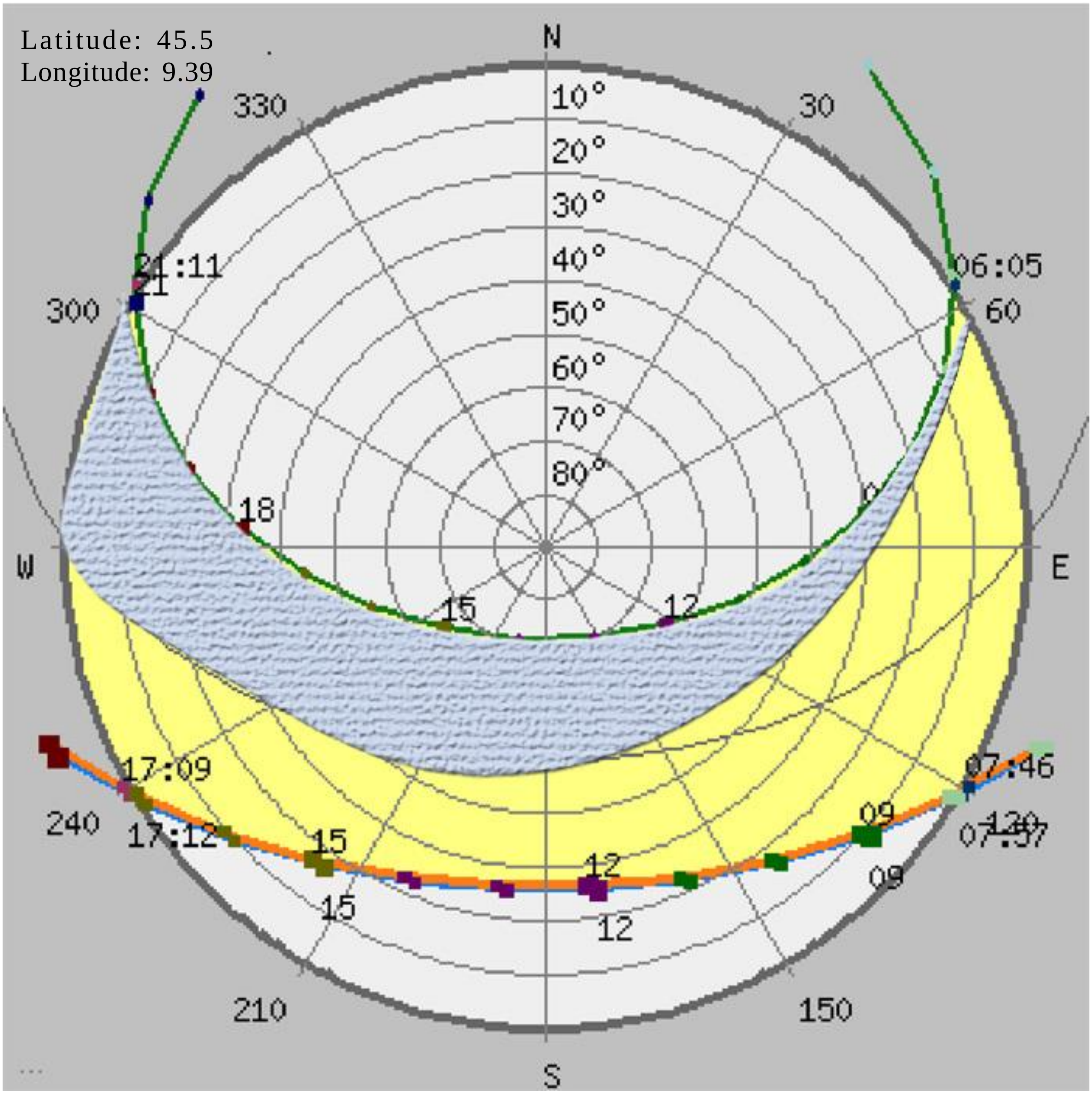


Figure 61 : The Stereographic Diagrams of 3M Headquarters (Illustration drawn by Autodesk Ecotect Analysis 2011, 2014)

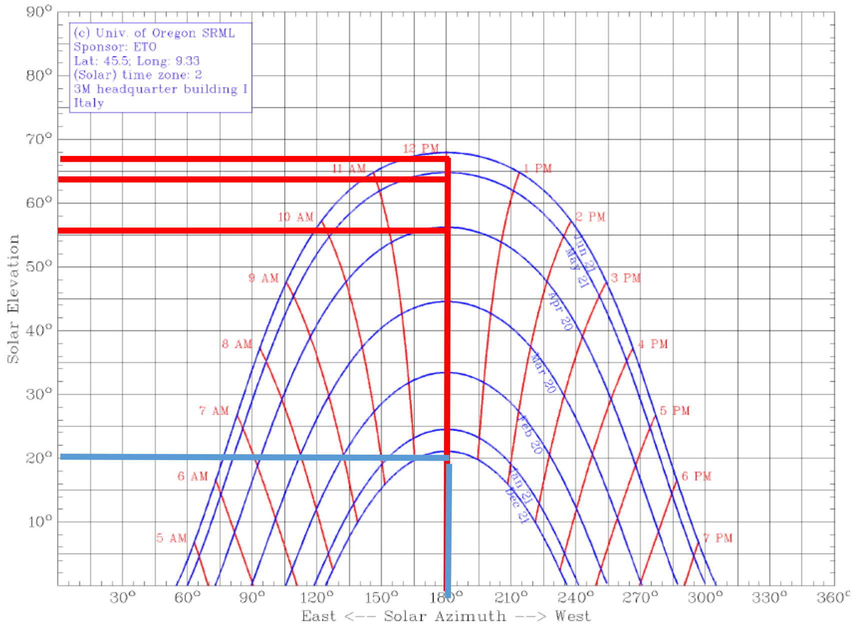


Figure62: The cylindrical sun path diagram of 3M Headquarters (Illustration drawn by Autodesk Ecotect Analysis 2011, 2014)

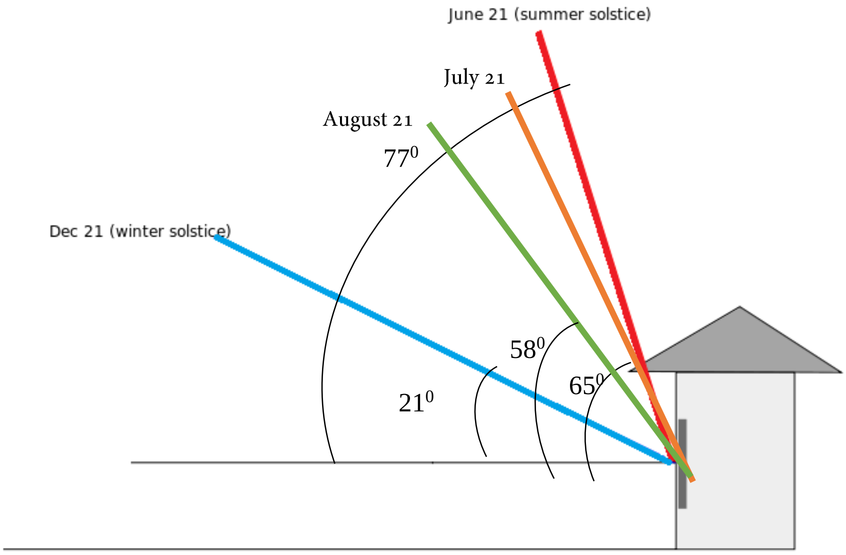
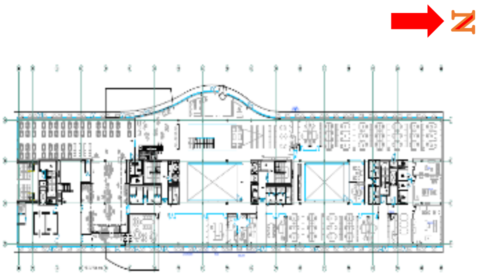


Figure63: The illustration of angles in 3M Headquarters (Illustration drawn by author, 2014)

3.1.2.2.2 Data analysis of 3M Headquarters building

Table 4: Analysis of the North Facade of 3M Headquarters Building (Drawn by author.2014)

Orientation	Plan	Picture
North		

Window Type		**Shading Orientation**			
Vertical	**Horizontal**	**Exterior**	**Interior**	**Interior + Exterior**	**None**
YES	**YES**	**YES**	**YES**	**YES**	**---**

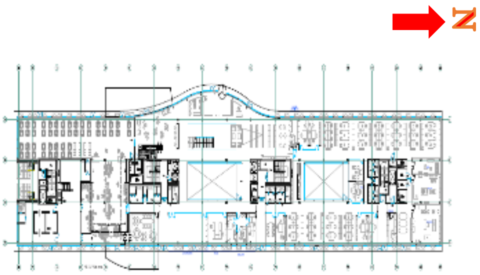
Shading Type			
Vertical	**YES**	**Inappropriate Shading Device Type (Mistake Type)**	**---------**
Horizontal	**YES**	**Appropriate Shading Device Type**	**1- Extending Horizontal Type 2-Fixed Type 3-Moveable interior**
Moveable	**YES**		
Fixed	**YES**		
Egg Crate	**---**	**Proposed Shading Devices**	**1- Eaves 2-Adjustable Shading (seasonal vegetation)**
None	**---**		

As demonstrated in table 4, north orientation have both vertical and horizontal window type and the orientation of shading includes exterior, interior and both exterior and interior shading devices. About the shading devices in north orientation, have vertical, horizontal, fix and moveable types.

For north-facing openings, the right work, fix extending horizontal type are used to allow good passive sun control. In this respect sun can be excluded in summer and admitted in winter.

For proposing, for approaches shading devices, eaves can be used which regulated solar access on northern elevations throughout the year, without requiring any user effort. Furthermore adjustable shading (seasonal vegetation) facilitates adaptation to climatic conditions.

Table 5: Analysis of the South Facade of 3M Headquarters Building (Drawn by author.2014)

Orientation	**Plan**	**Picture**
South		

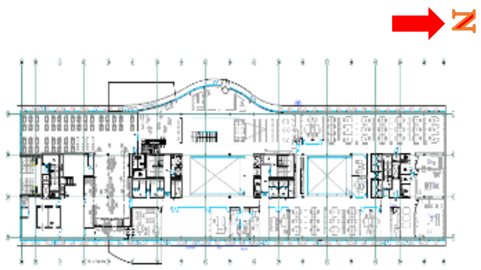
Window Type		**Shading Orientation**			
Vertical	**Horizontal**	**Exterior**	**Interior**	**Interior + Exterior**	**None**
YES	**YES**	**YES**	**YES**	**YES**	**----**

Shading Type			
Vertical	**-----**	**Inappropriate Shading Device Type (Mistake Type)**	**-----**
Horizontal	**YES**	**Appropriate Shading Device Type**	**1- Fixed horizontal overhang type** **2-Moveable type**
Moveable	**YES**		
Fixed	**YES**		
Egg Crate	**---**	**Proposed Shading Devices**	**-----**
None	**---**		

As in table 5 presented, south orientation have both vertical and horizontal window type and the orientation of shading includes interior and both exterior and interior. The shading devices type for south orientation are vertical, fixed and moveable.

South-facing openings receive higher angle sun in summer. Within the range of south orientation it allows good passive sun control, sun can be excluded in summer and admitted in winter. For this reason it, require narrow overhead shading devices, by using fixed horizontal overhang devices and terraces which offer shaded is outdoor space for the office staff. The terraces work as an environmental buffer area which protects the building from climate inordinate in winter and in summer.

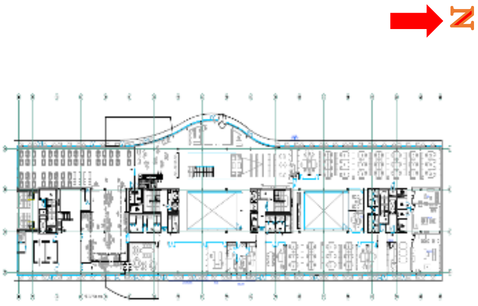
Table 6: Analysis of the East Facade of 3M Headquarters Building **(**Drawn by author.2014)

Orientation	**Plan**	**Picture**
East		

Window Type		**Shading Orientation**			
Vertical	**Horizontal**	**Exterior**	**Interior**	**Interior + Exterior**	**None**
YES	**YES**	**YES**	**YES**	**YES**	**----**

Shading Type			
Vertical	**YES**	**Inappropriate Shading Device Type(Mistake Type)**	**No egg crate type**
Horizontal	**YES**	**Appropriate Shading Device Type**	**1- Vertical type** **2- Horizontal Type** **3- Fix & moveable Type**
Moveable	**YES**		
Fixed	**YES**	**Proposed Shading Devices**	**1- Egg crate type** **2- Adjustable type**
Egg Crate	**---**		
None	**---**		

Table 7: Analysis of the West Facade of 3M Headquarters Building

Orientation	Plan	Picture
West		

Window Type		Shading Orientation			
Vertical	Horizontal	Exterior	Interior	Interior + Exterior	None
YES	YES	YES	YES	YES	----

Shading Type			
Vertical	YES	Inappropriate Shading Device Type (Mistake Type)	No egg crate type
Horizontal	YES	Appropriate Shading Device Type	1- Vertical type 2- Horizontal Type 3- Fix & moveable type
Moveable	YES		
Fixed	YES	Proposed Shading Devices	1- Egg crate type 2- Adjustable Type
Egg Crate	---		
None	---		

Tables 6 and 7 displayed, west and east orientation have both, vertical and horizontal window type and furthermore the orientation of shading includes exterior, interior and both exterior and interior. The shading devices type in west and east orientation are vertical, horizontal, fixed and moveable.

East and west-facing openings require a different approach. Low angle morning and afternoon summer sun from these directions are difficult to shade. Minimize the glazed area on the east and west orientations to a minimum, still allowing for good cross-ventilation, and appropriate shading devices.

In this building, west and east orientation used fixed-baled sun shading system which allows passive solar energy gain during winter, and shades glazed façade to avoid overheating of interior spaces in summer.

As proposed because of east and west sun angles, egg crate and adjustable shading is especially useful for eastern and western elevations, the low angle of the sun makes it difficult to get adequate protection from fixed shading. An egg crate which is a combination of vertical fins and horizontal overhangs (louvers), dominant sun penetration by both the azimuth and altitude angle of the sun, receives extremely impressive shading of windows. Adjustable shading also gives greater control while enables daylight levels and manipulated views. Appropriate adjustable systems include sliding screens, louver screens, shutters, retractable awnings and adjustable external blinds.

3.1.2 Barcelona City in Spain

Spain is situated between latitudes 26° and 44° N, and longitudes 19° W and 5° E. Spain borders Gibraltar (a British overseas territory) and Morocco, on the south, on the west, it borders Portugal, along the Pyrenees mountain range, it borders France and the tiny principality of Andorra, on the northeast. Barcelona is located at the northeast coast of the Iberian Peninsula, facing to Mediterranean Sea, on a comprehensible five kilometer wide restricted range of Collserola, the Besòs watercourse to the north and therefore the Llobregat watercourse to the southwest .(Alsamamra, 2009)

Figure 64: Location of Barcelona in Spain (Illustration taken from URL 8: http://www.siterary.com/cities/barcelona_guide.html, (2014))

3.1.2.1 Weather information of Barcelona at a glance

Barcelona has a Mediterranean climate with warm, dry summers and mild, humid winters. Although, the weather is moderated by westerly winds from the Atlantic, and therefore the town sits on an elevated plateau. These factors mix to supply slightly cooler temperatures and better precipitation than Spain's a southerly coastal resorts. (Remondo, 2003)

Figure 65: Average monthly hours of sunshine over the year (Illustration taken from URL 9: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-fahrenheit,barcelona,Spain, (2014))

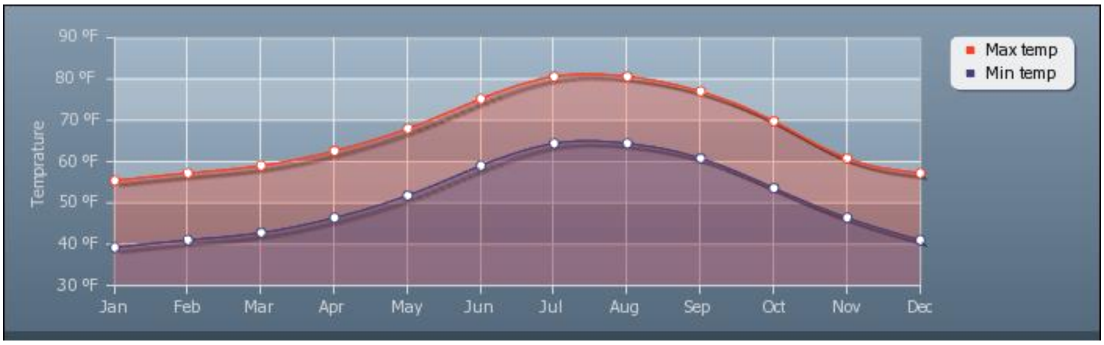


Figure 66: Average minimum and maximum temperature over the year (Illustration taken from URL 10: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-fahrenheit,barcelona,Spain, (2014))

3.1.3 Social Security Administration Building in Barcelona/ Spain

Figure 67: Social Security Administration Building **(**Illustration taken from URL 11**:** http:// www.archdaily.com**,** (2014))

Social Security Administration Building is located in Barcelona, Spain. The building is designed by David Baena, Toni Casamor, Maria Taltavull, Manel Peribáñez. The first design proposal adapts to the fact of the prevailing urban setting. (Plan, section and elevation in appendix D)

3.1.2.2.1 Analysis of Sun Path Diagrams of Social Security Administration Building in Barcelona/ Spain

Investigating the Social security building geographical information in Barcelona, Spain, it has been determined that the longitude is 2.17 and the latitude is 41.37. Based on Stereographical diagram wall azimuth angel is amongst 110 -290. It can also be found out that the overheated period in this city are 21st of June, 21st of July, 21st August and 21st of September. Likewise it can be obtain that in 21st of December this building has the maximum solar optimum depth meanwhile sun radiation height is fewer and oblique. The most important facades are east and south which have the maximum length in overheated periods. Following this condition, for south façade horizontal shading should be utilized while east façade should use vertical and egg crate shading device. (Figure 68, 69 and 70)

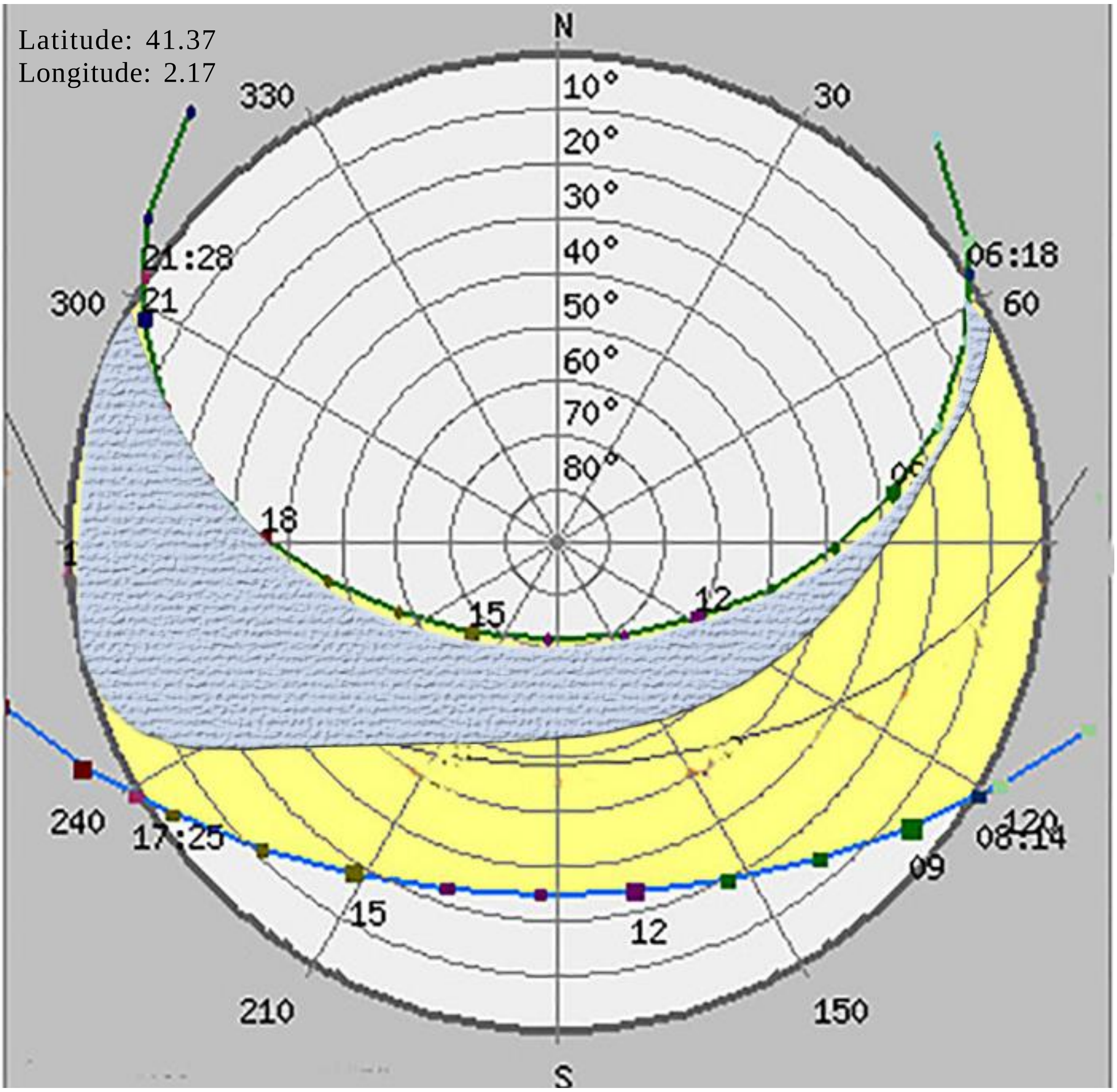


Figure 68: The Stereographic Diagrams of Social Security Administration Building (Illustration drawn by Autodesk Ecotect Analysis 2011, 2014)

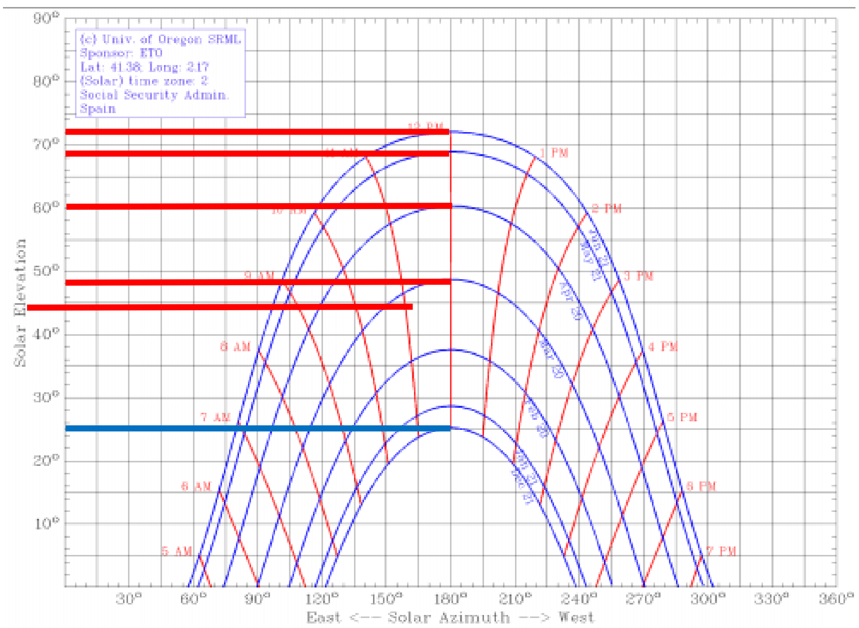


Figure 69: The Cylindrical Sun Path Diagram of Social Security Administration (Illustration drawn by Autodesk Ecotect Analysis 2011, 2014)

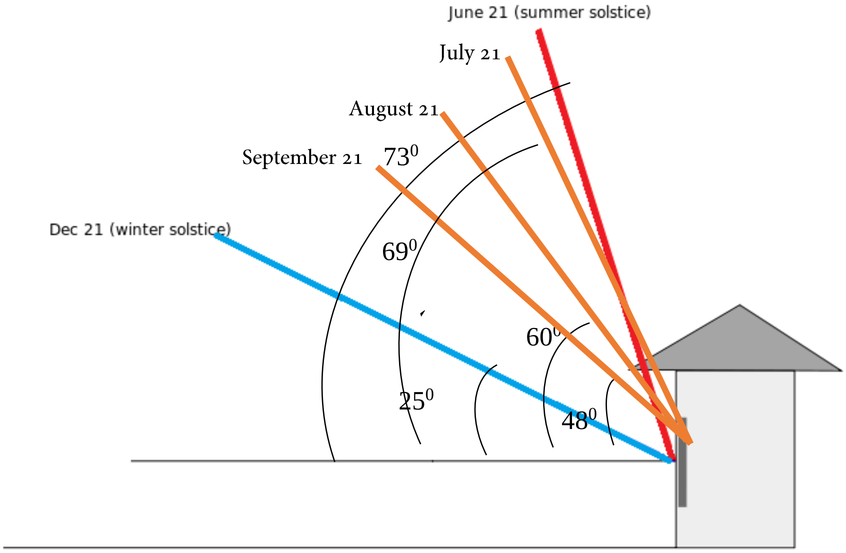
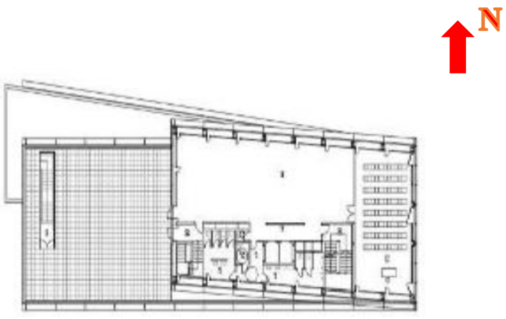


Figure70: The illustration of angles in Social Security Administration Building (Illustration drawn by Autodesk Ecotect Analysis 2011, 2014)

3.1.3.2.2 Data analysis and system detail of Social Security Administration Building

Table 8: Analysis of the North Facade of Social Security Administration Building (Drawn by author.2014)

Orientation	Plan	Picture
North		

Window Type		Shading Orientation			
Vertical	Horizontal	Exterior	Interior	Interior + Exterior	None
YES	YES	YES	YES	YES	---

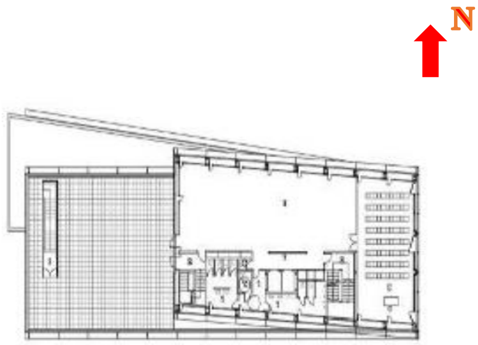
Shading Type			
Vertical	YES	Inappropriate Shading Device Type (Mistake Type)	Egg crate type
Horizontal	YES	Appropriate Shading Device Type	1- Horizontal Type 2-Fixed type 3-Moveable interior type 4- Eaves 5- Adjustable shading (seasonal vegetation) type
Moveable	YES		
Fixed	YES		
Egg Crate	YES	Proposed Shading Devices	-----
None	---		

As demonstrated in table 8, north orientation have both vertical and horizontal window type and the orientation of shading includes exterior, interior and both exterior and interior. Vertical, horizontal, fix and moveable types are utilized as shading devices for north orientation.

In north-facing openings, the right work which is used in this building, is fix extending horizontal, including eaves and awnings type are used to allow good passive sun control. In this respect sun can be excluded in summer and admitted in winter.

Furthermore adjustable shading (mechanical or seasonal vegetation) facilitates adaptation to changing climatic conditions.

Table 9: Analysis of the South Facade of Social Security Administration Building (Drawn by author, 2014)

Orientation	Plan	Picture
South		

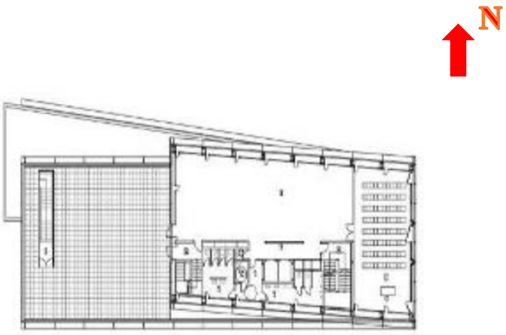
Window Type		Shading Orientation			
Vertical	Horizontal	Exterior	Interio	Interior + Exterior	None
YES	YES	YES	YES	YES	YES

Shading Type			
Vertical	----	Inappropriate Shading Device Type(Mistake Type)	Egg crate type
Horizontal	YES	Appropriate Shading Device Type	1- Horizontal Type 2-Fixed Type 3-Moveable interior type 4- Eaves 5- Adjustable shading (seasonal vegetation) type
Moveable	YES		
Fixed	YES		
Egg Crate	YES	Proposed Shading Devices	----
None	---		

Table 9 share that, south orientation have both vertical and horizontal window type and the orientation of shading includes interior and exterior at the same time. The shading devices type for south orientation used horizontal, fixed, moveable and egg crate.

Moreover south-facing openings, requires narrow overhead shading devices, by using of eaves, adjustable shading (seasonal vegetation) and fixed horizontal overhang devices through endless envelope of aluminum slats. These slats which offered personality to the building facades: they are organized horizontally on the main facades of the building (longitudinal facades) and in vertical on the beams.

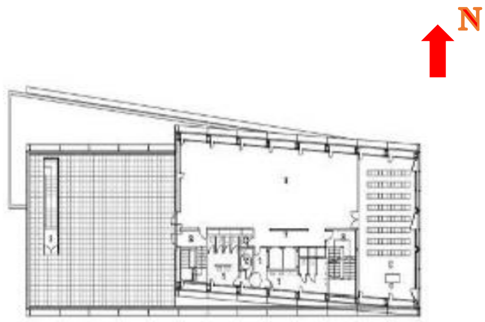
Table10: Analysis of the West Facade of Social Security Administration Building (Drawn by author, 2014)

Orientation	Plan	Picture
East		

Window Type		Shading Orientation			
Vertical	Horizontal	Exterior	Interior	Interior + Exterior	None
YES	YES	YES	YES	---	---

Shading Type			
Vertical	----	Inappropriate Shading Device Type	1-No used vertical type 2- No use egg crate
Horizontal	YES	Appropriate Shading Device Type	1- Horizontal type 2-Fixed type 3-Moveable interior type
Moveable	YES	Proposed Shading Devices	1- Egg crate type 2- Vertical type
Fixed	YES		
Egg Crate	---		
None	---		

Table 11: Analysis the East Facade of Social Security Administration Building (Drawn by author, 2014)

Orientation	**Plan**	**Picture**
West		

Window Type		**Shading Orientation**			
Vertical	**Horizontal**	**Exterior**	**Interior**	**Interior + Exterior**	**None**
----	**YES**	**----**	**YES**	**----**	**----**

Shading Type			
Vertical	**----**	**Inappropriate Shading Device Type (Mistake Type)**	**1-No vertical type** **2- No egg crate** **3-No fixed horizontal type** **4-No eaves type**
Horizontal	**----**		
Moveable	**YES**	**Appropriate Shading Device Type**	**Interior Moveable type**
Fixed	**-----**	**Proposed Shading Devices**	**1- Egg crate type** **2- Adjustable shading type** **3- Vertical type** **4- Horizontal type**
Egg Crate	**---**		
None	**---**		

As shown in tables 10 and 11, east orientation have both vertical and horizontal window type but west orientation has only horizontal type. The orientation of shading at the east façade include interior and exterior but west facade has only interior shading. The shading devices type for east orientation have horizontal, fixed and moveable types and for west orientation only moveable type.

The correct shading device for these orientation of building, proposed egg crate type, adjustable shading, vertical type and horizontal type.

3.1.3 Gazimagusa Town in Cyprus

Cyprus is located at 35° N latitude of the equator and 34° E longitude and is the third largest island in the Mediterranean Sea after Sardinia and Sicily. Furthermore, it is 65 km far from Turkey, 750km from Greece, 350 km from Egypt, and 95 from Syria. Geographically, there are two main mountains known as Besparmark and Trodos, which are situated on the northern part and in the middle part of the island respectively. Nevertheless, city of Gazimağusa (Famagusta) is a coastal town at the eastern part of Cyprus with 7m elevation above sea level(Ozay, 2005).

Figure 71: Map of Cyprus (picture taken from URL12: en.wikipedia.org,2014)

Gazimağusa (Famagusta) is one of the fast growing cities recognized as an upturn in favor of North Cyprus development with a historic old town and a harbor. Actually, with the advent of University (EMU) at 1979 the trend of city development has been increased, so that Gazimagusa has been one of the migration destination especially for students. Gazimağusa (Famagusta) is full of great medieval architecture examples.

Besides, according to 2004 census, the population number of city is 42,526 (Pasaogullari & Doratli, 2004)

Figure72: Location of Gazimağusa (Famagusta) in North Cyprus (picture taken from URL 13: www.iansmithestate.com, 2014)

3.1.3.1 Solar Energy of Cyprus

5kWh/m2 solar radiation and the average of 9 hours sunny period (range from 5.5 to 12.5 hours daily) offer almost high potential in solar energy use for buildings . Apart from that, July and August as hottest months reach a peak showing highest average temperature of 36 C° and 8.1 kWh/m2 radiations; by the way of contrast, coldest periods occurs for December and January accounted for radiation of approximately 2.3kWh/m2. In other words, according to Atalar’s thesis of 2001 (a 4-year period research) Gazimağusa (Famagusta) town represents the most desirable solar rays and radiations among other cities in North Cyprus such as Ercan and Guzelyurt. Gazimağusa (Famagusta) receives more than 3.84 kWh/m2 solar energy and just in

January and December (less than 5% of all occasion), the radiations are just below 1.92kWh/m2 (URL12: mediaindiagroup.wordpress.com, 2014)

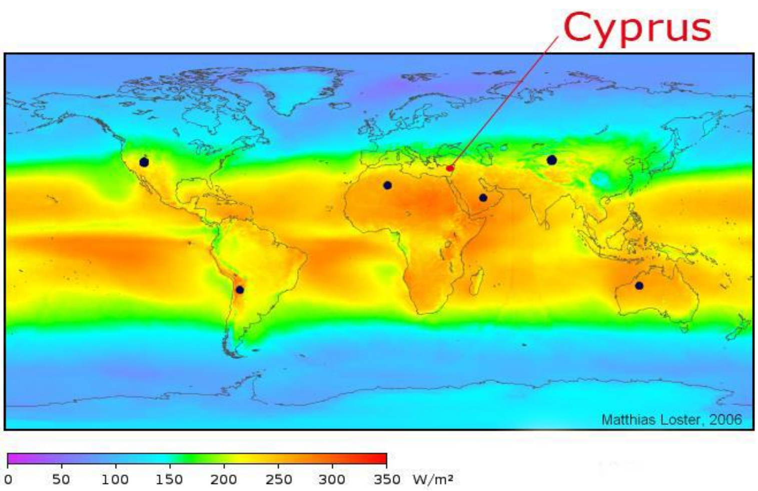


Figure 73: Cyprus Situation Based on Solar Land Use (picture taken from URL14: mediaindiagroup.wordpress.com, 2014)

In the figure 73 display the typical insolation land area and solar zones representation with black dots which may provide over world's whole primary energy demand. The several shades of colors display the mean local solar irradiance derived from weather satellites. It seems that North Cyprus can be taken into account as one of proven solar lands with great potential.

Figure 74: Average monthly hours of sunshine over the year in Gazimağusa (Illustration taken from URL15: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Famagusta,Cyprus, (2014))

Furthermore, the effect of political subjects can be seen within the utilization of widespread solar hot water collectors to emphasize the high potential of solar energy in North Cyprus notably in Gazimağusa. When Cyprus was compartmented into two components after 20th of July 1974, refugees settled as the population in interim homes; thus, the start of a vital evolution in construction started.

3.1.3.2 Weather information of Famagusta at a Glance

At first, Cyprus did not have a fixed climate. Moreover, in terms of architectural methods Cyprus climate can be represented as both composite and hot-humid climate. Furthermore, Gazimağusa (Famagusta) town possesses hot-dry summers in conjunction with rainy winters in generally. Except that, the wind belongs to west path and there are very high ratio of humidity levels through the early day time and nights.(Ozay, 2005)

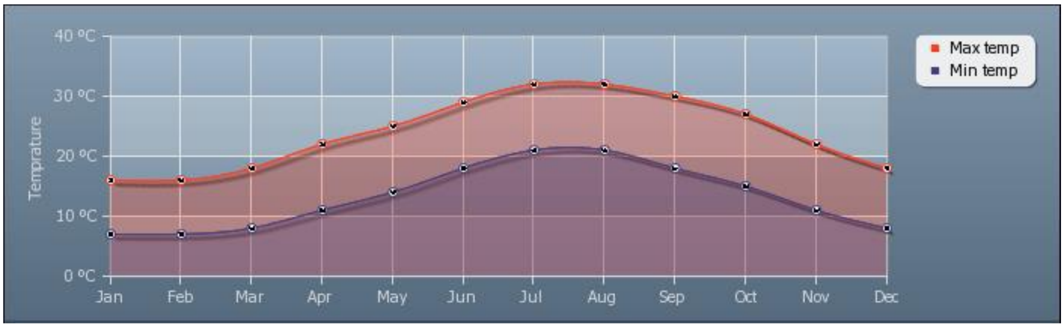


Figure 75: Average Minimum and Maximum Temperature over the Year in Gazimağusa (Famagusta) (Illustration taken from URL16: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Famagusta,Cyprus, (2014))

3.1.3.3 Rectorate office Building in Famagusta/North Cyprus

The first case study is the Rectorate office building, which is located in the EMU Campus, Famagusta (Gazimagusta), North Cyprus, which is an office building. The construction process has finished in 2013. The gross building area is approximately 2545m^2. (Plan, section and elevation in appendix B)

Figure 76: The Emu Rectorate Office Building, EMU in Famagusta/North Cyprus (taken by author, 2014)

Figure 77: Situation of Emu Rectorate Office Building (Google earth, Illustration edited by author, 2014)

3.1.3.3.1 Analysis of Sun Path Diagrams of Emu Rectorate Office Building Based on Rectorate office building geographical information for Famagusta, North Cyprus, the longitude is 33.84 and the latitude is 35.29. Considering Stereographical diagram wall azimuth angel is amongst 80 – 260. Overheated periods in Famagusta are 21st of June, 21st of July and 21st August. This building has the maximum solar optimum depth in 21st of December since sun radiation height is fewer and oblique. The most significant façades in contact with sun radiation among overheated periods are south, east and west facades which south should be covered by horizontal shading while east and west should be covered by vertical and egg crate shading device. (Figure78, 79, 80)

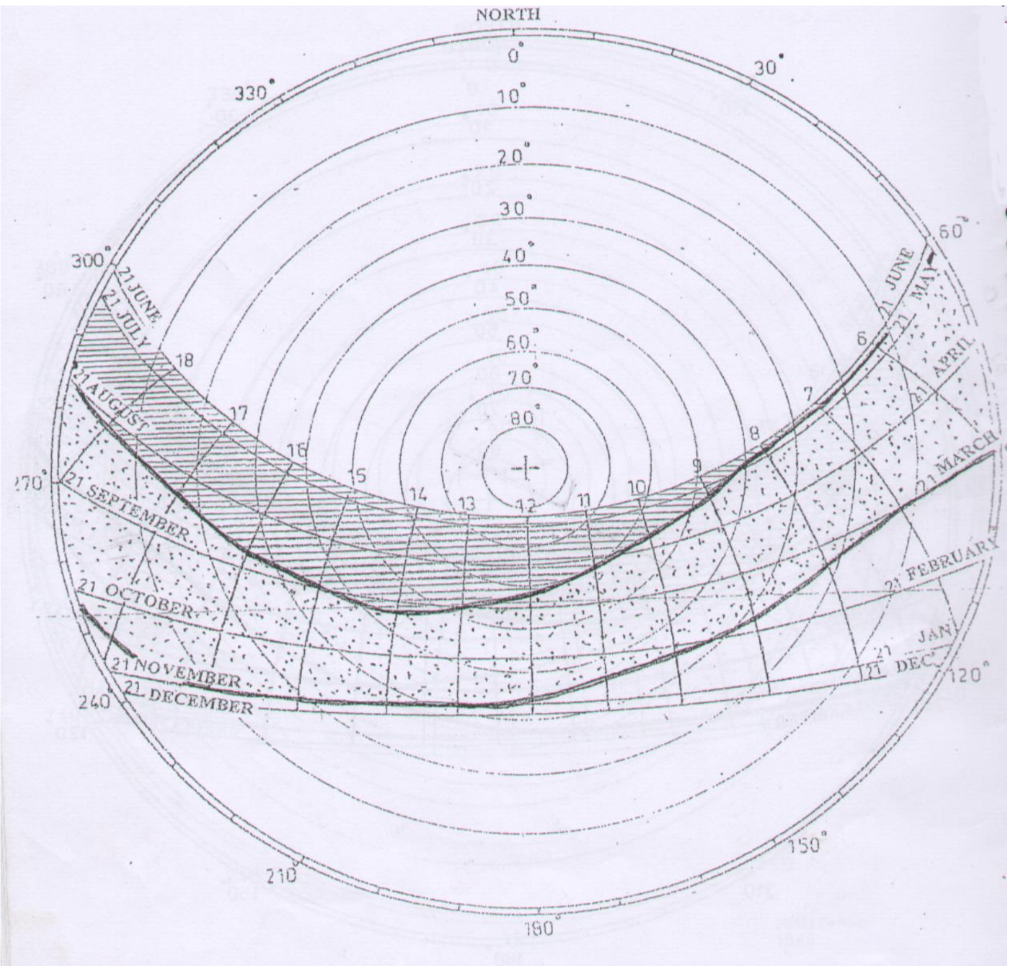
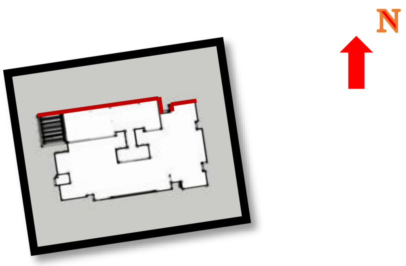


Figure 78: The Stereographic Diagrams of Emu Administration building (Illustration Taken from Arch 246,Halil.Z.Alibaba, 2014)

3.1.1.3.2 Data Analysis of Emu Rectorate Office Building

Table 12: Analysis of the North Facade of Emu Rectorate Office Building (Drawn by author, 2014)

Orientation	**Plan**	**Picture**
North		

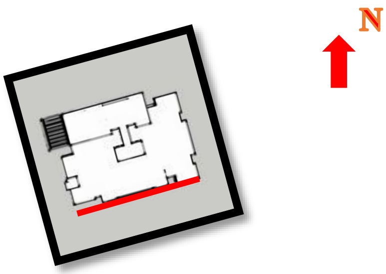
Window Type		**Shading Orientation**			
Vertical	**Horizontal**	**Exterior**	**Interior**	**Interior + Exterior**	**None**
YES	**YES**	**YES**	**YES**	**YES**	**YES**

Shading Type			
Vertical	**YES**	**Inappropriate Shading Device Type**	**One window don't have shading device**
Horizontal	**YES**		
Moveable	**YES**	**Appropriate Shading Device Type**	**1-Horizontal type** **2-Fixed type** **3-Eaves** **4-Moveable interior type**
Fixed	**YES**		
Egg Crate	**---**	**Proposed Shading Device**	**1-Extension of horizontal shading devices on each side** **2-Adjustable Shading (Mechanical or manual)** **3-Shadinf of seasonal vegetation)**
None	**YES**		

As it is represented in table 12, north orientation have both vertical and horizontal window type and also about the orientation of shading it include exterior, interior and at the same time both exterior and interior. The shading devices in north orientation are vertical, horizontal, moveable and fixed. For proposing appropriate shading devices, fixed shading devices (eaves, awnings, pergolas and louvers) can be used which can regulate solar access on northern elevations throughout the year, without requiring any user effort.

Furthermore adjustable shading (mechanical shading or seasonal vegetation) facilitates adaptation to changing climatic conditions.

Table 13: Analysis of the South Facade of Emu Rectorate Office Building (Drawn by author, 2014)

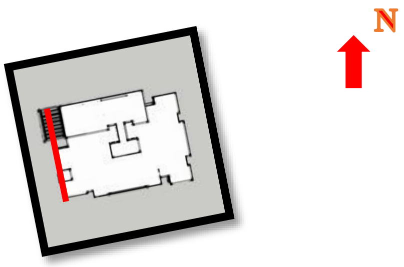
Orientation	**Plan**	**Picture**
South		

Window Type		**Shading Orientation**			
Vertical	**Horizontal**	**Exterior**	**Interior**	**Interior + Exterior**	**None**
---	**YES**	**---**	**YES**	**YES**	**YES**

Shading Type			
Vertical	**YES**	**Inappropriate Shading Device Type**	**1- Vertical type** **2- No horizontal type** **3-Don't use fixed type** **4-One window hasn't shading device**
Horizontal	**---**	**Appropriate Shading Device Type**	**Moveable interior**
Moveable	**YES**	**Proposed Shading Devices**	**Fixed overhangs**
Fixed	**---**		
Egg Crate	**---**		
None	**YES**		

As it shown in table 13, south orientation have only horizontal window type and also the orientation of shading it includes interior and both exterior and interior at the same time. About the shading devices type in south orientation, only vertical and moveable shading devices are used. For proposing correct shading devices in south facade, fixed horizontal overhangs are advised. Fixed horizontal shading devices are typically utilized on the external view of glazing since they will let the low winter sun into the interior spaces whereas absolutely shade the high summer sun with minimum occlusion of the view.

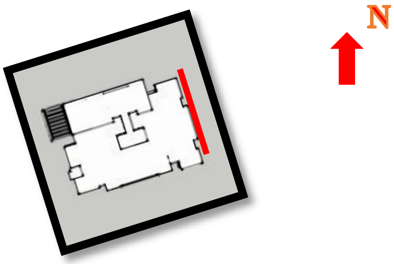
Table 14: Analysis of the west Facade of Emu Rectorate Office Building (Drawn by author, 2014)

Orientation	**Plan**	**Picture**
West		

Window Type		**Shading Orientation**			
Vertical	**Horizontal**	**Exterior**	**Interior**	**Interior + Exterior**	**None**
YES	**YES**	**YES**	**YES**	**---**	**YES**

Shading Type			
Vertical	**YES**	**Inappropriate Shading Device Type**	**1-No egg crate type** **2- One window hasn't got shading Device**
Horizontal	**YES**	**Appropriate Shading Device Type**	**1- Vertical type** **2- Horizontal type** **3- Fixed & moveable type**
Moveable	**YES**	**Proposed Shading Devices**	**1- Egg crate type** **2- Adjustable shading**
Fixed	**YES**		
Egg Crate	**---**		
None	**YES**		

Table 15: Analysis of the east Facade of Emu Rectorate Office Building (Drawn by author, 2014)

Orientation	Plan	Picture
East		

Window Type		Shading Orientation			
Vertical	Horizontal	Exterior	Interior	Interior + Exterior	None
YES	YES	YES	YES	YES	YES

Shading Type			
Vertical	YES	Inappropriate Shading Device Type	1-No egg crate type 2- One window hasn't got shading device
Horizontal	YES	Appropriate Shading Device Type	1- Vertical type 2- Horizontal type 3- Fixed & moveable type
Moveable	YES	Proposed Shading Devices	1- Egg crate type 2- Adjustable shading
Fix	YES		
Egg Crate	---		
None	YES		

As it displayed in tables 14 and 15, west and east orientation have both vertical and horizontal window type and also about the orientation of shading it includes interior and both exterior and interior at the same time. About the shading devices type in west and east orientation, vertical, horizontal, fixed and moveable types are utilized.

East and west-facing openings require a different approach, as low angle morning and afternoon summer sun from these directions is more difficult to shade. Keep the area of glazing on the east and west orientations to a minimum where possible, still allow good cross-ventilation, or use appropriate shading devices.

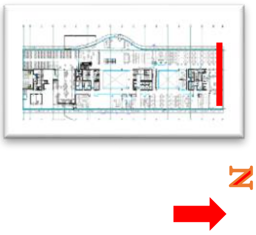
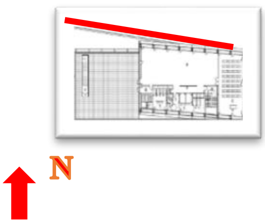
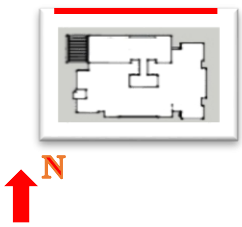
Because east and west sun angles are low, vertical shading structures are useful in allowing light, views and ventilation while excluding sunroof overhangs, pergolas and verandahs that incorporate vertical structures such as screens, climber covered lattice and vertical awnings are also effective.

For proposing, egg crate and adjustable shading is especially useful for eastern and western elevations, as the low angle of the sun makes it difficult to get adequate protection from fixed shading. Adjustable shading also gives greater control while enabling daylight levels and views to be manipulated.

3.2 Discussion

Collecting data, analyzing and comprising three case studies from Italy, Spain and Famagusta in terms of shading devices, it can be determined that there are some deficiencies in the case of Famagusta in comparison with Italy and Spain as two successful cases used shading devices properly. Accordingly there will be some criteria by means of improvement and correction for rectorate office building in following tables:

Table 16: Analysis of the North Facade of Case Studies (Drawn by author, 2014)

The Evaluation of Office Buildings in terms of Shading Devices					
Basic Information			Case Study	Case Study	Case Study
			3M Headquarters Building	Social Security Administration Building	EMU Rectorate Office Building
	Photo view				
	Function		Office Building	Office Building	Office Building
	Location		Milan	Barcelona	Famagusta
	Weather Data		Hot-Humid	Hot-Humid	Hot-Humid
	Area		10300 m^2	6921 m^2	2545 m^2
Data Analysis	Plan Orientation (North)				
	Window Type	Vertical	YES	YES	YES
		Horizontal	YES	YES	YES
	Shading Orientation	Interior	YES	YES	YES
		Exterior	YES	YES	YES
	Shading Type	Horizontal	YES	YES	YES
		Vertical	YES	YES	YES
		Fixed	YES	YES	YES
		Moveable	YES	YES	YES
		Egg Crate	------	YES	-----
		None	-----	-----	YES
	Proposed		1- Eaves 2- Adjustable shading (seasonal vegetation) type	-----	1-Extention of horizontal shading devices on each side 2- Adjustable Shading type

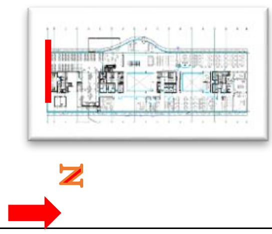
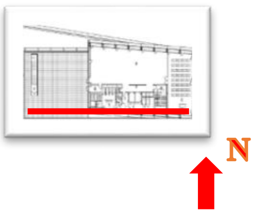
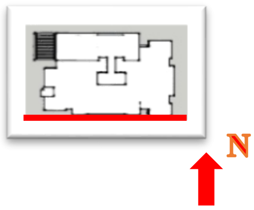
Based on The comparison of these three cases studies:

1- North orientation :

3M headquarters in Milan, Italy as first case study, used appropriate kind of shading devices which utilized in this office building for its climate is fixed-baled sun shading system in north orientation which allows passive solar energy gain during winter and protects glazed façade from overheating in summer.

In the second case study, social security administration building in Barcelona, Spain, the appropriate shading device in this building is fix extending horizontal, including eaves and awnings type are used to allow good passive sun control. Furthermore adjustable shading (seasonal vegetation) facilitates adaptation to changing climatic conditions. While for the third case study of Emu Rectorate Office Building in Famagusta, North Cyprus, after the comparison with the successful cases, proposed appropriate shading devices use fixed shading devices (eaves, awnings, pergolas and louvers) which can regulate solar access on Northern elevations throughout the year, without requiring any user effort. Additionally adjustable shading (mechanical or manual and seasonal vegetation) facilitates must adapt to changing climatic conditions.

Table17: Analysis the South Facade of Case Studies (Drawn by author, 2014)

Basic Information			**Case Study**	**Case Study**	**Case Study**
			3M Headquarters Building	**Social Security Administration Building**	**EMU Rectorate Office Building**
	Photo view				
	Function		**Office Building**	**Office Building**	**Office Building**
	Location		**Milan**	**Barcelona**	**Barcelona**
	Weather Data		**Hot-Humid**	**Hot-Humid**	**Hot-Humid**
	Area		**10300 m^2**	**6921 m^2**	**2545 m^2**
Data Analysis	**Plan Orientation (South)**				
	Window Type	**Vertical**	**YES**	**YES**	**----**
		Horizontal	**YES**	**YES**	**YES**
	Shading Orientation	**Interior**	**YES**	**YES**	**YES**
		Exterior	**YES**	**YES**	**----**
	Shading Type	**Horizontal**	**YES**	**YES**	**----**
		Vertical	**----**	**----**	**YES**
		Fixed	**YES**	**YES**	**----**
		Moveable	**YES**	**YES**	**YES**
		Egg Crate	**YES**	**-----**	**YES**
		None	**------**	**-----**	**YES**
	Proposed		**-----**	**-----**	**Fixed overhangs**

2- South orientation:

In 3M headquarters in Milan, Italy, appropriate kind of shading devices which are utilized in this office building for its climate is require overhead shading devices, by using of fixed horizontal overhang devices and the building steps make a series of terraces which offer shaded outside space for the office staff. The terraces work as an environmental buffer area which protects the building from climate inordinate in each winter and summer.

In other case study, social security administration building in Barcelona, Spain, appropriate shading device which is used in this building is narrower overhead shading devices, by using eaves, adjustable shading (seasonal vegetation) and fixed horizontal overhang devices through endless envelope of aluminum slats. These slats offer personality to the building facades: they are organized horizontally on the main facades of the building (longitudinal facades) and in vertical on the beams.

Though in the case study of Emu Rectorate Office Building in Famagusta, North Cyprus, for proposing correct shading devices in south façade after comparing, fixed horizontal overhangs are advised.

Table 18: Analysis of the West Facade of Case Studies (Drawn by author,

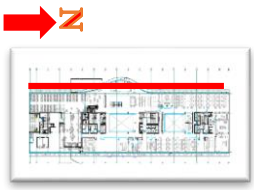
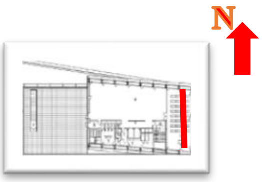
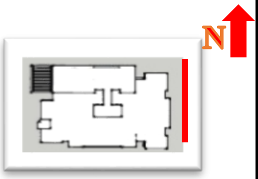
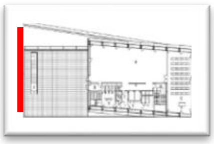
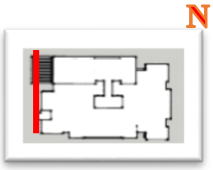
The Evaluation of Office Buildings in terms of Shading Devices Efficiency					
Basic Information			Case Study	Case Study	Case Study
			3M Headquarters Building	Social Security Administration Building	EMU Rectorate Office Building
	Plan Shape				
	Function		Office Building	Office Building	Office Building
	Location		Milan	Barcelona	Famagusta
	Weather Data		Hot-Humid	Hot-Humid	Hot-Humid
	Area		10300 m^2	6921 m^2	2545 m^2
Data Analysis	Plan Orientation (West)				
	Window Type	Vertical	YES	----	YES
		Horizontal	YES	YES	YES
	Shading Orientation	Interior	YES	YES	YES
		Exterior	YES	YES	YES
	Shading Type	Horizontal	YES	YES	YES
		Vertical	YES	----	YES
		Fixed	YES	YES	YES
		Moveable	YES	YES	YES
		Egg Crate	------	-----	----
		None	----	-----	YES
	Proposing Correct		1-Use egg crate type 2-Use adjustable shading	1-Use egg crate type 2-Use vertical type	1-Use egg crate type 2-Use adjustable shading

Table 19: Analysis of the East Facade of Case Studies (Drawn by author, 2014)

The Evaluation of Office Buildings in terms of Shading Devices Efficiency					
Basic Information			Case Study	Case Study	Case Study
			3M Headquarters Building	Social Security Administration Building	EMU Rectorate Office Building
	Plan Shape				
	Function		Office Building	Office Building	Office Building
	Location		Milan	Barcelona	Famagusta
	Weather Data		Hot-Humid	Hot-Humid	Hot-Humid
	Area		10300 m^2	6921 m^2	2545 m^2
Data Analysis	Plan Orientation (West)		N 	N 	N 
	Window Type	Vertical	YES	----	YES
		Horizonta	YES	YES	YES
	Shading Orientation	Interior	YES	YES	YES
		Exterio	YES	----	YES
		Horizonta	YES	----	YES
	Shading Type	Vertical	YES	----	YES
		Fixed	YES	----	YES
		Moveable	YES	YES	YES
		Egg Crate	------	-----	----
		None	----	-----	YES
	Proposing Correct		1-Use egg crate type 2-Use adjustable shading	1-Use egg crate type 2-Use vertical type 3-Use adjustable shading 4-Use horizontal	1-Usee crate type 2-Use adjustable shading

3-In east and west orientation:

In the 3M headquarters in Milan, Italy, The proper kind of shading devices which Utilized is fixed-baled sun shading system allows passive solar energy gain during winter and protects glazed façade from overheating in summer. But it is proposed because of east and west sun angles, egg crate and adjustable shading is especially useful.

In other case study, social security administration building in Barcelona, Spain, the applicable shading devices are egg crate type, adjustable shading, vertical type and horizontal type.

While in the Emu case study, Cyprus, the appropriate shading devices in terms of thermal comfort for Emu Rectorate Office Building which is proposed after evaluation are to use, egg crate and adjustable shading devices.

Chapter 4

CONCLUSION

Thermal considerations is one of the significant key concepts of design, a way for providing occupants with comfort conditions which deal with a wide range of factors such as economic, environmental and ecological approaches. Thermal comfort in interior spaces can be achieved through various means for which the most functional one in the case of office buildings are shading devices. To achieve desirable feedback, responsive passive energy design should be prioritized as the main objective of design. The effect of solar energy on building interior spaces is an important issue, encompasses lots of research works and design strategies. Accordingly, for the purpose of this study, solar gain through building openings should be controlled and optimized through shading devices which would be highly suggested as an efficient strategy providing occupant thermal comfort.

Shading devices prevent the direct solar gain and filter it out against improper condition. Different types of shading devices such as fixed, movable, horizontal, vertical, interior and exterior made of different shape and material are available in building market and can be used in different orientation by means of variable function. They place most likely outside of the glazed openings so that they can produce shadow over these transparent surfaces. Finding out the shading devices performance for improving comfort condition at the office buildings, this study emphasizes on the role of shading devices types and direct solar gain effect on users comfort condition. In this respect, the present study after introducing the subject and specifying its aim and objectives, reviewed the thermal comfort literature and linked that to the climatic factors. Subsequently, the passive solar building design as well as shading devices and their types and functions are debated in detail. Moreover three case studies which are investigated in terms of shading devices improve thermal comfort. The comparison of these three case studies reveal the significant varies of shading devices function and how they act against solar radiation. Analyzing case studies in terms of different shading devices and their sun path diagram showed that applying some strategies for shading devices in Rector's office building. These strategies can adapt and apply on this office building:

North orientation :3M headquarters in Milan, Italy as first case study, used appropriate kind of shading devices which utilized in this office building for its climate is fixed-baled sun shading system in north orientation which allowing passive solar energy gain during winter and protecting glazed façade from overheating in summer.

In the second case study, social security administration building in Barcelona, Spain, the appropriate shading device in this building is fix extending horizontal, including eaves and awnings type are used to allow good passive sun control. Furthermore adjustable shading (seasonal vegetation) facilitates adaptation to changing climatic conditions. While for the third case study of Emu Rectorate Office Building in Famagusta, North Cyprus, after the comparison with the successful cases, proposed appropriate shading devices use fixed shading devices (eaves, awnings, pergolas and louvers) which can regulate solar access on northern elevations throughout the year, without requiring any user effort. Additionally adjustable shading (mechanical or manual and seasonal vegetation) facilitates must adapt to changing climatic conditions.

South orientation: In 3M headquarters in Milan, Italy, appropriate kind of shading devices which utilized in this office building for its climate is require overhead shading devices, by using Fix horizontal overhang devices and the building steps making a series of terraces which offer shaded outside space for the office staff. The terraces work as an environmental buffer area which protects the building from climate inordinate in each winter and summer.

In other case study, social security administration building in Barcelona, Spain, appropriate shading device which is used in this building is narrower overhead shading devices, by using eaves, adjustable shading (seasonal vegetation) and fix horizontal overhang devices through endless envelope of aluminum slats. These slats offer personality to the building facades: they are organized horizontally on the main facades of the building (Longitudinal facades) and in vertical on the beams.

Though in the case study of Emu Rectorate Office Building in Famagusta, North Cyprus, for proposing correct shading devices in south façade after comparing, fixed horizontal overhangs are advised.

E*ast and west orientation:* In the 3M headquarters in Milan, Italy, The proper kind of shading devices which utilized is fixed-baled sun shading system allowing passive solar energy gain during winter and protecting glazed façade from overheating in summer. But for proposed because of east and west sun angles, egg crate and adjustable shading is especially useful.

In other case study, social security administration building in Barcelona, Spain, to propose the applicable shading devices are egg crate type, adjustable shading, vertical type and horizontal type must.

While in the Emu case study, Cyprus, the appropriate shading devices in terms of thermal comfort for Emu Rectorate office building which proposed after evaluation is to use, egg crate and aAdjustable shading.

This study can be carried a step forward in the future with a focus on the compatibility assessment of shading devices as used in office buildings.

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APPENDICES

Appendix A: Shadow Angels

Shadow angles

Vertical:

VSA = arctan(tanALT/cosHSA)

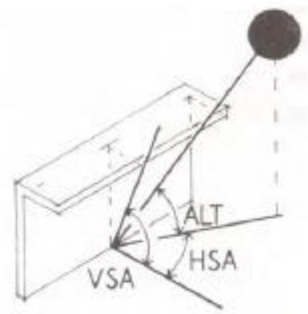
Horizontal:

HSA = AZI - ORI

if 90° < abs | HSA | < 270° then sun is behind the facade, it is in shade

if HSA > 270° then HSA = HSA - 360°

if HSA <-270° then HSA = HSA + 360°



Angle of incidence

Generally:

INC = arcos(sinALT•cosTIL + cosALT•sinTIL•cosHSA)

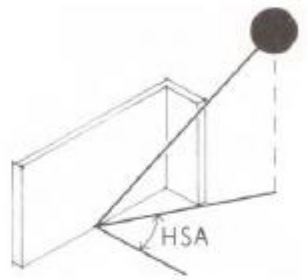
where TIL = tilt angle of receiving plane from horizontal

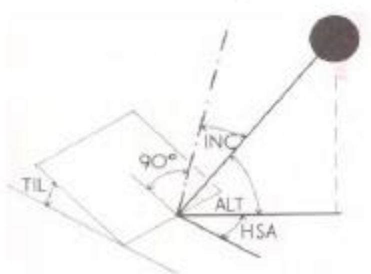
For vertical planes, as TIL = 90, cosTIL = 0, sinTIL = 1

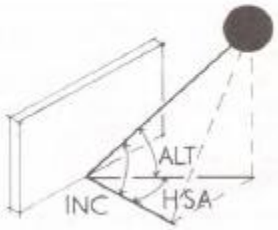
INC = arcos(cosALT • cosHSA)

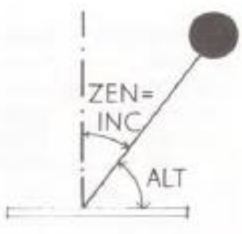
For a horizontal plane

INC = ZEN = 90 - ALT

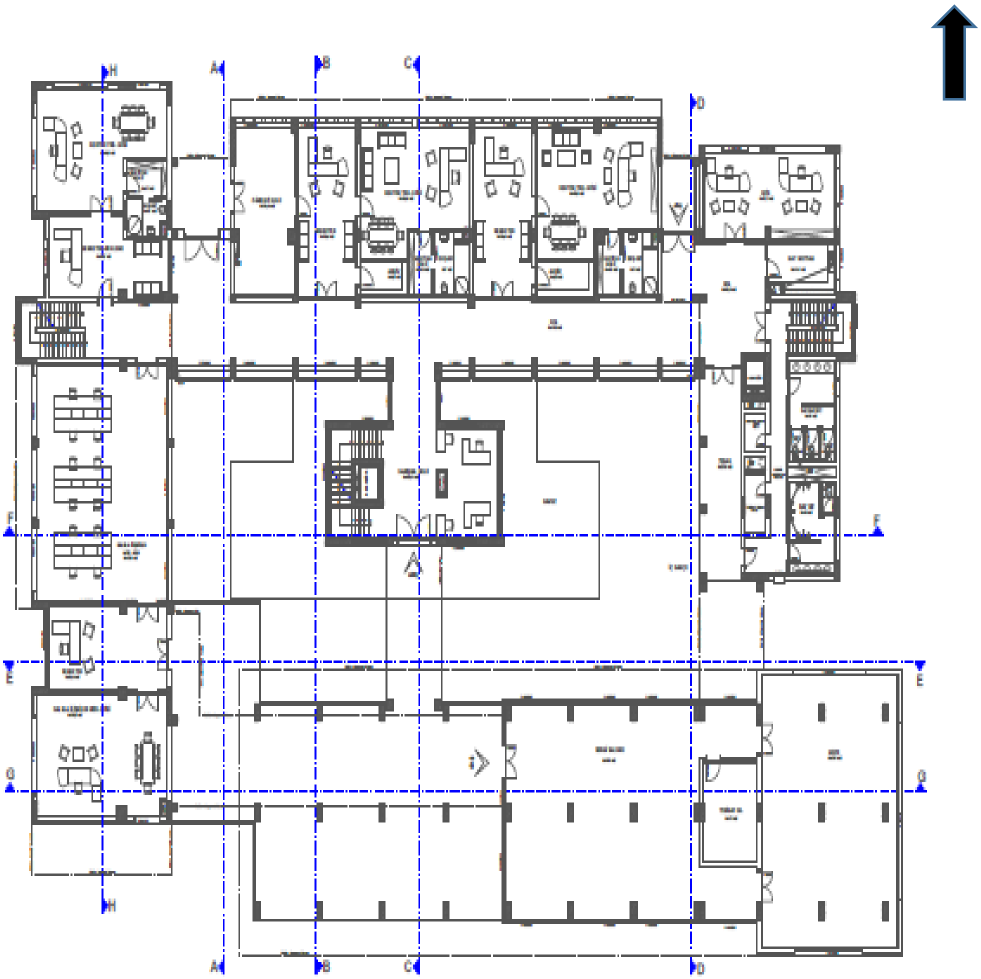




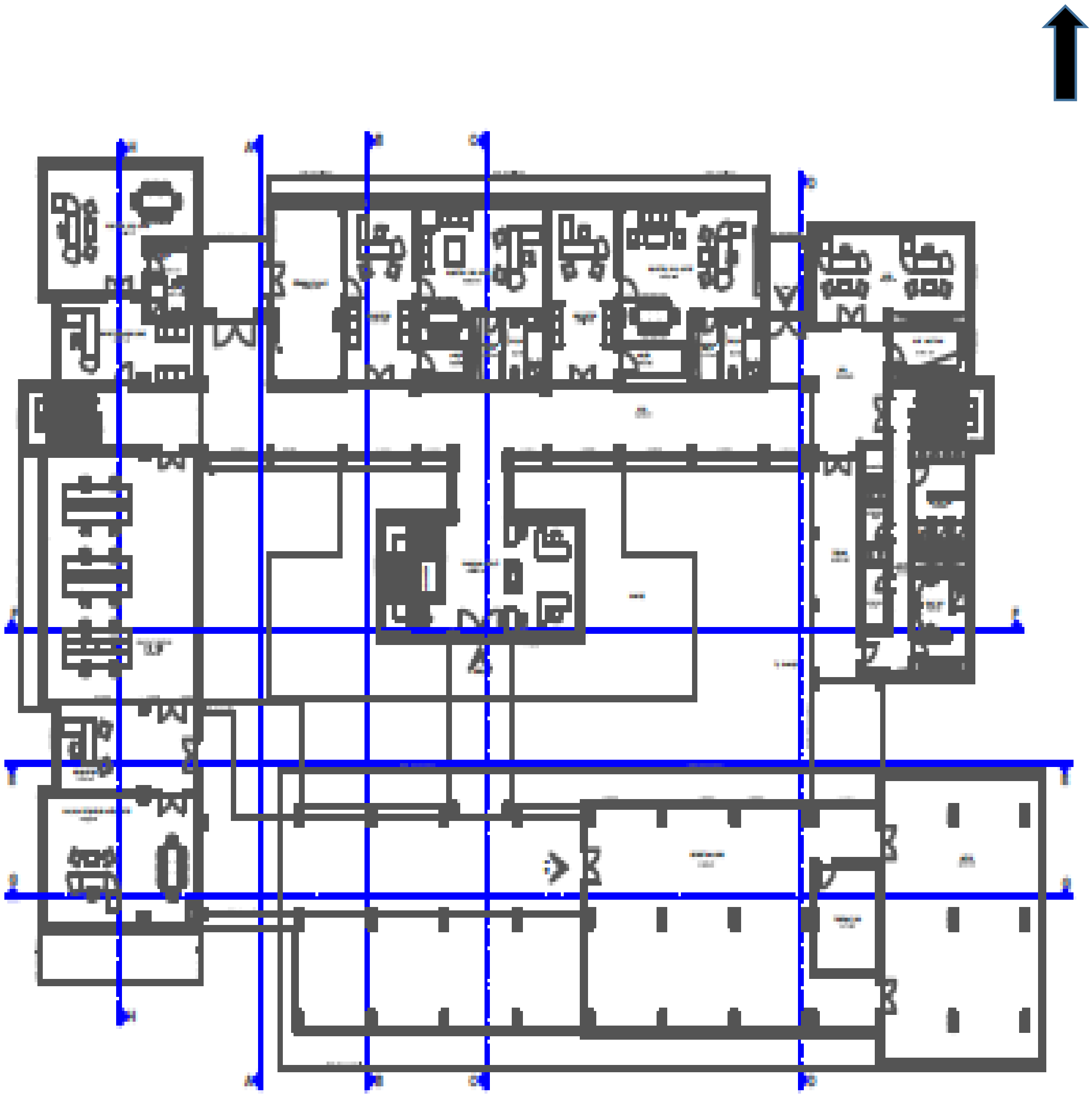




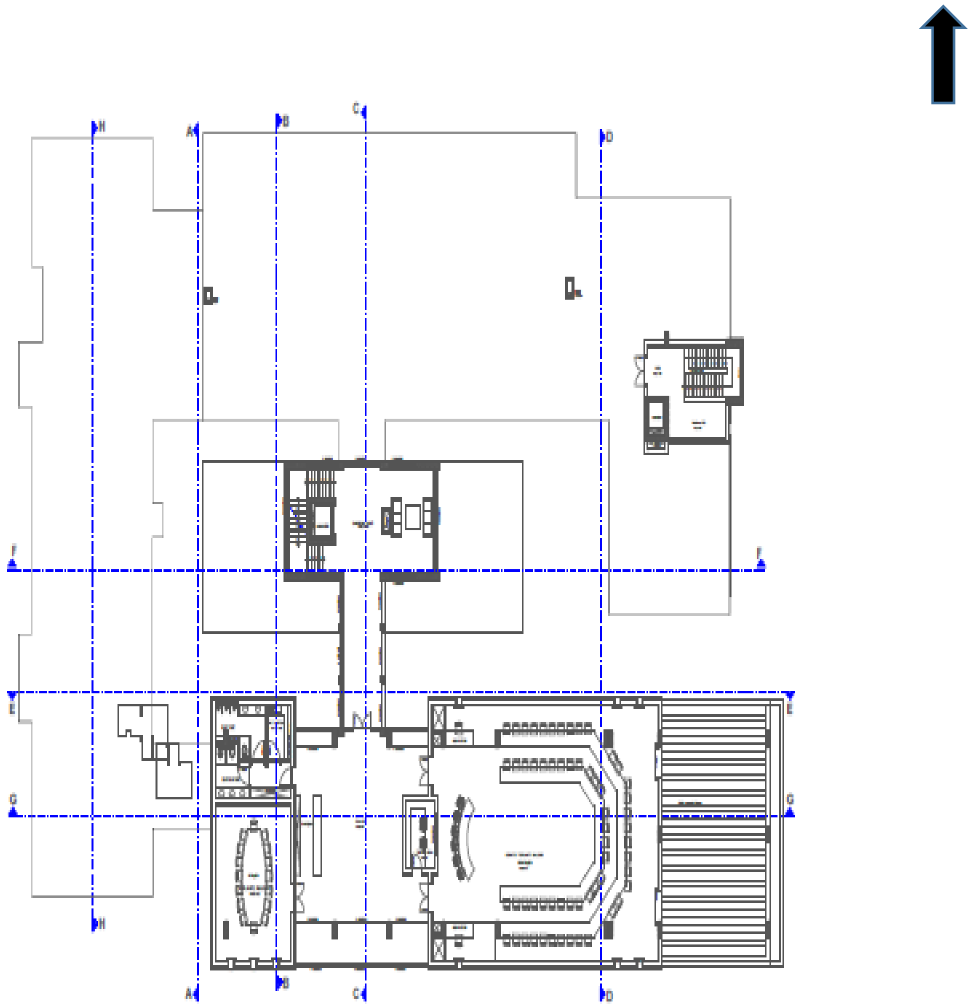
Appendix B: Emu Rectorate office building plans



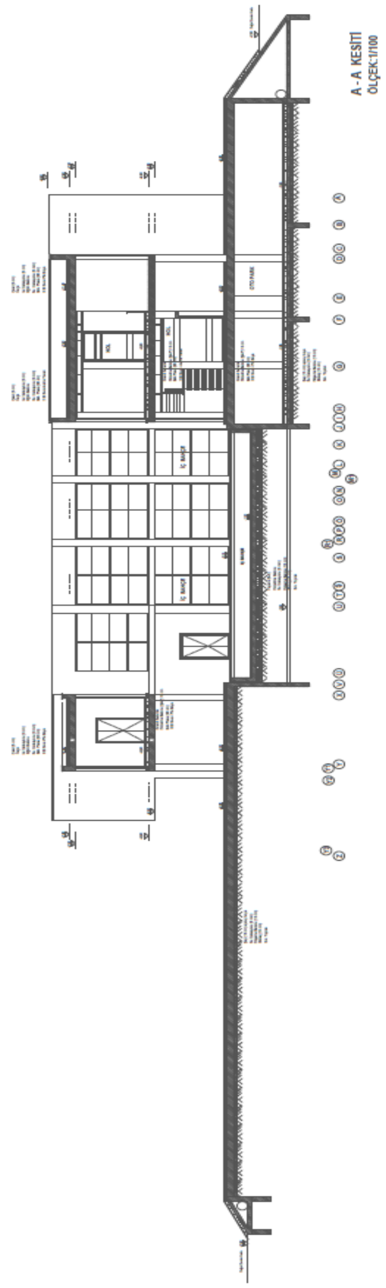
Ground Floor of Emu Rectorate office building plan (No scale)



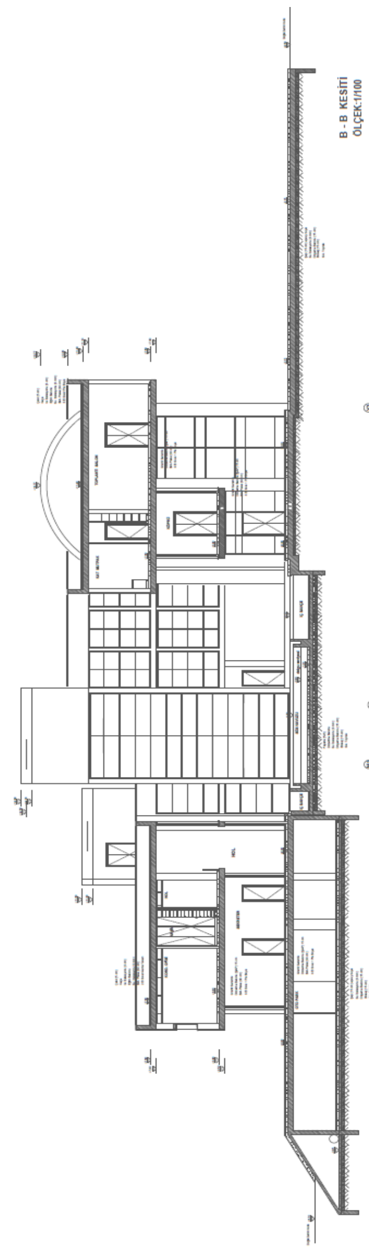
First Floor of Emu Rectorate office building plan (No scale)



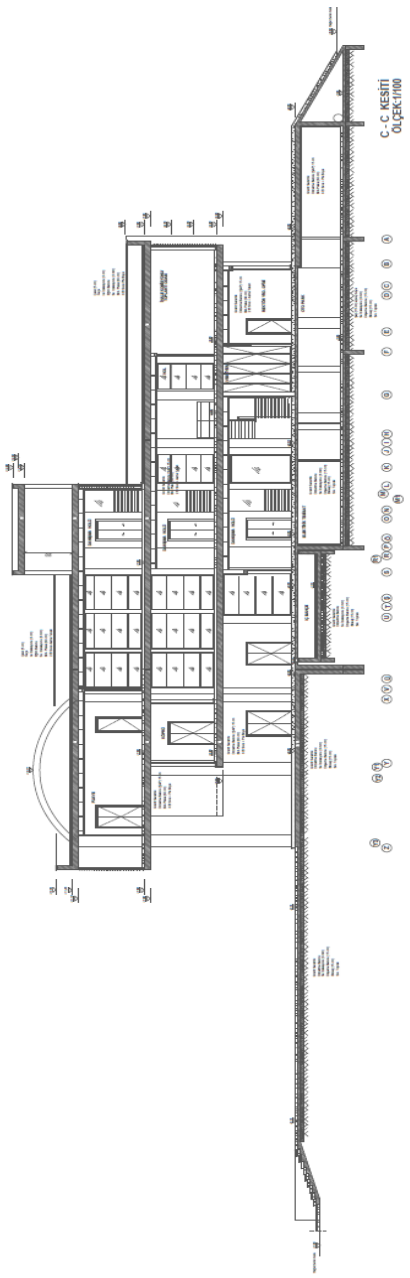
Second Floor of Emu Rectorate office building plan (No scale)



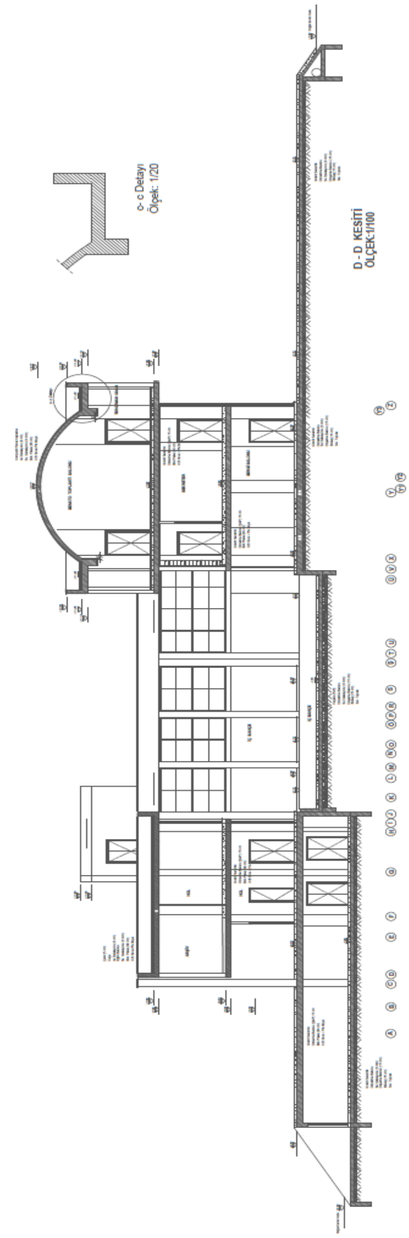
Section A-A of Emu Rectorate office building (No scale)



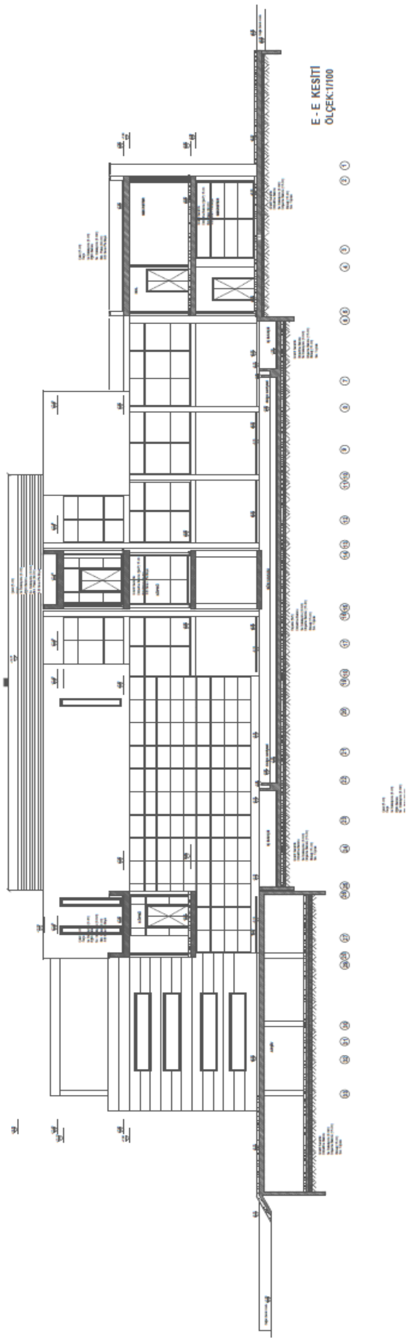
Section B-B of Emu Rectorate office building (No scale)



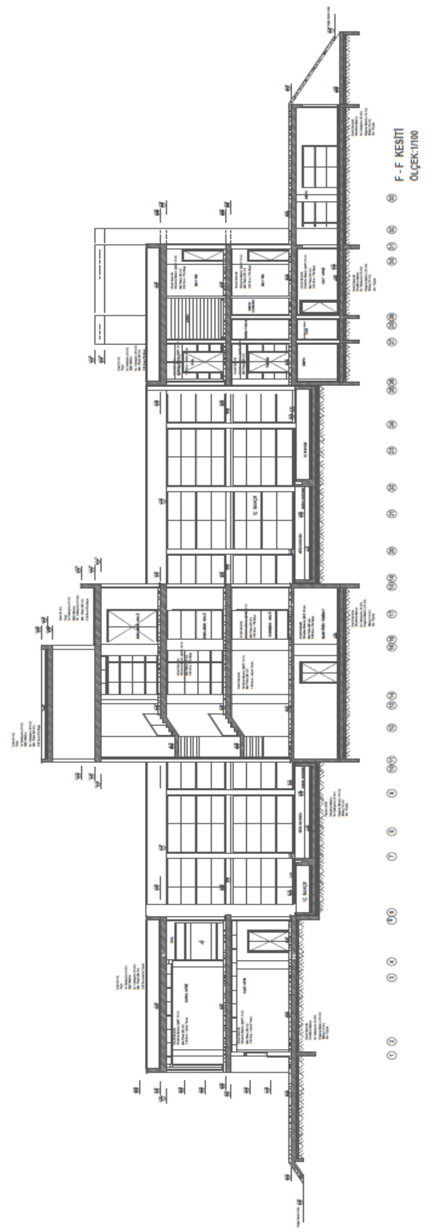
Section C-C of Emu Rectorate office building (No scale)



Section D-D of Emu Rectorate office building (No scale)

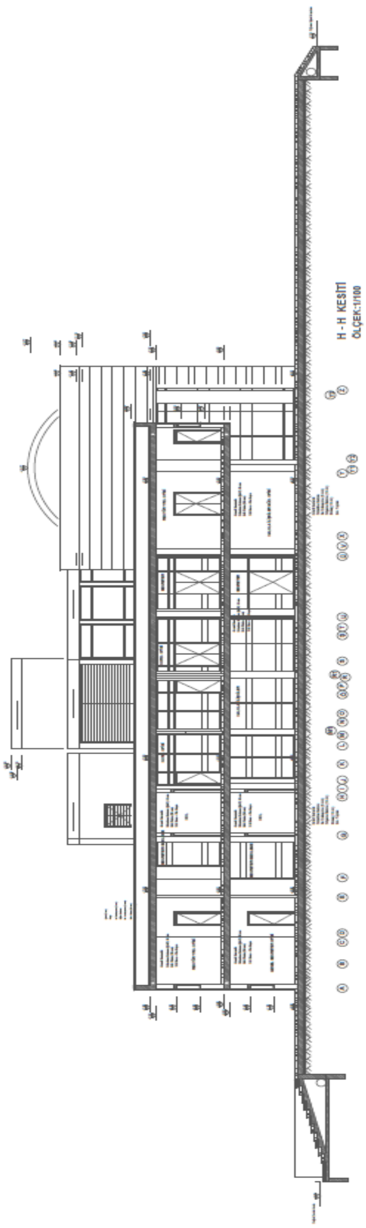


Section E-E of Emu Rectorate office building (No scale)



Section F-F of Emu Rectorate office building (No scale)

Section G-G of Emu Rectorate office building (No scale)



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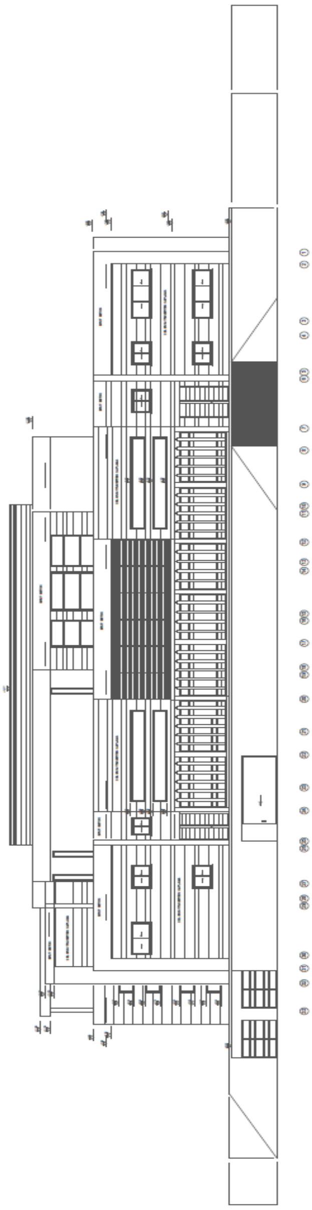
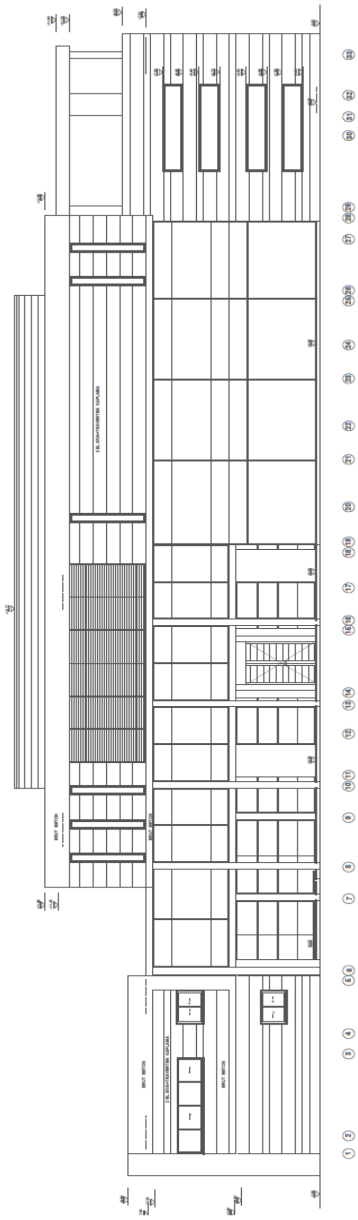
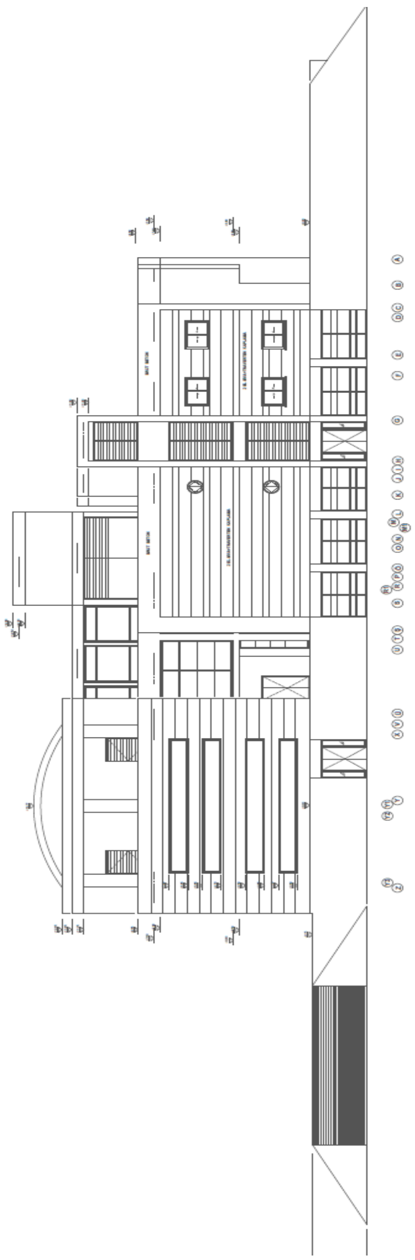


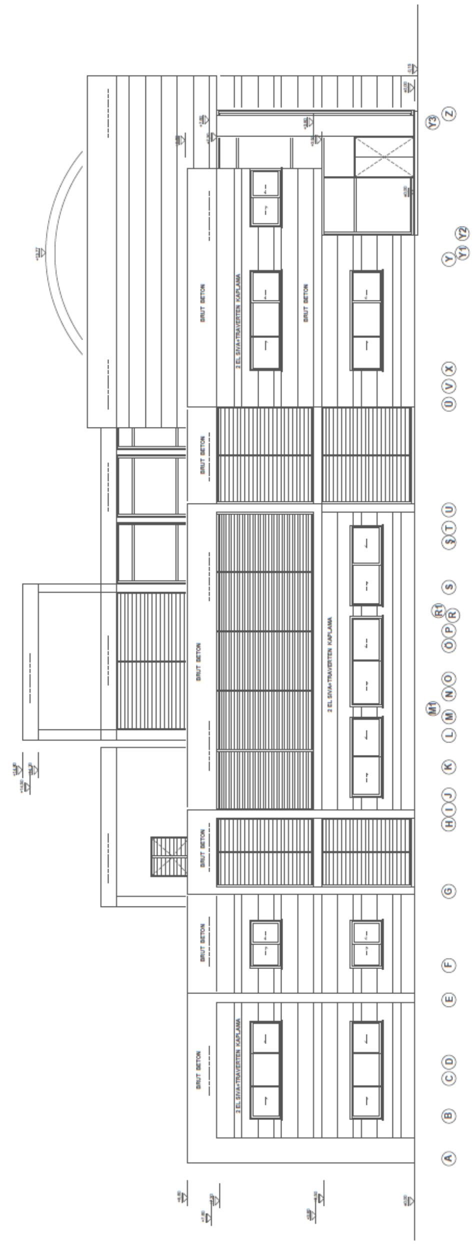
South elevation of Emu Rectorate office building (No scale)



North elevation of Emu Rectorate office building (No scale)

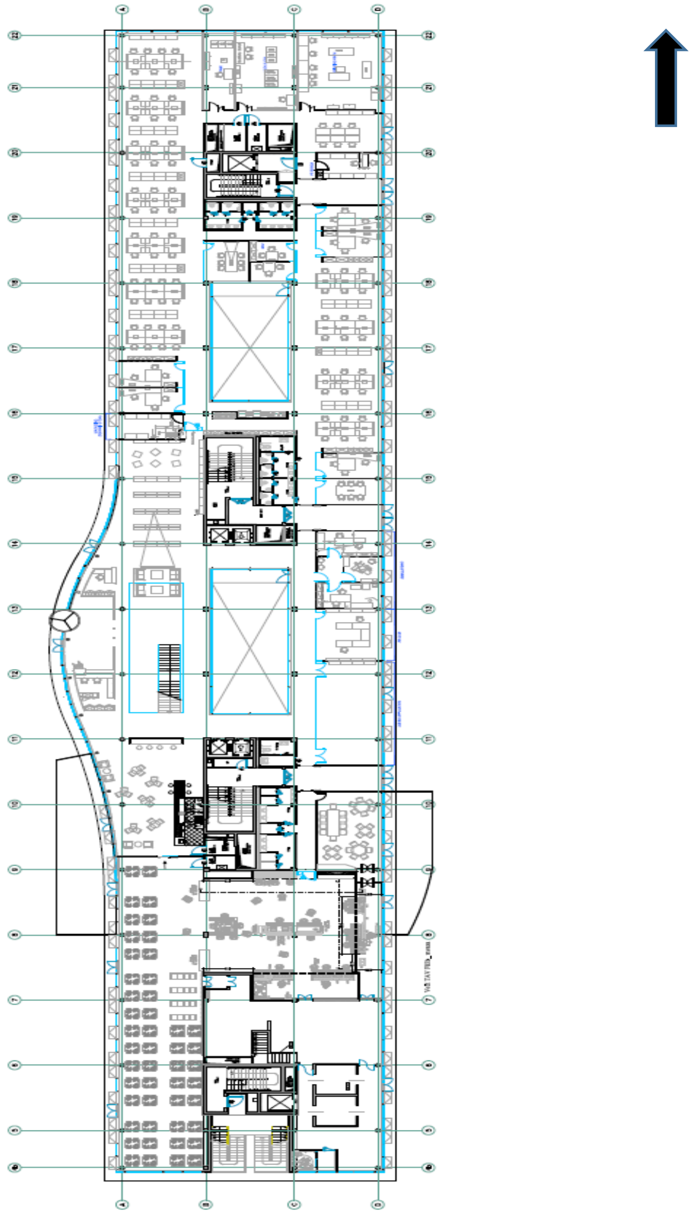


West elevation of Emu Rectorate office building (No scale)

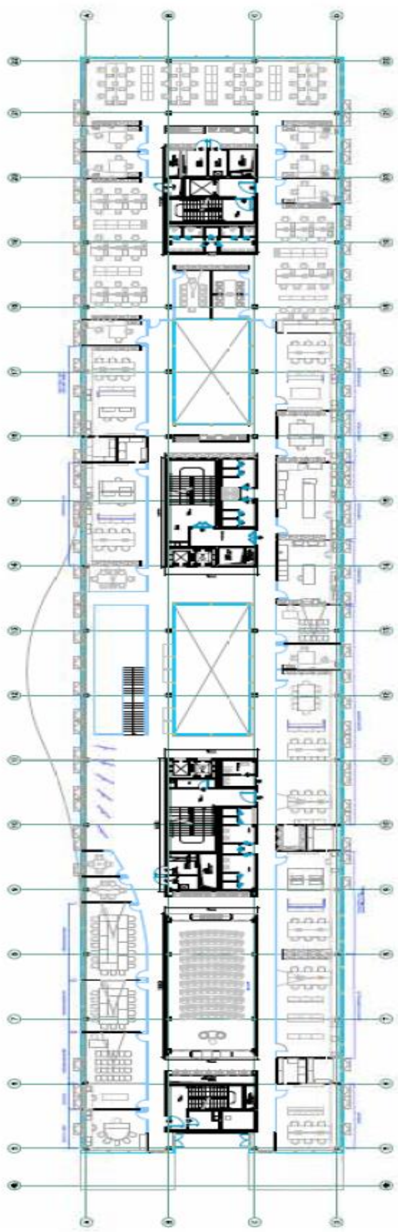


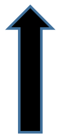
East elevation of Emu Rectorate office building (No scale)

Appendix C: 3M Headquarters plans

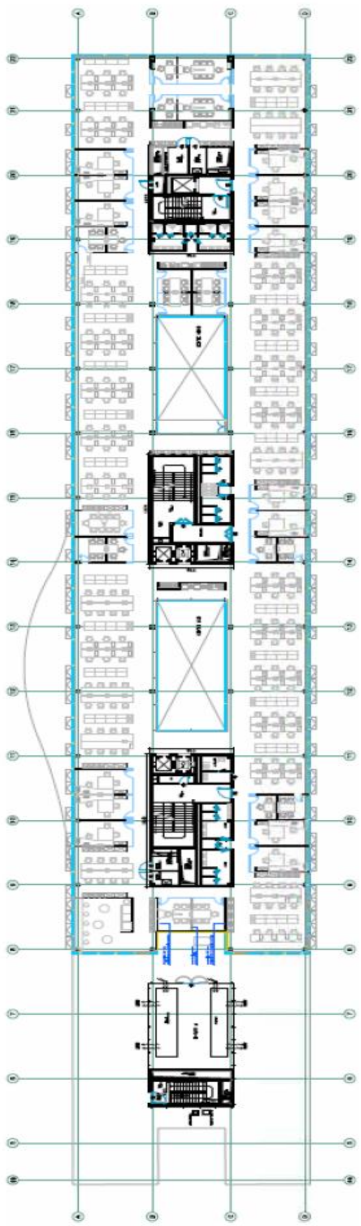


Ground floor plan of the 3M Headquarters plan (No scale)

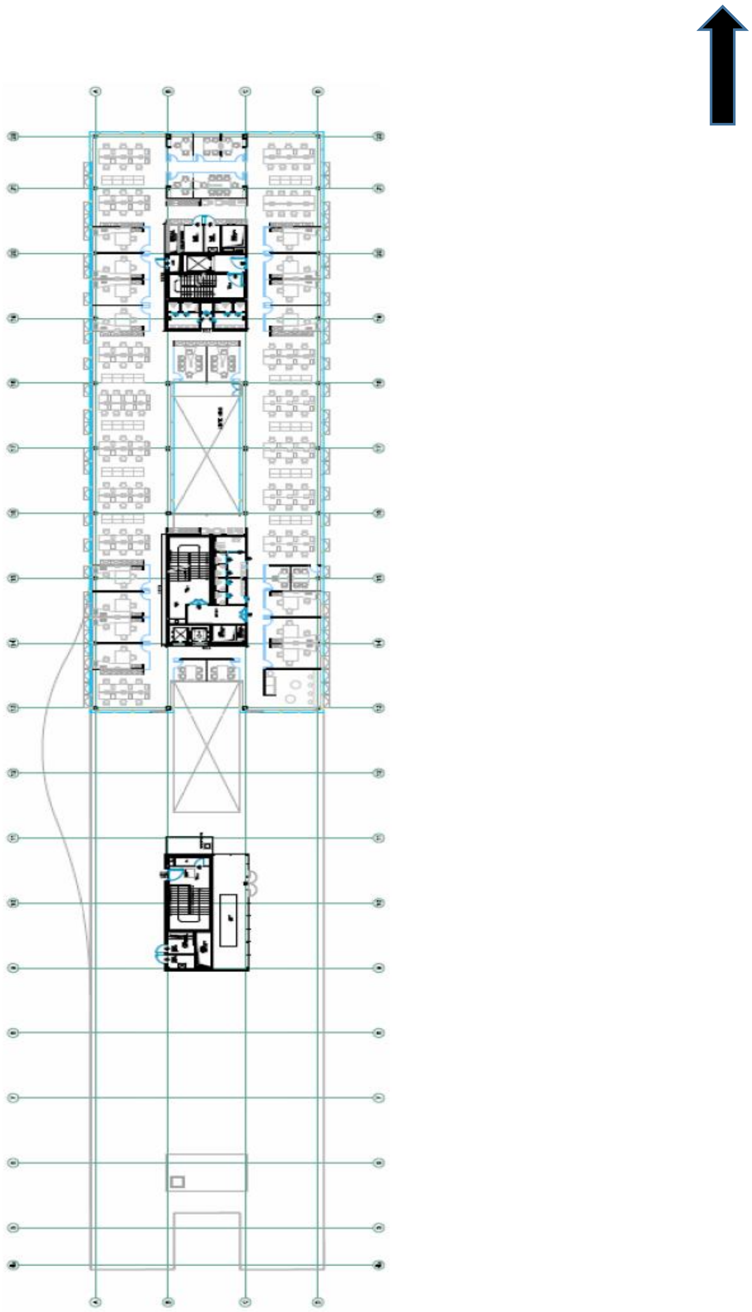




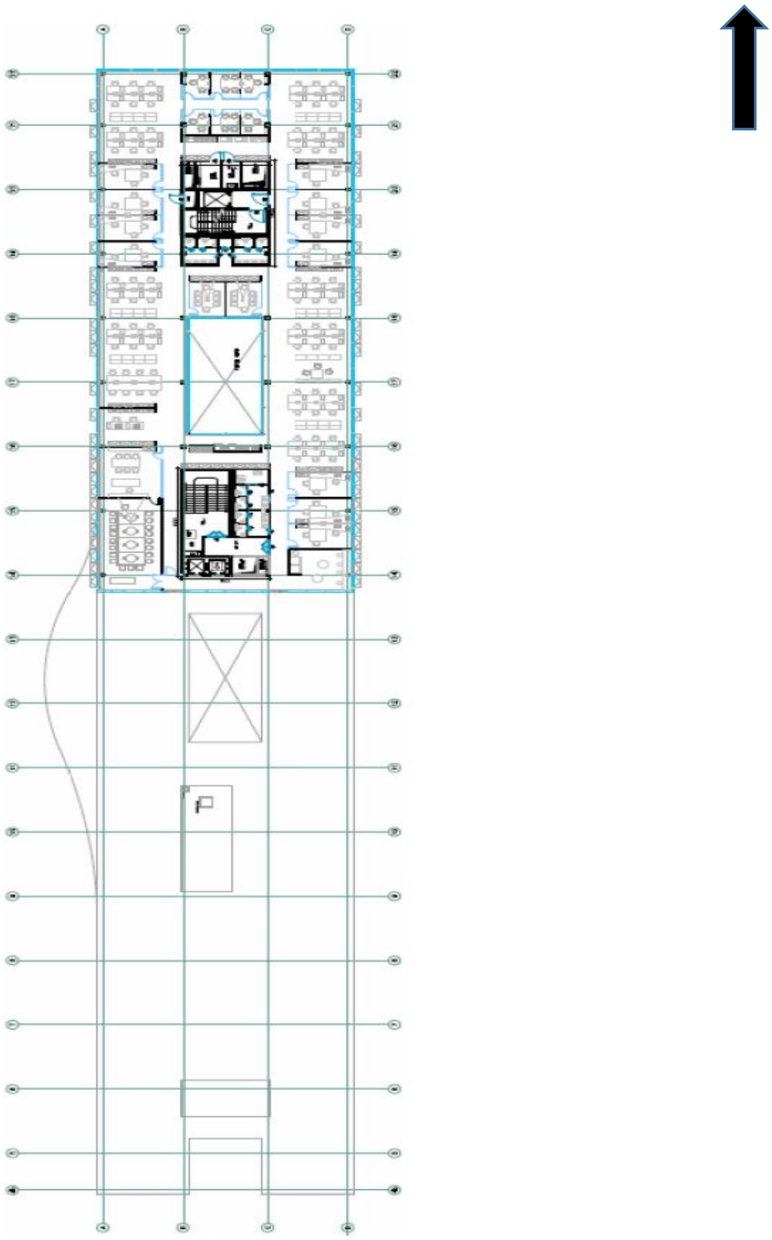
First floor plan of the 3M Headquarters plan (No scale)



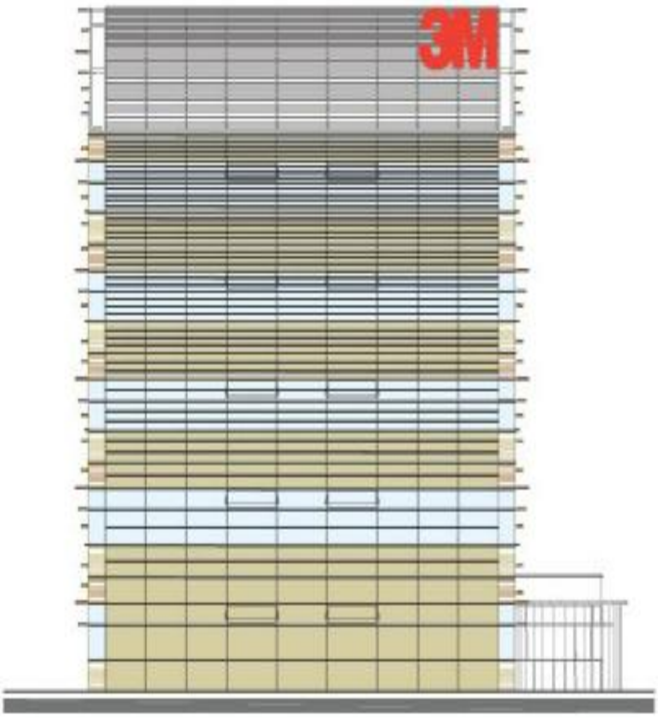
Second floor plan of the 3M Headquarters plan (No scale)



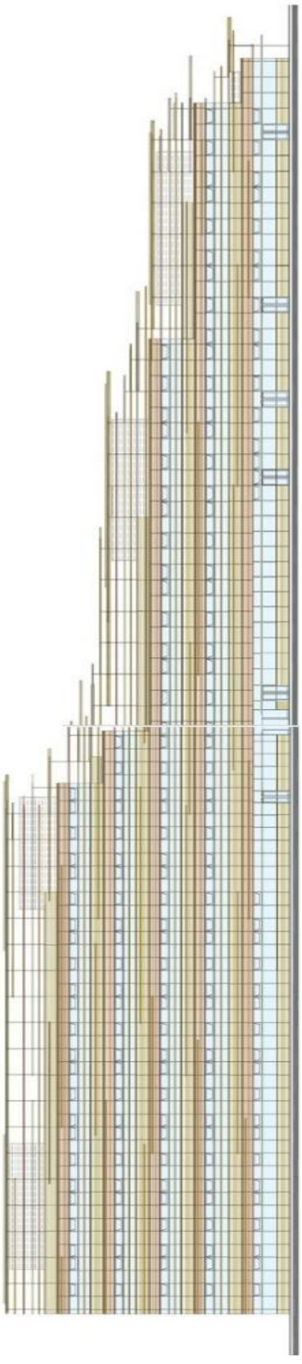
Third floor plan of the 3M Headquarters plan (No scale)



Fourth floor plan of the 3M Headquarters plan (No scale)

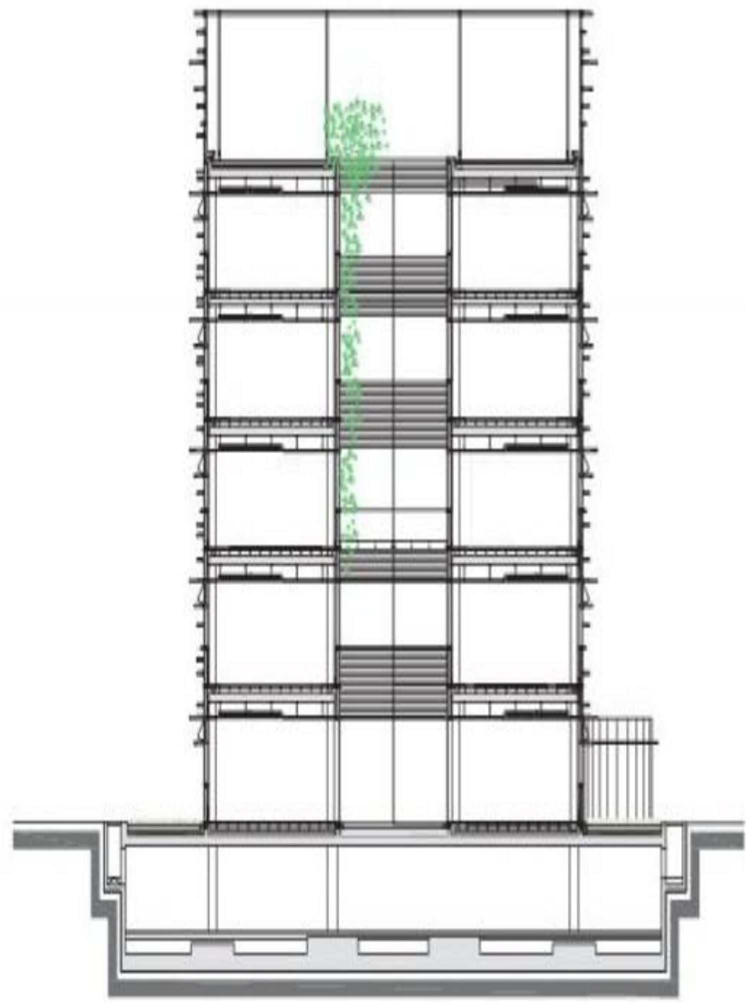


North elevation of the 3M Headquarters (No scale)

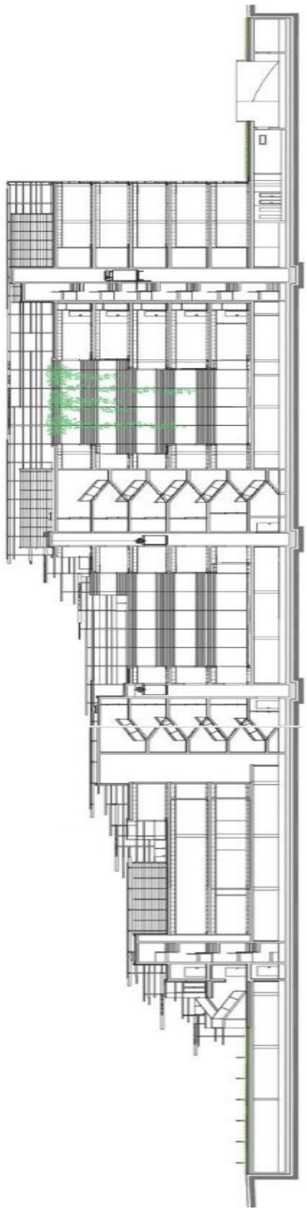


West elevation of the 3M Headquarters (No scale)

South elevation of the 3M Headquarters (No scale)

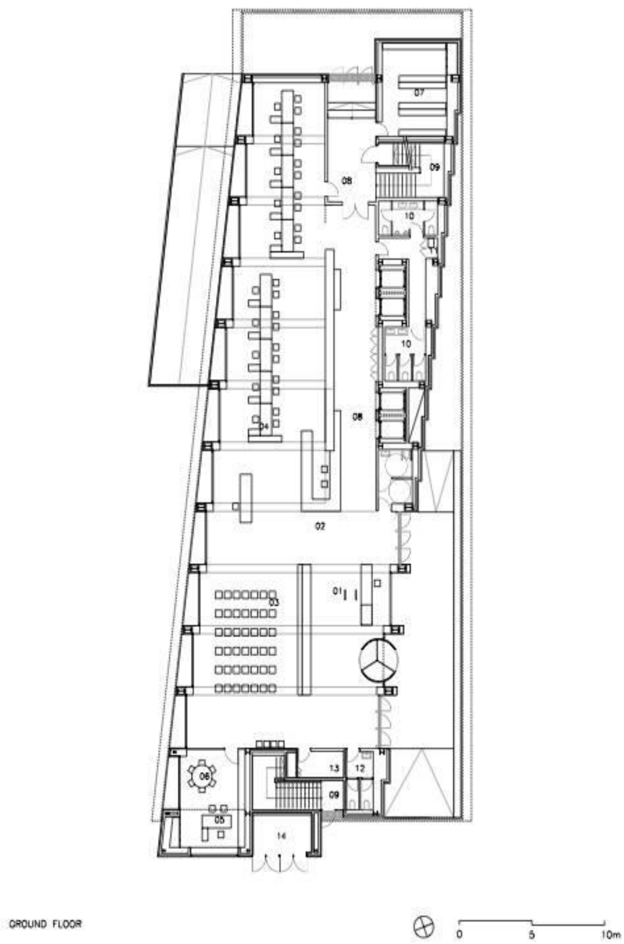


Section A-A of the 3M Headquarters (No scale)

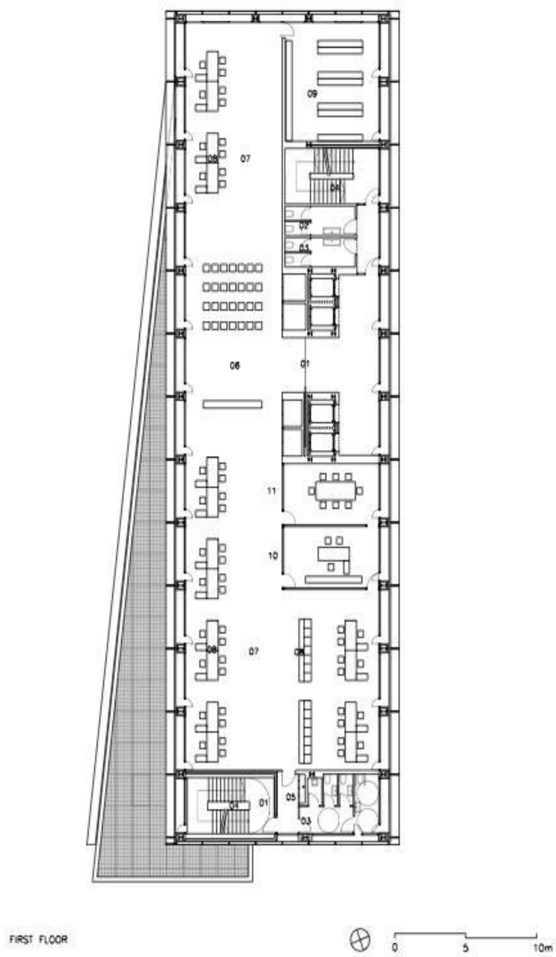


Section B-B of the 3M Headquarters (No scale)

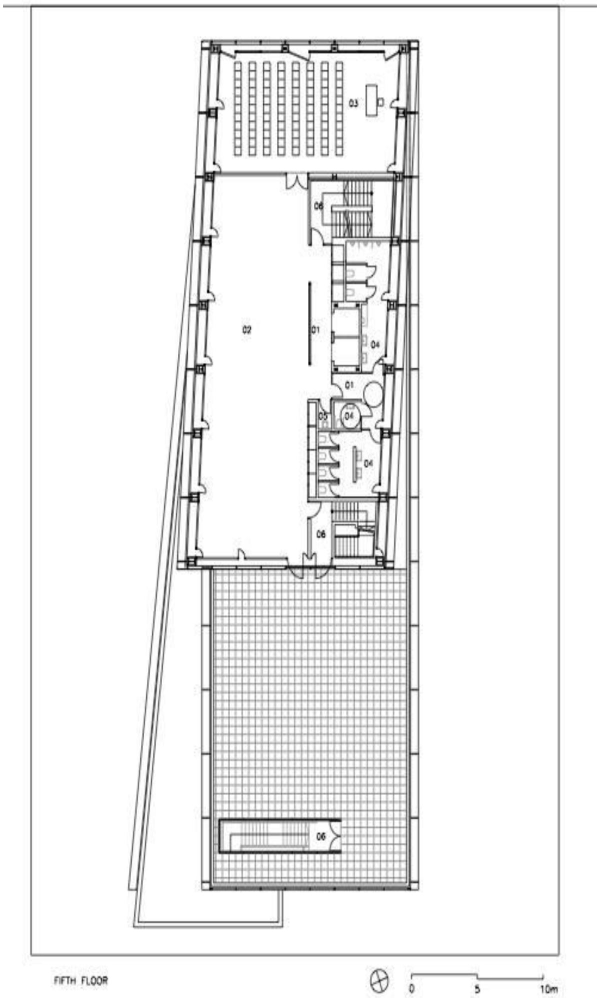
Appendix D: Social Security Administration Building Plans



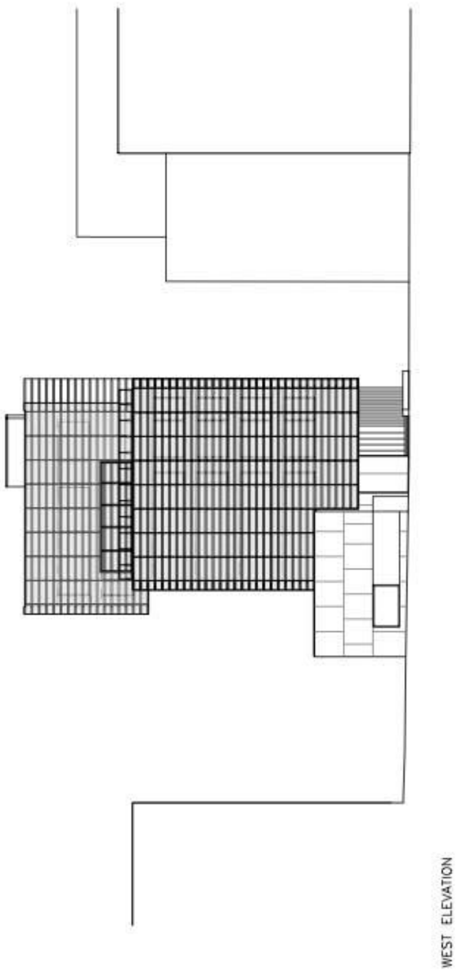
Ground floor of Social Security Administration Building Plan



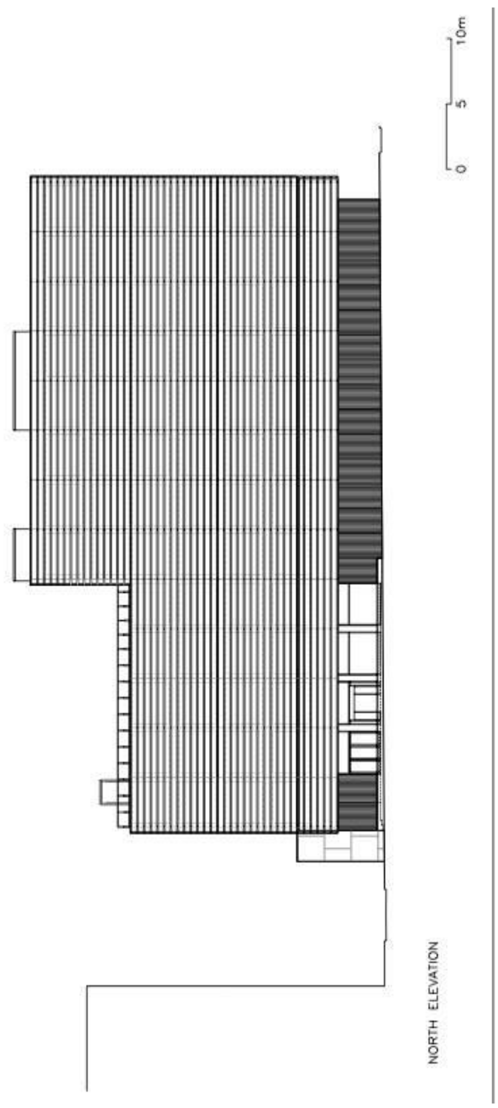
First-second-third-fourth floor of Social Security Administration Building



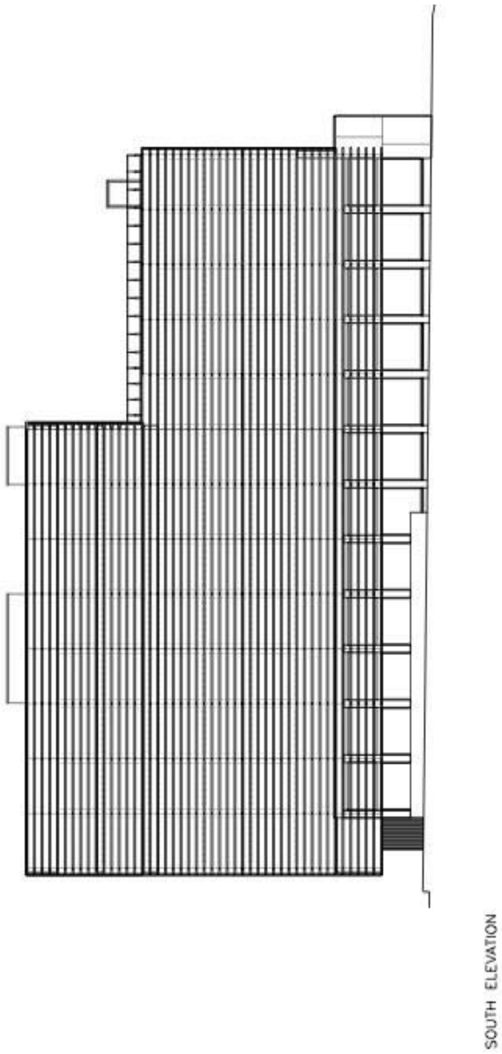
Fifth and sixth floor of Social Security Administration Building



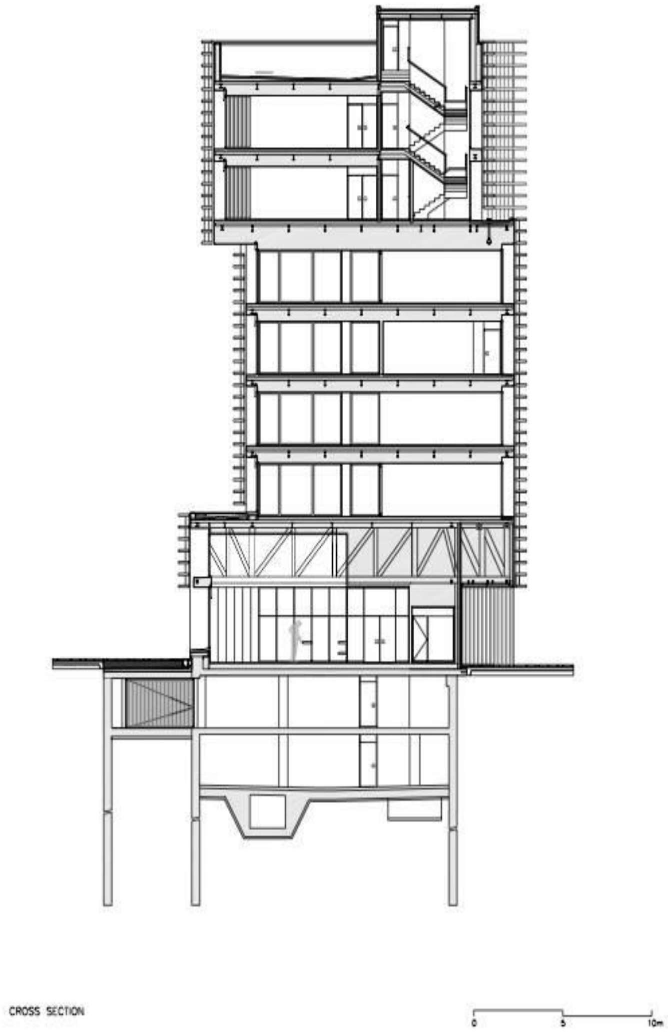
West elevation of Social Security Administration Building



North elevation of Social Security Administration Building



South elevation of Social Security Administration Building



Section of Social Security Administration Building