OPTIMIZING DAYLIGHTING USING VERTICAL LIGHTPIPES IN THE DESIGN OF VERTICAL SHOPPING MALL KANO

By

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P14EVAT8136

A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES,
AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS DEGREE IN ARCHITECTURE

DEPARTMENT OF ARCHITECTURE,
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JUNE, 2018.

Declaration

I declare that the work in this project thesis entitled OPTIMIZING DAYLIGHTING USING VERTICAL LIGHT PIPES IN THE DESIGN OF VERTICAL SHOPPING MALL KANO has been performed by me in the Department of Architecture. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this project report/thesis/dissertation was previously presented for another degree or diploma at this or any other Institution.

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Certification

This dissertation entitled OPTIMIZING DAYLIGHTING USING VERTICAL LIGHT PIPES IN THE DESIGN OF VERTICAL SHOPPING MALL KANO by YAHAYA AMINU meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, and is approved for its‟ contribution to knowledge and literary presentation.

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Dedication

I dedicate this thesis to my loving mother, Hajia Bilkisu Abdussalam.

Acknowledgment

All due praise be to Allah, the Exalted. He Whom we give thanks, with Whom we seek refuge, Who's guidance and forgiveness we seek, and the One with Whom we seek refuge from the evils of our own selves and the evils of our bad deeds, for giving me all the resources to accomplish this project.

I will also like to thank my supervisors Dr. Hamza Babangida and Dr. M. D. Ahmad for their guidance, support and time given, in putting me through this dissertation. So also, to the Head of Department Dr. Abubakar Sadiq Salisu, Dr. R. B. Tukur and other members of staff of the Department, who at one time or the other, contributed immensely to the realization of this project. I would not forget to extend my thanks to Arc. Sani Lukman, for his support, especially during my enrolment in to the M.Sc. programme.

To my loving mother, Hajia Bilkisu Abdussalam. My brother Usman (Nurain), my sisters Zaheeda, Zainab (maama), and Saudat (ammi) I appreciate them all. Also to my nephew Muhammad Bello and nieces Ikram and Ilham, I thank them for their support and prayers God bless you.

My sincere thanks goes to my fiancé Zainab Muhammadu Jibo for the love, care, advice, and support all the way, from inception to the end of this M.Sc. May God bless her.

So also to my colleagues, Mukhtar Abubakar Yakubu, Salisu Bello, Khaleed Baffa Sani Gaya, Jibril Abdulkadir, Kabir Samaila, Kachalla Bukar Abba, Usman Kanoma, Elijah Ngutor, Yannick Ngatah I appreciate them all. In addition, Salisu Kutama, Umar Idris, John Adamu, Ukashatu Musa Yunusa and other friends, who are too numerous to mention, for supporting me and understanding my absence, when I was needed most. I really appreciate all the support, in one way or the other.

Abstract

In commercial buildings, two-thirds of the sale time is during the day, it provides opportunity for optimizing the daylight potential of the region and reducing electric consumption. This solves the two key problems in shopping malls; these are visual and thermal discomfort of workers and customers. The current population growth and scarcity of land in Kano triggered the adaptation of vertical mall, which has a higher height ratio in relation to its area. Most of the shopping malls lack one of the two important key areas which are thermal and visual comfort, therefore the need to optimise these two key elements in design and hence the problem of this study. The aim of the study is to design a vertical shopping mall that optimises daylighting using vertical light pipes (VLP) in Kano. A careful study of the literature reveals that the above is only possible using experimental research design as it is the best to test the efficiency of light pipes in buildings. The methodology adopted for the study was an in depth literature review, case study and experimental research design with simulation as a tool. The major factor considered in the simulation was illuminance within a 3m x3m x 3m windowless box, to investigate the efficiency of dual technology of light pipes and light rods with an increase in diameter as well as in length. The results show that inclusion of vertical light pipes in a space showed a 20% increase in daylighting in that space and that the illuminance within a space reduces by 6% in every 1.5m length. It was concluded that vertical light pipes transfer uniform light to places other daylight apertures cannot reach, while excluding heat and glare. It implies that using light pipes in a shopping mall reduces the cost of lighting the interior and reduces the cost of cooling. Due to the width of a space in a shopping mall, side light and exterior toplight is inadequate to provide daylight within the space. As daylight travels in a straight path, the shelves and merchandise provided within a space obstructs its transfer deeper into a space. Orientation determines the shading to

be provided for sidelight apertures to further exclude glare from reaching interior of a shopping mall. The fenestration material used also determines the quality and quantity of daylighting within the space. Light pipes transfer more daylighting to lower floors than other toplighting strategies like skylights. Finally, this study could be said to have achieved its objectives and answers its research questions. Furthermore, some recommendations are given as follows; Based on the simulation results, it is recommended that vertical light pipe should not exceed a height of 9.5m for effective and efficient light transmission. Although vertical light pipes improved the interior daylight up to 20%, it cannot be used on its own. Other daylight strategies should also be considered during the design stage of any project.

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1.0 INTRODUCTION

1.1 Background of Study

For many years now, Nigeria has been facing an extreme electricity shortage. This deficiency is multi-faceted, with causes that are financial, structural, and socio-political, none of which are mutually exclusive. There is insufficient cash generation because of these inefficiencies and the power sector is consequently reliant on fuel subsidies and funding of capital projects by the government. With over 150 million people, according to the Nigerian Energy Policy report from 2003, it is estimated that the population connected to the grid system is short of power supply, over 60% of the time and at present only 10 % of rural households and 40% of the country's total population have access to electricity (Obadote, 2009).

Green building Technology (2007) opines that daylighting provides the opportunity for both energy savings and improved visual comfort. The science of daylighting design is not just how to provide enough daylight to an occupied space, but how to do so without any undesirable side effects. Beyond adding windows or skylights to a space, it involves carefully balancing heat gain and loss, glare control, and variations in daylight availability. For example, successful daylighting designs will carefully consider the use of shading devices to reduce glare and excess contrast in the workspace. Additionally, window size and spacing, glass selection, the reflectance of interior finishes, and the location of any interior partitions must all be evaluated (Ander, 2014).

There are ways to reduce the excess reliance on electricity and reduce the cost, especially in a commercial building like vertical mall; one of it, is the use of daylight strategy. Daylighting helps create a visually stimulating and productive environment for building occupants, while reducing as much as one-third of total building energy costs. Similarly, a daylighting system is comprised not just of daylight apertures, such as skylights and

windows, but is coupled with a daylight-responsive lighting control system. When there is adequate ambient lighting provided from daylight alone, this system has the capability to reduce electric lighting power (Ander, 2014).

The concept of vertical mall, came in existence because of the complexities of densely populated cities/nations where land price was so high, and it was becoming difficult for existing retailers to think of any kind of horizontal expansion to accommodate increasing crowd to their retail outlets. The Water Tower Place skyscraper was ultimately in 1975 appeared as the very first vertical mall in Chicago, Illinois. It contains a hotel, luxury condominiums, and office space and sits atop a block-long base containing an eight-level atrium-style retail mall that fronts on the Magnificent Mile. And also Times Square is considered the first of its kind, the first "vertical mall" in Hong Kong.

1.2 Statement of Problem

Electric power outage has become a problem on daily basis in Nigeria, especially Kano, which draw a major setback in the day to day activities, especially commercial activity; Power consumption in a shopping mall used in lighting the interior part influence the cost of product which is not economically viable and which affects consumer satisfaction.

Matt Kitson (2016) said: “Two key areas that tend to get overlooked when designing malls are thermal and visual comfort”. Malls are designed to maintain air temperature; however, comfort is derived from a number of factors. For internal spaces, these are air temperature, the impact of solar gain on surfaces and air speed. “Daylight is also an important factor; it can significantly drive footfall and increase dwell time”. Independent research shows that stores with daylight can increase sales by 40 per cent, reduce operating costs, and provide better employee satisfaction. By understanding these two, it provides greater opportunities for designers going forward.” (Kitson, 2016).

Most buildings have access to daylight but not all optimise it, this leads to either under lighting of the interior or over lighting therefore leads to excess glare and contributes to visual discomfort. Commercial centres such as shopping malls have now become part of people's life and a place to spend their leisure time. Most of the shopping malls lack one of the two important key areas which are thermal and visual comfort, therefore the need to optimise these two key elements in design and hence the problem of this study.

1.3 Justification

Electric lighting accounts for 35% to 50% of the total electrical energy consumption in commercial buildings. The energy savings from reduced electric lighting through the use of daylighting strategies can directly reduce building cooling energy usage by an additional 10% to 20%. Consequently, for many institutional and commercial buildings, total energy costs can be reduced by as much as one-third, through the optimal integration of daylighting strategies (Ander, 2014). This give way to test new ways of optimizing daylight through light pipes.

The need for shopping mall, as a necessity for commercial activities in the 21st century has become imperative with the attendant need to reduce energy consumption and enhances profit, this will also enhance the shopping atmosphere and which come to the need for the research and design of vertical shopping mall due to High land prices and dense population.

Kano state has a population of approximately 9.4 million based on the 2006 census, and current estimates at 12 million as of 2013. It has a population growth rate of approximately 3.5% per annum (Kano State Government, 2013). According to Kano State Investors Handbook (2013), investment opportunities exist in construction of modern shopping complexes especially within the metropolitan areas of Kano state.

1.4 Aim and Objectives

The aim of the study is to design a vertical shopping mall that optimises daylighting using vertical light pipes (VLP). The objectives are to:

1. Identify general strategies of achieving daylighting in vertical shopping malls.
2. Determine how to optimize daylight provision using vertical light pipes.
3. Develop a framework for integrating it into the windowless part of the vertical mall for a hot semi-arid zone.
4. Propose a vertical shopping mall design that reflects strategies of daylighting.

1.5 Scope

There are eight types of shopping mall viz: Neighbourhood, Regional, Community, Superregional, Fashion/Specialty, Theme/Festival, Power and Outlet centre. This study is limited to vertical shopping malls under superregional centre.

1.6 Research Questions

I. What are the strategies used in vertical shopping mall?

II. Which strategy optimizes daylighting in vertical shopping mall?

III. What type of framework can be developed to optimize it in the windowless parts of the vertical shopping mall?

IV. Which of the strategy strategies should be used in the design of vertical shopping mall.

2.0 LITERATURE REVIEW

2.1 Introduction

For centuries, daylight was the only efficient source of light available. Architecture was dominated by the goal of spanning wide spaces and creating openings large enough to distribute daylight to building interiors. Efficient artificial light sources and fully glazed facades have liberated designers from these constraints of the past. Implementing daylighting on a project goes beyond simply listing the components to be gathered and installed (Ander, 2014). Advanced daylighting systems and control strategies are another step forward in providing daylit, user-friendly, energy-efficient building environments. These systems need to be integrated into a building's overall architectural strategy and incorporated into the design process from its earliest stages (Ruck, et al., 2000). Daylight integration involves decisions about the building form, siting, climate, building components (such as windows and skylights), lighting controls, and lighting design criteria. (Ander, 2014).

In this chapter the concepts of daylight, its types, strategies, principles, and benefits will be discussed. Furthermore, the meaning of shopping mall (specifically vertical shopping mall), its types, requirements and concepts will also be discussed. Finally, the contributions of other researchers and the strengths/weaknesses of each study will be reviewed.

2.2 Daylighting

Reinhart (2011) defines daylight from several points of view, which include definitions for architecture, lighting energy savings, building energy consumption, load management, and cost, they are discussed as follows:

Architectural definition: the interplay of natural light and building form to provide a visually stimulating, healthful, and productive interior environment.

Lighting Energy Savings definition: the replacement of indoor electric illumination needs by daylight, resulting in reduced annual energy consumption for lighting.

Building Energy Consumption definition: the use of fenestration systems and responsive electric lighting controls to reduce overall building energy requirements (heating, cooling, and lighting)

Load Management definition: dynamic control of fenestration and lighting to manage and control building peak electric demand and load shape.

Cost definition: the use of daylighting strategies to minimize operating costs and maximize output, sales, or productivity.

In the above definitions from the architectural point of view, it's seen as the manipulation of building form, natural light while from building energy consumption sees it as a way of reducing overall building energy consumption, and the most important here is to minimize cost and maximize sales or productivity.

2.3 Benefits of Daylight

Daylight can be the primary illumination source, with electric lights available merely to back it up for nights and dark days (Gelfand, 2010) the benefits are:

i. Better light quality
ii. Lower operational costs. Decreasing the 40% to 60% of power going to electric lighting is the first cost saving. Daylighting, with less waste heat from lights, can also contribute up to 20% to energy saving due to decreased cooling loads.

iii. Decreased carbon footprint. Nearly 60% of electricity production comes from the burning of coal and its attendant emission of carbon. Every watt of energy saved reduces the amount of carbon emission released into the atmosphere.

iv. Reduced peak usage. Daylight provides its benefits during the daytime, when the demand for electricity is at its peak. Reducing energy usage during the day reduces the strain on the electricity grid infrastructure.

v. Connection to nature. Daylighting changes with weather and time and in the spectrum human being are biologically adapted to perceive. Daylighting can enhance a connection to nature.

2.4 Strategies of Daylighting

A successful daylighting strategy is one that maximizes daylight levels inside the building but optimizes the quality of the luminous environment for the occupants. Daylighting design is not only about maximizing light levels. Excessive sunlight in an interior can be extremely uncomfortable for its occupants. The key word in daylighting design is control, not only of light levels but also of the direction and the distribution of light (Boubekri, 2008).

Daylighting strategies can be divided into two main categories: sidelighting and toplighting strategies. The key difference of the two strategies is that sidelighting admits light from the perimeter walls of the building while toplighting strategies admit light through the top of the building. The selection of daylighting system will depend on the layout, the orientation and the surroundings of the building (Green Building Technology, 2007).

2.4.1 Side Light

Sidelighting is a technique that provides daylight through apertures located in the perimeter walls of a building. Those apertures include curtain wall or other continuous fenestration systems. In order to maximize the daylight penetration and reduce window glare, it is a good practice to separate the view aperture from the daylight aperture. For this reason, the daylight glazing is placed as close to the ceiling as possible for bouncing daylight deep into the room by the ceiling. In this way, higher visible transmittance glazing can be used in the daylight aperture. Figure 2.1 illustrates a standard sidelight concept (Green Building Technology, 2007).

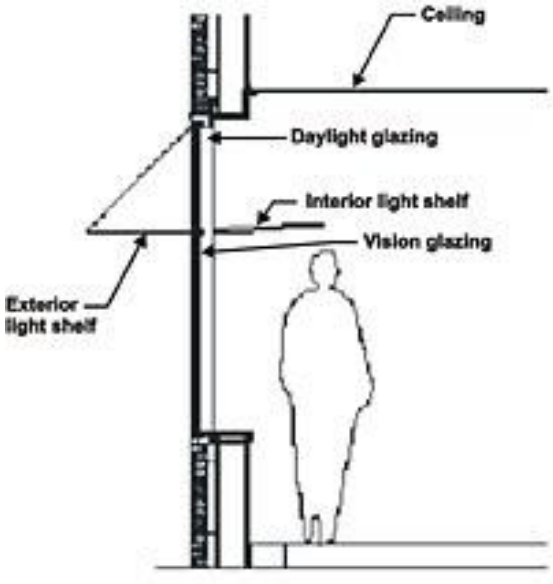


Figure 2.1 A typical sidelighting concept.
Source: (Green Building Technology, 2007)

Light coming from side apertures like windows can only penetrate so far into a building. This is the reason why shallow floor plans are usually recommended for daylighting multi-story buildings. A simple rule of thumb for most latitudes is that daylight penetrates into a room roughly 2.5 times the height of the top of the window as illustrated in Figure 2.2 (Autodesk Education Community, 2015).

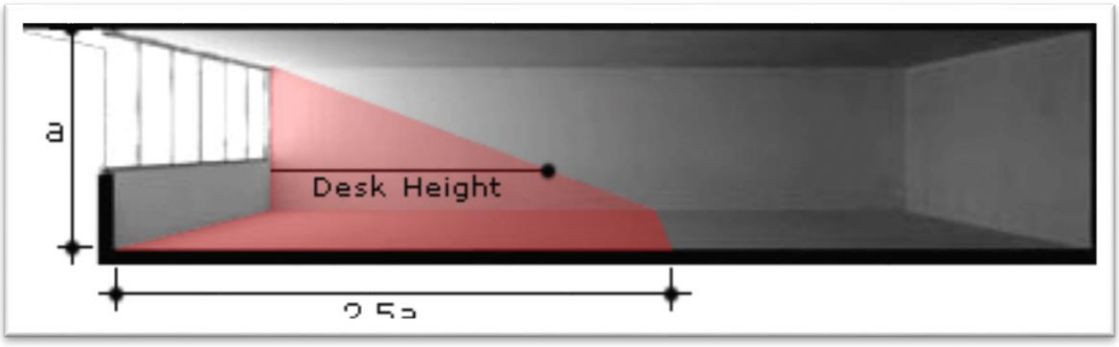


Figure 2.2 Showing Side Light from Window.

Source: (Autodesk Education Community, 2015)

2.4.2 Top Light

Toplighting strategies provide daylight through rooftop apertures. These strategies can provide uniform daylight distribution to the entire top floor area if the entire top floor uses rooftop apertures distributed across the roof area. Large single level floor areas and the top floor of multi-story buildings can benefit from toplighting (Green Building Technology, 2007). There are various types of toplighting as illustrated in Figure 2.3 and Figure 2.4 below.

Skylights are not the only kind of aperture to bring light in through roofs. Other "top lighting" strategies include clerestories, monitors, and saw-tooth or other scoop-shapes. This each has their own advantages and disadvantages in construction cost and how they bring the sun into the space at different times of day and year (Autodesk Education Community, 2015).

Top lights are usually much brighter than side lights per unit area, for the same glazing properties. A rough approximation for moderate latitudes is that a vertical monitor brings in twice as much light as a view window, an angled monitor brings in three or more times as much depending on the angle and a horizontal skylight brings in five times as much light as a view window.

Baffles are often used in top lighting to help direct the light usefully into the room, and splaying the edges of openings can help the light spread more broadly though the space.

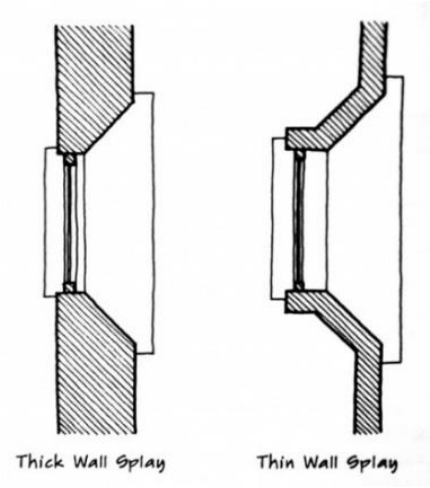


Figure 2.3 Two kinds of splayed opening.

Source by G.Z. Brown and Mark DeKay

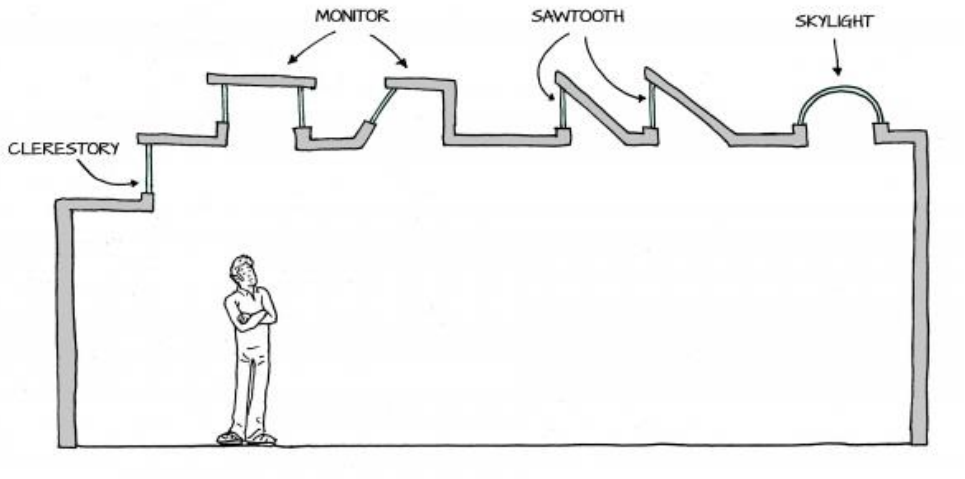


Figure 2.4 Showing Different kinds of top lighting.

Source: (Autodesk Education Community, 2015).

2.4.2.1 Roof Monitor

A roof monitor consists of a flat roof section raised above the adjacent roof, with vertical glazing on at all sides of the raised bay. This arrangement can provide daylight in all directions, but may result in higher heat gain.

2.4.2.2 Saw tooth roof

Saw tooth roofs employ a series of either vertical or sloped glasses, which are separated by sloped roof elements. Saw tooth roof can be used to uniformly illuminate a large floor area while minimizing impacts on building's overall height. The orientation of the glazing can be selected so as to maximize daylight level while reducing direct solar radiation and heat gain.

2.4.2.3 Skylight

Skylights can have many forms including dome, pitched and flat panels that are placed in the plane of the building's roof. Horizontal skylights can be an energy problem because they receive solar heat directly at the midday. Integration of louver systems can control solar heat gain as well as glare in skylight.

2.4.2.4 Clerestories

A clerestory is a high wall with a band of narrow windows along the very top. The clerestory wall usually rises above adjoining roofs (Craven, 2016).

2.5 Planning for Daylighting

Daylighting strategies and architectural design strategies are inseparable. Daylight not only replaces artificial lighting, reducing lighting energy use, but also influences both heating and cooling loads. Planning for daylight therefore involves integrating the perspectives and requirements of various specialities and professionals. Daylighting design starts with the selection of a building site and continues as long as the building is occupied (Ruck, et al., 2000). Daylighting planning has different objectives at each stage of building design:

i. *Conceptual Design*: As the building scheme is being created, daylighting design influences and/or is influenced by basic decisions about the building’s shape,

proportions, and apertures, as well as about the integration and the role of building systems.

ii. *Design Phase*: As the building design evolves, daylighting strategies must be developed for different parts of the building. The design of facades and interior finishing, and the selection and integration of systems and services (including artificial lighting), are all related to the building's daylighting plan.

iii. *Final/Construction Planning*: The selection of materials and products is affected by the building's daylighting strategy; final details of the daylighting scheme must be worked out when construction plans are created.

iv. *Commissioning and Post-Occupancy*: Once the building is constructed, lighting controls must be calibrated and on-going operation and maintenance of the system begins.

2.6 Design Principle of Daylight

Daylight is a vital natural resource that will significantly improve the environment within any building. Roof lights provide three times more light than the same area of vertical glazing. They can also provide a much more even distribution of light, particularly in larger structures. Where vertical glazing exists, the effective area for natural lighting will only be within 6m of the wall containing the window. These facts are well understood by most people involved in building design. However, the huge potential of roof lights to provide exactly the amount, type and distribution of natural light required to meet any given specification is not always appreciated. Roof lights can help to provide natural light with qualities appropriate to the use of the building (National Association of Rooflight Manufacturers , 2003).

2.6.1 Principles of Daylighting Design

i. Provide a daylighting scheme that works under the range of sky cases expected at that location.

ii. Brighten interior surfaces

iii. Organize electric lighting to complement daylight

iv. Provide daylight controls on electric lighting.

2.7 Daylighting Process of Designing Buildings

Daylighting is the complete process of designing buildings to utilize natural light to its fullest. It includes all of the activities given below:

i. Siting the building- Orient the building on an east-west axis for optimum solar exposure (Ruya, 2015) and to maximize daylighting, this can be done by maximizing south glazing and minimizing east and west glazing (Koh & Meyer, 2015).

ii. Massing the building- present the optimum building surfaces toward the sun (Ruya, 2015).

iii. Choose fenestrations to permit the proper amount of light into the building, taking into account seasons, weather, and daily solar cycles (Ruya, 2015).

iv. Brighten interior surfaces (Environmental Building News, 1999) this will aid in the amount and distribution of daylight (Bristolite Daylighting Systems, 2016)

v. Shade the façade and fenestration from unwanted solar radiation (Ruya, 2015) using external features (Bristolite Daylighting Systems, 2016).

vi. Add appropriate operable shading devices, such as blinds and curtains, to permit occupant control over daylight admission (Ruya, 2015; Bristolite Daylighting Systems, 2016).

v. Organize electric lighting to complement daylight and provide daylight controls on electric lighting (Environmental Building News, 1999) that permit full realization of the energy savings benefit of daylighting (Ruya, 2015).

2.7.1 Design Considerations

The components of a daylighting system are designed to bring natural light into a building in such a way that electric lights can be dimmed or turned off for a portion of the day, while preventing occupant discomfort or other building loads from increasing (Ander, 2014). For example, direct sun in the eye of a building occupant can cause disability glare, which interferes with the occupant's ability to see and perform work and should be avoided (Ander, 2014).

2.7.1.1 optimized building footprint

It is a foundational element of a daylit building design. Maximizing the amount of south- and north-facing facade area and minimizing east and especially west exposure allows for the easiest controllable daylight fenestration (Ander, 2014).

2.7.1.2 daylight penetration

This is limited by the siting and facade design; the circuiting of the electric light fixtures is critical in gauging success of a daylighting strategy. Ideally, the light fixtures should be circuited in groups, or zones, that relate to the predominant daylight distribution in the space. In general, the first 10 to 15 feet from the building perimeter receives adequate daylight illumination to allow for light dimming or switching. By zoning the lighting accordingly, there's a greater chance of ensuring maximum dimming of the lights (Ander, 2014).

2.7.2 Design Recommendations

During the design process, the following design strategies should be understood and explored:

i. Increase perimeter daylight zones—extend the perimeter footprint to maximize the usable daylighting area.

ii. Allow daylight penetration high in a space. Windows located high in a wall or in roof monitors and clerestories will result in deeper light penetration and reduce the likelihood of excessive brightness.

iii. Reflect daylight within a space to increase room brightness. A light shelf, if properly designed, has the potential to increase room brightness and decrease window brightness.

iv. Slope ceilings to direct more light into a space. Sloping the ceiling away from the fenestration area will help increase the surface brightness of the ceiling further into a space.

v. Avoid direct beam daylight on critical visual tasks. Poor visibility and discomfort will result if excessive brightness differences occur in the vicinity of critical visual tasks.

vi. Filter daylight. The harshness of direct light can be filtered with vegetation, curtains, louvers, or the like, and will help distribute light.

vii. Understand that different building orientations will benefit from different daylighting strategies; for example, light shelves—which are effective on south facades—are often ineffective on east or west elevations of buildings.

2.8 Massing & Orientation for Daylighting

"Massing" is deciding on the overall shape and size of the building. Will the building be tall or short? Long and thin? Will it have significant cut-outs, or be more solid?

Successful massing uses the general shape and size of the building to minimize energy loads as much as possible and to maximize free energy from the sun and wind (Autodesk Education Community, 2015). Orientation is simply what compass direction the building faces. Does it face directly south? 80° east-northeast? Along with massing, orientation can be the most important step in providing a building with passive thermal and visual comfort. Orientation should be decided together with massing early in the design process, as neither can be truly optimized without the other (Autodesk Education Community, 2015). Massing and orientation are important design factors to consider for visual comfort, or daylighting. Many of the strategies are similar to those for passive heating, but also different factors to consider such as glare. It should be optimized early-on, along with massing, and can be the most important step for passive design (University College Dublin, Energy Research Group).

2.9 Component of Daylight

A daylighting system consists of systems, technologies, and architecture. While not all of these components are required for every daylighting system or design, one or more of the following are typically present:

i. Daylight-optimized building footprint

If possible, the building footprint should be optimized for daylighting. This is only possible for new construction projects and does not apply to retrofits. If the project allows, consider a building footprint that maximizes south and north exposures, and minimizes east and west exposures. A floor depth of no more than 60 ft., 0 in. from south to north has been shown to be viable for daylighting. A maximum facade facing due south is the optimal orientation. Deviation from due south should not exceed 15° in either direction for best solar access and ease of control (Ander, 2014).

ii. Climate-responsive window-to-wall area ratio

With the building sited properly, the next consideration is to develop a climate-responsive window-to-wall area ratio. As even high-performance glazing do not have insulation ratings close to those of wall constructions, the window area needs to be a careful balance between admission of daylight and thermal issues such as wintertime heat loss and summertime heat gain (Ander, 2014).

iii. High-performance glazing

A high-performance glazing system will generally admit more light and less heat than a typical window, allowing for daylighting without negatively impacting the building cooling load in the summer. This is typically achieved through spectrally-selective films. These glazings are typically configured as a double pane insulated glazing unit, with two 6 mm thick panes of glass that are separated by a 12 mm air gap (Ander, 2014).

iv. Daylighting-optimized fenestration design

Daylighting-optimized fenestration design will increase system performance. The window has two essential functions in a daylit building: (1) daylight delivery or admittance, and (2) provision of view to the occupants. The former dictates a glazing with a very high visible light transmittance, the latter merely needs to be clear. As a general rule, the higher the window head height, the deeper into the space the daylight can penetrate. Therefore, good daylighting fenestration practice dictates that the window should ideally be composed of two discrete components: a daylight window and a view window. As in Figure 2.6Figure 2.5 and Figure 2.6, the daylight window should start at 2200mm. above the finished floor at a minimum (Ander, 2014).

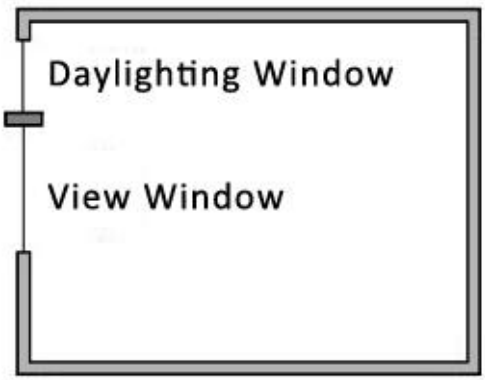


Figure 2.5 Showing Daylighting window vs. view window.
Source: (Autodesk Education Community, 2015)

v. Skylights (passive or active)

Many daylighting designs will employ skylights for toplighting, or admitting daylight from above. Active skylights, by contrast, have a mirror system within the skylight that tracks the sun and are designed to increase the performance of the skylight by channelling the sunlight down into the skylight well (Ander, 2014).

vi. Tubular daylight devices

Tubular daylight devices are another type of toplighting device. These devices employ a highly reflective film on the interior of a tube to channel light from a lens at the roof, to a lens at the ceiling plane. Tubular daylight devices tend to be much smaller than a typical skylight, yet still deliver sufficient daylight for the purpose of dimming the electric lighting (Ander, 2014).

vii. Daylight redirection devices

Redirecting light is the use of building elements to bounce sunlight into more desirable locations in the building. Light shelves and baffles are two strategies that can distribute light more evenly (Autodesk Education Community, 2015).

- Light Shelves

Light shelves are devices that both shade view windows from glare and bounce light upward to improve light penetration and distribution, this is illustrated in Figure 2.6. A light shelf is generally a horizontal element positioned above eye level that divides a window into a view area on the bottom and a daylighting area on the top. It can be external, internal, or combined and can either be integral to the building, or mounted upon the building (Autodesk Education Community, 2015).

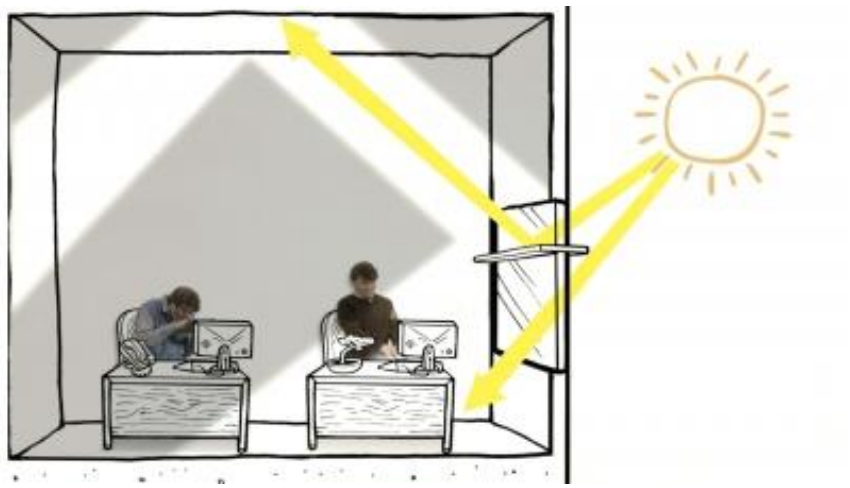


Figure 2.6 A light shelf avoiding glare and pulling daylight deeper into the room.
Source: (Autodesk Education Community, 2015)

Light shelves are most effective on walls facing the sun's path; on pole-facing walls they simply act as shades. Light shelves on east and west orientations may not bounce light that much further into the spaces, but are an effective means of reducing direct heat gain and glare.

Exterior light shelves reduce daylight near the window but improves the light uniformity. The recommended depth of an external light shelf is roughly equal to its height above the work plane.

To reduce cooling loads and solar gain, an exterior light shelf is the best compromise between requirements for shading and distribution of daylight. Because they are only shades, they do not change the ratio of incoming light to heat, but better distribution of light can reduce the amount needed in a space, which helps with cooling (Autodesk Education Community, 2015).

- Baffles

When light shelves are oriented vertically, they are known as baffles (Figure 2.7). They are used with skylights or roof monitors to better distribute daylight and avoid glare. Designing the optimal height and placement of baffles is done the same way as designing light shelves (Autodesk Education Community, 2015).

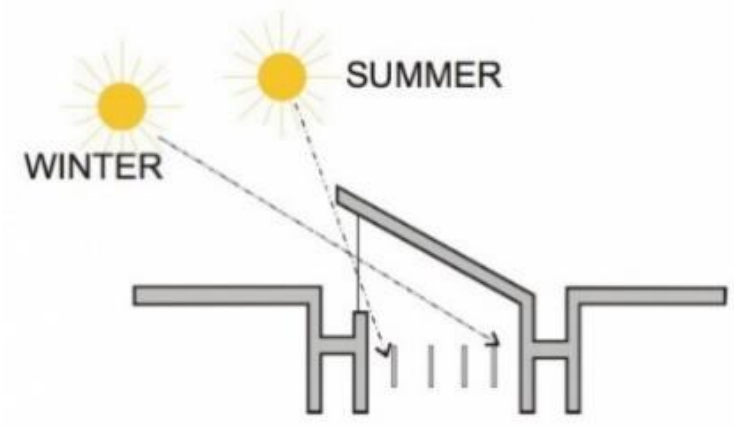


Figure 2.7 Baffles in a roof monitor avoid direct glare.
Source: (Autodesk Education Community, 2015)

- Solar shading devices

As mentioned previously, the windows must be carefully designed to control the solar gains and potential glare stemming from a daylighting design. To this end, solar shading devices are often employed—particularly on the view windows—to minimize the amount

of direct sun that enters the space. These are typically called overhangs because they are usually hanged over windows, as illustrated in Figure 2.8.

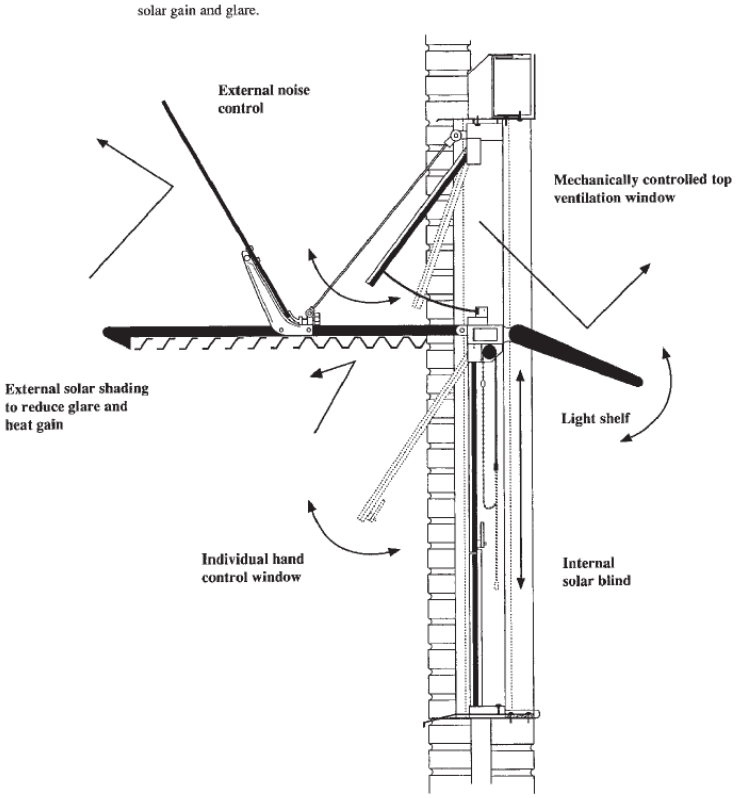


Figure 2.8 Solar Shading in Window.

Source: (Phillips, 2004)

- Daylight-responsive electric lighting controls

Daylight-responsive electric lighting controls are absolutely essential to any daylighting system. No daylighting design will save any energy unless the electric lights are dimmed or turned off when there is sufficient illumination from daylight. Indeed, if daylighting features such as windows and skylights are not paired with daylighting functionality such as daylight-responsive dimming controls, then the daylighting-enhanced building will more than likely use more energy, not less, than a comparable building without any daylighting features. Daylight-responsive lighting controls consist of continuous

dimming- or stepped-ballasts in the light fixtures, and one or more photocells to sense the available light and dim or turn off the electric lighting in response (Ander, 2014).

viii. Daylight-optimized interior design.

An often overlooked element in a successful daylighting design is the interior design. A daylight-optimized interior design considers furniture design, placement, and room surface finishes with respect to daylight performance as shown in Figure 2.9. For example, office cubicle partition heights will be limited, particularly those running parallel to the south facade, enclosed offices will be kept to a minimum, and walls and ceilings will be as highly reflective as possible, to help "bounce" and distribute the redirected daylight more fully. (Ander, 2014).

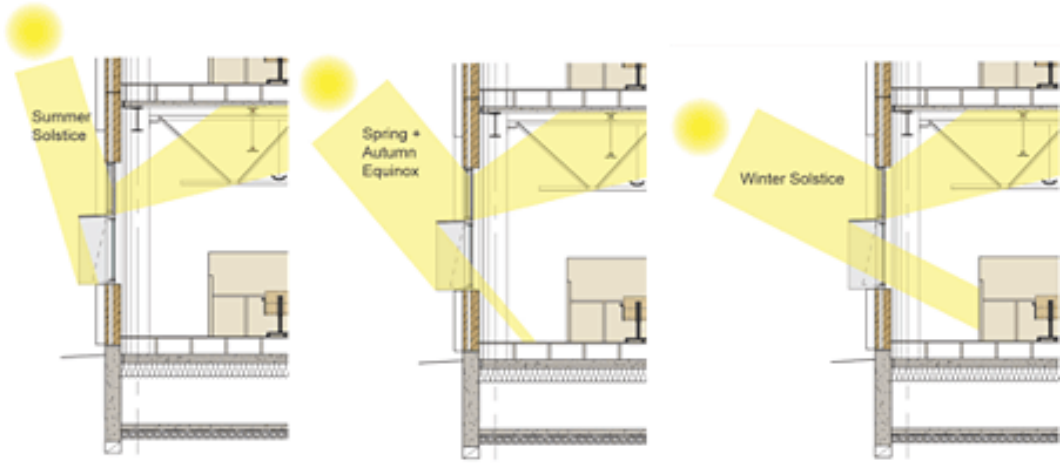


Figure 2.9 Seasonal performance of shading, redirection devices.

Source: (Ander, 2014)

2.10 Energy Efficient Lighting systems

2.10.1 Light Pipes

Light pipes in addition to the above strategies, daylight can be brought into the indoors by using light pipes. Light pipe is device used to capture daylight and reflect it into the

building. It consists of an outside collector (usually on the roof), a pipe with high reflectance on the internal surface and a diffuser, this is better illustrated in Figure 2.10. By using light pipes, daylight can not only be reached the perimeter zones but also the deep regions of the rooms.

Light pipes are a device which allows the increasing use of daylight in buildings. They use the principle of high efficiency reflection to introduce light into interior of a building. They are simply empty pipes which can be straight or angled assemblies. The internal surface of the light pipe is coated with highly reflective material such as anodized aluminium or coated plastic films to enhance the efficiency of light reflection. The figure below provides the typical structure of a light pipe (Energy Efficient Technologies, 2015).

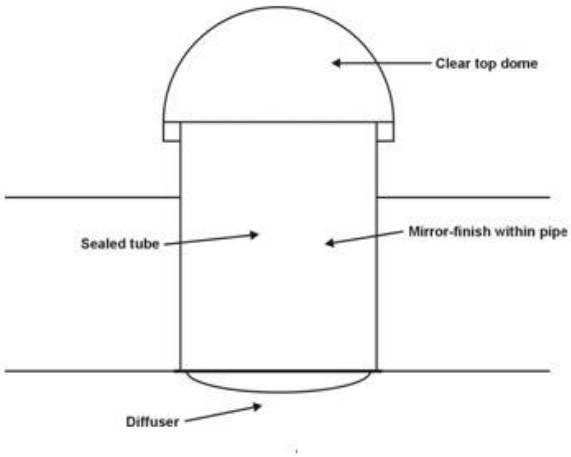


Figure 2.10 Schematic of a typical light pipe.
Source: (Energy Efficient Technologies, 2015)

2.10.2 Light Transport Systems

Light transport system includes the following:

i. Mirrored Light Pipes

In Mirrored Light Pipes as in Figure 2.11, the light is transmitted inside the pipe from the source to the output aperture by a number of multiple specular reflections at the inner wall surface of the pipe (Aizenberg, 2003).

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

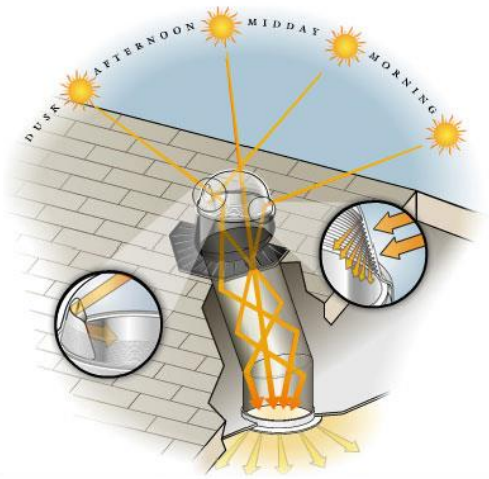


Figure 2.11 Mirrored Light Pipe
Source: (Aizenberg, 2003)

ii. Horizontal Light Pipes (HLP)

The horizontal light pipe is a device that brings daylight into the inner parts of buildings without the use of any electrical or other sources of energy. The extraction and emission of daylight is transmitted horizontally and vertically using internal mirrored surfaced

within a box-tube structure (hence the term “pipe”) coupled with laser-cut panels at the outer edge of the pipe as collectors.

The horizontal light pipe comprises of a box (i.e. Like a duct, that has highly reflective interior mirrored surfaces and an arrangement of laser cut light deflecting panels (LCP) at the outside edge as sub-light collectors and extractors that redirect light along the 69 pipe to the interior spaces as required and with light emitters to spread the light uniformly around the space, this is shown in Figure 2.12.

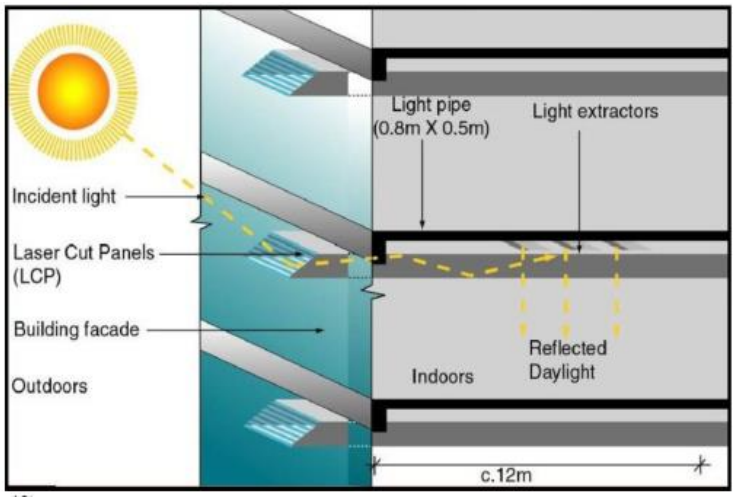


Figure 2.12 Horizontal Light Pipe Illustration

Source: (Aizenberg, 2003)

i. Vertical Light Pipes

The design of the vertical light pipes follows the same principles as the design of the horizontal light pipes. The main difference is in VLP, the light is transferred vertically from the roof as shown in Figure 2.13.

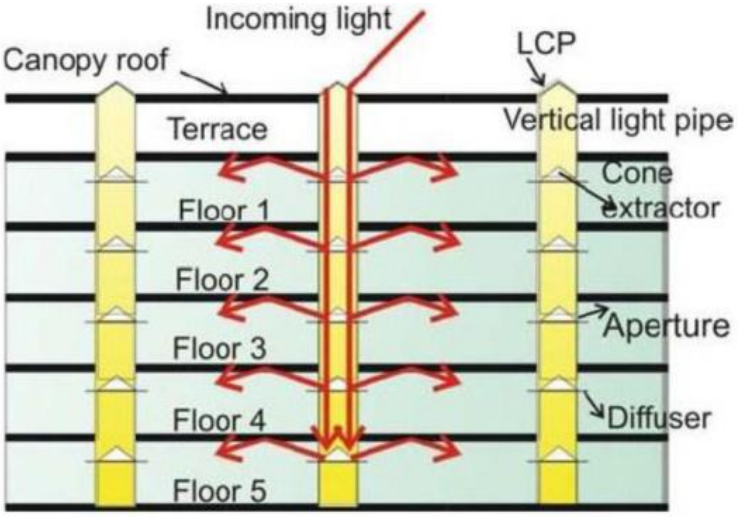


Figure 2.13 Vertical Light Pipe illustration

Source: (Callow, 2003)

How much energy can be saved:

The amount of energy saving by the use of light pipes greatly depends on the number of light pipe used. Usually straight light pipes perform better than angled ones as light energy decreases with increased reflections. The light pipe that illustrates in the above figure is usually integrated on the roof of a building. There is another type of light pipe that can be integrated in a building façade to capture daylight and distribute it into the deep zone of a building as shown in Figure 2.14 (Energy Efficient Technologies, 2015).

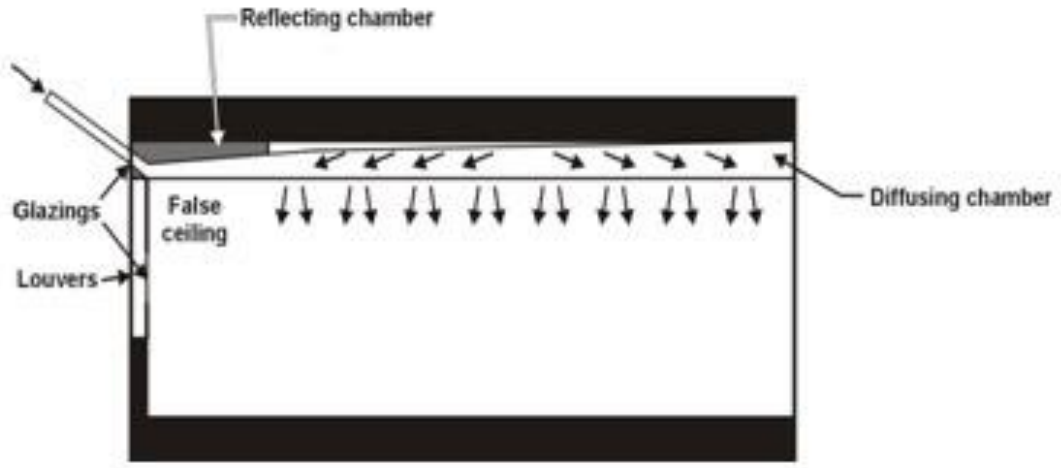


Figure 2.14 Light pipe integrated in the building façade.

Source: (Energy Efficient Technologies, 2015)

2.10.3 Benefits of Tubular Daylighting Devices

In 2014, the world consumed approximately 412 billion kWh of energy just for lighting. This value has steadily increased from the late nineties and is expected to increase to 4250 TWh by 2030. Using natural light instead of artificial light not only reduces lighting costs for the residential, commercial, and industrial sectors but also has additional financial, physiological, and psychological benefits. There are several different ways to bring natural light into a building. Skylights are one option which comes in a range of types including traditional, prismatic, tubular, and solar-tracking skylight. Below are the highlights of some benefits of tubular skylights as well as the disadvantages they present (Brain, 2015).

2.10.3.1 Light Tubes Are Energy-Efficient

Tubular skylights can reduce this energy consumption significantly. With tubular daylighting devices, you can eliminate dependence on artificial lighting, which uses 11% of energy in residential buildings, and reduce dependence on HVAC, which

contributes 41% of the cost of energy in residential buildings, resulting in savings between 50-60% of those costs (Brain, 2015).

2.10.3.2 Light Tubes Produce More Light than Traditional Skylights

The design of traditional skylights produces less light than modern tubular lighting devices of the same size. Tubular skylights maximize the light transmitted to the interiors by using special transparent domes. During dawn and dusk, when the sun's angle is low, the dome of tubular daylighting devices capture sunlight more efficiently than traditional skylights and allows light to pass through to the interior of a building (Brain, 2015).

2.10.3.3 Tubular Skylights Are More Thermally Insulated

One of the biggest concerns with traditional skylights is the lack of thermal insulation. Traditional skylights let more than 70% of external heat into the building. In contrast, tubular skylights are far more energy efficient because of their small size and insulated shaft that prevents heat loss during winter and heat gain during the summer. Apart from meeting lighting requirements for your space, they reduce the strain on HVAC systems which is common with traditional skylights (Brain, 2015).

2.10.3.4 Tubular Skylights Carry Light to Lower Floors

Light tubes are applicable in situations where other skylights would not be able to function, such as when the room that needs illuminated is not directly adjacent to the roof. Their light pipes can be flexible and or can bend around obstructions in the building. They are also useful under roofs with drop ceilings and attics. Light pipes can be 4 to 33m in length and are designed to pass through entire floors so lower floors can receive natural light as well as the top floor (Brain, 2015).

2.10.3.5 Tubular Skylights Are Affordable

Tubular daylighting devices offer affordability due to their compact size and modular design. The purchase and installation required for a tubular skylight is far less than that of traditional skylights. (Brain, 2015).

2.11 Daylight and Climate

Daylight availability depends on the availability of natural light which varies for different locations due to different sun paths and sky conditions through the course of the day, the season and the year. Daylight levels vary significantly on horizontal and vertical surfaces by time of day and season, directly related to the local sun paths and sky conditions (VELUX Group, 2014). Daylighting is also affected by climate and it's important to identify various seasonal variations, prevailing climate conditions, particularly ambient temperatures, and sunshine probability. Knowing climate and the daylight availability in a proposed building site is an essential first step in designing for daylight (International Energy Agency, 2010)..

2.11.1 Nigeria Climate Classification

As shown in Figure 2.15 Nigeria is segmented into three classes of climate based on the Koppen Trewartha and Horn climate classification which classifies regions based on its location on earth. Nigeria has a topical climate and is situated on the west coast of Africa, lies on latitudes 4° north of the Equator and latitudes 3° and 14° on the east of the Greenwich Meridian (Nigerian National Petroleum Corporation, 2016).

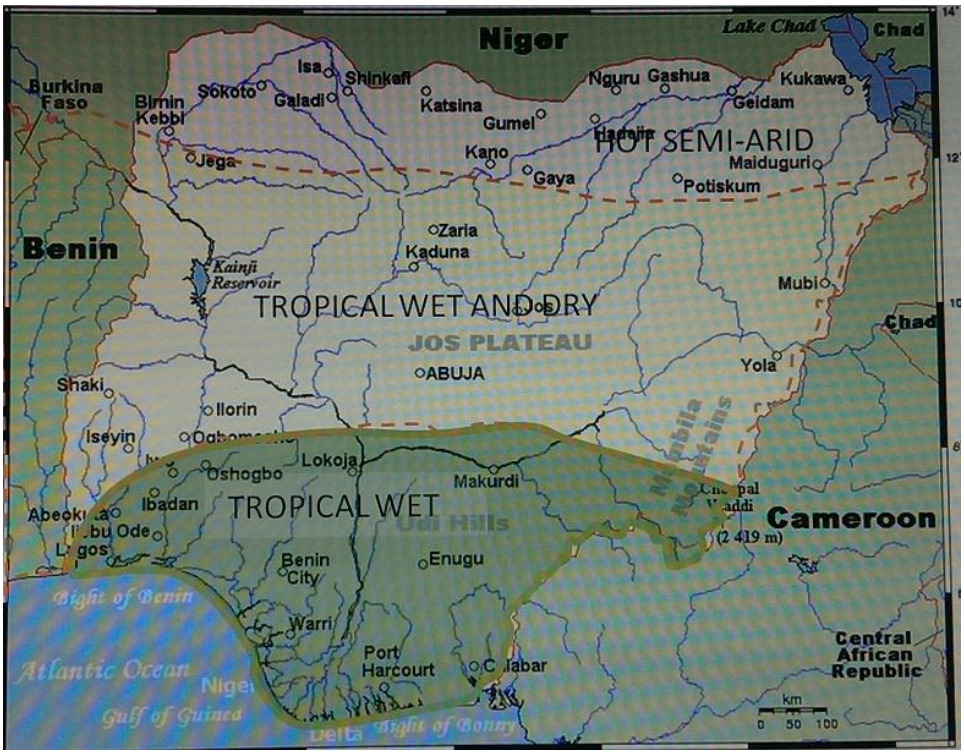


Figure 2.15 Map of Nigeria showing the climate classification.

Source: (Salisu, 2015)

2.11.2 The Hot-Semiarid Climate

Semi-arid climates have little rainfall and are usually located in-between the tropical wet-and – dry climates and the desert climates. The predominant feature of this climate is that it is dry with hot weather for significant periods of the year. It has the characteristics of dryness (both in rainfall and relative humidity). The hot dry season comes with clear skies and hot winds, while at the end of the year, a cold and dusty harmattan for about three months becomes the dominant feature. The amount of rainfall in this region varies between 250 to 750mm per year and occurs for a period of three or four months starting from May or June and is normally brief and intense. However, despite when the rainfall occurs, the sky is generally clear and the annual precipitation rate is less than the sum of the potential rate of evaporation of groundwater and the water lost by transpiration of plants (Heerwagen, 2004). The major ecology of this climate type is the Sahel savannah made up of shrubs and grassland with occasional trees (Salisu, 2015).

2.12 Walk Through Shopping Mall

Mall can refer to a shopping mall**,** which is a place where a collection of retail stores all adjoin a pedestrian area, or an exclusively pedestrian street, that allows shoppers to walk without interference from vehicle traffic (New World Encyclopedia, 2015). A shopping mall, shopping centre, shopping arcade, shopping precinct, or simply mall is one or more buildings forming a complex of shops representing merchandisers, with interconnecting walkways enabling visitors to walk from unit to unit, along with a parking area – a modern, indoor version of the traditional marketplaces (World Heritage Encyclopedia, 2015). A shopping mall combined the worlds of retailing and entertainment, providing the roof under which all the tenants are assembled (EHI Retail Institute, 2011)

2.13 Types of Shopping Mall

Shopping malls have been classified by the International council of shopping centres. These include community centre, neighbourhood centre, fashion centre, specialty centre, outlet centre, superregional centre, and a theme or festival centre (Tandon, 2015).

The International council of Shopping Centres (ICSC) has defined eight principal shopping centre types as shown below.

i. Neighbourhood Centre: This centre is designed to provide convenience shopping for the day-to-day needs of consumers in the immediate neighbourhood. A neighbourhood centre is typically a straight-line strip with no enclosed walkway or mall area.
ii. Regional Centre: This centre sells a full variety of general merchandise, mostly apparel. Its main attractions are its anchors; they are typically enclosed malls.

iii. Community Centre: A community centre offers a wider variety of apparel and other goods than a neighbourhood centre. Configuration is a straight line, L- or U-shaped.

iv. Superregional Centre: This centre is similar to the regional centre, but it is larger with more anchors and carries a deeper selection of merchandise. Superregional centres draw from a larger population base. Typical configuration is enclosed with multilevel.

v. Fashion/Specialty Centre: This centre is composed of upscale apparel shops, boutiques and craft shops carrying unique, high-quality fashion and other merchandise. They may not be anchored, but restaurants or entertainments provide the draw of anchors. A sophisticated design emphasizes the rich decor and landscaping.

vi. Theme/Festival Centre: The centres appeal to tourists; restaurants and entertainment facilities may anchor. Anticipate seeing them in urban areas, maybe adapted from historic buildings and part of mixed-use projects.

vii. Power Centre: Several large anchors, including discount department stores, off-price stores, warehouse clubs or "category killers" (stores that offer huge selection in particular merchandise categories at low prices) dominate. The centre consists of several freestanding anchors and only a few, small specialty tenants.

viii. Outlet Centre: Outlet centres usually consist of manufacturers' outlet stores selling their own brands at a discount. They are found in rural or tourist locations. Typical outlet centre designs include enclosed malls, a "village" cluster or a strip configuration.

In the above context The Regional Centre and Superregional Centre which is termed as the vertical because it is also design in a multilevel structure. Agarwal (2015) in his article

has categorised the types of mall into six which are regional mall, super-regional mall, vertical mall, strip mall, dead mall and outlet mall.

i. Vertical Malls:

The concept of vertical mall came in existence because of the complexities of densely populated cities/nations where land price was so high that it was becoming difficult for existing retailers to think of any kind of horizontal expansion to accommodate increasing crowd to their retail outlets. Therefore, retail stores were configured over a number of stories accessible by elevators or/and escalators connecting the different parts and levels of the mall. The main philosophy behind such creations was to dedicate each story or a part of the mall to particular theme like beauty and fashion, apparel, furniture, grocery and kitchen ware and so on (Agarwal, 2015).

The Water Tower Place skyscraper was ultimately in 1975 appeared as the very first vertical mall in Chicago, Illinois. It contains a hotel, luxury condominiums, and office space and sits atop a block-long base containing an eight-level atrium-style retail mall that fronts on the Magnificent Mile. The mall which is still operational has almost 100 shops spread in eight different levels. Besides this, mall contains several restaurants, eateries, and a live theatre, arranged around a chrome-and-glass atrium with glass elevators (Agarwal, 2015).

Times Square is considered the first of its kind, the first "vertical mall" in Hong Kong. Due to the high land price in Hong Kong, and the higher yield on retail property, Times Square departs from the common western model of the flat shopping mall. The space allocated to retail is configured over 9 stories. The mall and lifts to the office tower are accessible by long escalators linking the ground floor podium and the first level of the mall.

The most obvious reasons for establishing vertical malls are: High land prices and densely populated cities.

ii. Strip Malls:

A strip mall (also called a shopping plaza, shopping centre, or mini-mall) is an open air shopping mall where the stores are arranged in a row, with a sidewalk in front. Strip malls are typically developed as a unit and have large parking lots in front.

iii. Dead Malls:

Dead malls are those malls which initially were operational like any other malls but due to some reasons now they have become unpopular and have very less or no footfall.

The main reasons for a mall to be declared as dead is the attraction of latest malls, where modem facilities such as automated parking, comfortable escalators, control temperature, capsules lifts. Provisions for entertainment, state of the art recreation conveniences, and multi-storeyed malls dedicated to different sections such as electronics, readymade garments, grocery, toys, jewellery & fashion are built, barring customers to visit early built malls.

2.14 Daylight Standard in a Shopping Mall

Table 2.1 below shows the minimum standard of daylighting needed within a shopping mall.

Table 2.1 Daylight Standard in a Mall.

Source: (Austrian Standards Institute, 2013; Richman, 2010)

Building Type	Space Type	Maintained Average Illuminance at working level (lux)	Measurement (working) Height (1 meter = 3.3 feet)
Circulation area within the mall	Circulation areas and corridors	100	0.0m
	Stairs, escalators, moving walkways	100	0.0m
	Elevators, lifts	100	0.0m
	Loading ramps/bays	150	0.0m
	Restrooms	300	0.0m
	Cloakrooms, washrooms, bathrooms, toilets	300	0.8m
General areas	Entrance halls	100	0.0m
	Cloakrooms	200	0.0m
	Lounges	200	0.0m
	Ticket offices	300	0.8m
Retail premises	Sales areas	300	0.8m
	Till areas	500	0.8m
	Wrapper tables	500	0.8m
Restaurants	Kitchens	200	0.8m
	Restaurant, dining room, function room		
	Self-service restaurants	300	0.8m
	Buffets	500	0.8m
Theatres, concert halls, cinemas	Practice rooms	300	0.0m
	Dressing rooms	300	0.8m
	Seating areas – maintenance, +cleaning	200	0.0m
	Stage areas – construction	300	0.0m
Public car parks (indoor)	In/out ramps (during the day)	300	0.0m
	Ticket offices	300	0.8m
Store rooms, cold stores	Store and stockrooms	100	0.0m
	Dispatch packing handling areas	300	0.0m

2.15 Review of Previous Works on Daylighting and Shopping Mall

Daylighting as a concept has been in use for centuries, many studies were done in context of application of its strategies or techniques, harnessing it, and using it as an energy efficient agent in so many project typologies such as shopping mall, civic centre, solar energy centre, faculty building, national art centre beauty and fashion centre and so on.

Ikuh (2011) in his work demonstrated that energy reduction can be achieved within the frame work set out by the regulations, relevant standards, and health and safety guidelines using innovative daylight design strategies that can be employed within energy centres only. He collated energy benchmark data for a range of energy centres, considering energy conscious which forms a method of benchmarking for future buildings of similar size and function.

In another study, daylighting techniques were used to improve energy efficiency in the design of faculty buildings. In the study, the building was modelled using two simulation tools; Ecotect analysis and energy plus were several glazing and shading strategies were substituted in order to assess the impact varied daylighting design by studying the relationship of the solar exposure as a results of the daylighting techniques used and the resulting daylight distribution in the space and resultant glare. The result shows a significant reduction in energy consumption (Ladan, 2011).

Another study by Adesina (2011) adopted daylight strategies such as atria, courtyards, skylights, roof monitors and innovative daylighting strategies which were studied and some were applied in the design of civic centre. However, the study did not evaluate or test the efficiency of those strategies using any sort of tools. Therefore, it can only be used as a basis or guide but not as a proof of energy consumption reduction.

A research done by Olatunji (2014), stated that site orientation and the building morphology are the first basic issues that affect the effective use of daylight in any interior space. Other components such as material use, shading device scheme and sizes of openings are basically used to control the amount and redirect daylight. The purpose of the study was to use as much natural light as possible in designing a beauty and fashion centre to accomplish low energy consumption, low costs, and require less heating and cooling from the building.

Adaji (2015) in his study focuses on the provision of adequate daylight in buildings to reduce over dependence on electrical energy for the artificial lighting. Three libraries were studied using Building information modelling (BIM) - Autodesk Revit 2014, Autodesk Ecotect 2011 to design for daylight in library and to analyse Daylight Illuminance level, Daylight Factor (DF) and daylight autonomy. The major factor considered in the study is the level of illumination on the work plane in the interior of the building, the area of the windows and the area floor of the spaces. The Strategies for admitting daylight were investigated to discover how building design can intelligently adopt the most energy efficient Daylighting for the library. Some recommendations from the research include:

i. Remodelling sections of the building to allow for natural lighting
ii. Installation of roller shade blinds which can be easily controlled for optimum light penetration.
iii. Design for buildings should go beyond provision of spaces for activity, but must adequately consider energy efficiency and the science of usability as part of the whole process in a buildings existence.
iv. Use of advanced building materials (smart materials) should be encouraged to achieve needed reading environment.

Idris (2015) in her research looked at energy as a global issue via energy efficiency adopting passive solutions in the design of shopping mall. Daylighting use was natural due to the topography and as such use of photovoltaic panels, skylights, double paned glazing on windows and a lots of windows to aid natural lighting and also ventilation aided by pattern of winds circulations afforded by the placement of the openings strategically.

2.16 Conclusion

Many studies have been conducted on daylighting, application of its strategies on different type and form of structures but none has been done on vertical shopping especially the use of light pipe as the best way light reaches the deeper inner part of such typology.

A clear understanding of daylighting strategies is very essential for a vertical shopping mall to reduce excess cost of energy. A careful study of the literature reveals that the above is only possible using experimental research design as it is the best to test the efficiency of light pipes in buildings.

3.0 RESEARCH METHODOLOGY

3.1 Introduction

This aspect of research describes the rationale for the application of specific procedures or techniques used to identify, select, and analyse information applied to understanding the research problem, thereby, allowing the reader to critically evaluate the study's overall validity and reliability (Kallet & Richard, 2004). It provides information on the methodology selected and adopted to collect the relevant data that helped achieve the objectives of the research. This chapter covers the research method adopted, the study population, the sampling method adopted, research instruments used, simulation method and how the data gotten was analysed.

3.2 Research Methods

This study adopted the illustrative case study research design in conjunction with experimental research design. The experimental design is employed due to its reliability to determine causality, as established by Groat and Wang (2002) once the experiment is well designed, the effects of likely lying in wait for variables could be measured and actively change to observe the response. The case studies were used to identify the daylighting strategies used, types of building materials, nature of shading devices used and building orientation. The simulation was used to test the efficiency of using the vertical light pipes in vertical shopping malls and to test how effective the technology is.

3.3 Population

According to Polit & Hungler (1999), the population of a study comprises the totality of all subjects that have a set of specifications and characteristics that are of interest to the researcher and to whom the research results can be generalised. Vertical shopping malls are new trends, which have not yet been built anywhere in Nigeria, this makes establishing the population impossible as there are limitted resource. In view of this, the

population of this study comprise of four international vertical shopping malls that were accessed online. And two horizontal malls as the local case study.

3.4 Sampling

Sampling involves a subset of the research population selected to represent the research population. The limitation of establishing the population, the international case study sample was selected from temperate regions or regions with high temperature have nearly similar climatic conditions with the research region.

In this study however, a non-probability convenience sampling was used in selecting vertical shopping malls for the study. The main criteria used on the selection of the case study was the number of floors of the shopping mall, which is the main determinant of the vertical mall and the climatic zone of the shopping mall location as climate determine the daylighting strategy to be used. In addition, two local case study were conducted to understand some of the features of design criteria and requirements in relation to the climatic condition of study area.

3.5 Research Instruments

Two instruments were used for data acquisition. These were literature review, models and simulation (using Ecotect).

The literature review was chosen because the case studies chosen were reviewed from the literature available on it and a local case study was conducted from field survey.

The best method of analysing daylighting due to its dynamic nature and the rigour of the calculations is the simulation.

3.6 Pilot Study (reliability and validity test).

A pilot study was carried out to validate the research instrument, test the reliability of the results and to test the capability of the researcher to handle the tools. These results will be compared and assessed using statistical tests to ensure the reliability of the results.

The measurements for the validation study were carried out in two phases (test and retest). These are:

i. Assessment of daylight in a shop following the two IEA manuals using a calibrated illuminance metre (Konika Minolta T-10A illuminance metre).
ii. Simulation of daylight in shop of same properties as above also following the manuals and using the same values for the simulations.

The test and retest correlation coefficient for the case was: 0.974.

3.6.1 Assessment of Daylight in Existing space at ABM for Pilot Study

A shop that is relevant to the study and located in Kano (tropical wet and dry climatic zone) was chosen. The shop is from the case study conducted at Ado Bayero Mall Kano, it has a size of 9x18 metres.

3.7 Simulation Method

Monitoring Procedures for Assessment of Daylighting Performance of Buildings (2001), proposed procedures for assessing daylighting. However, these procedures have been optimised for the daylight-factor and using the overcast and clear skies. Salisu (2015) found part of this procedure to be very relevant to this type of research, these are:

3.7.1 Assessment of Daylighting in a shop for Pilot Study Retest

The process of daylight assessment for the validation was divided into three stages based on the IEA document as extracted by Salisu (2015).

1. The Decision Phase: In this phase, the type of variables to be measured and the type of instruments to be used, the number of sensors and the time of measurements were determined.
2. The Preparatory/Monitoring Phase: in this phase involves documenting all the information about the decision phase and monitoring phase were documented.
3. The Concluding Phase: in this phase, the measured illuminances were tabulated to be compared with simulated data.

3.8 Light pipe/ light tube Simulation Method

A typical windowless box 3mx3m with a core zone surrounded by four perimeter zones (3meters depth) was designed to be simulated for the study. It was considered to be situated in Kano, which is located in the hot semi-arid zone. The box and the rig were modelled with the aid of Autodesk Revit architecture and analysed using three variables in Ecotect Radiance® software.

In determining the daylight efficiency of the dual technology, the following variables were considered during simulation, they are:

i. Daylight: natural daylight is vital within a building both for visual comfort of the occupants and to limit the dependency on artificial lighting.
ii. Climate: the hot semi-arid climate acquires high temperature during the day and low during the evening depending on the season. Climatic data for Kano was sourced from - *Weather Analytics* - affiliated to EERE.
iii. Different sizes of light pipe and light rod. The cases show the relationship between the sizes of light pipe and light rod used for the simulations and analysis.

3.9 Simulation Process

The study intended to test the effect and efficiency of light pipe and light rod together as a dual technology as done by Tukur (2013), which was for residential building. In this study similar testing will be done to test the efficiency and how deep light pipe and light rod can transfer light optimally in vertical shopping malls.

The test was carried out using simulation with light pipes of various lengths and diameters and also light rod of various lengths and diameters. The test investigates the efficiency of dual technology with an increase in diameter as well as in length.

3.9.1 Device Transmittance

Transmittance is the key parameter affecting the efficiency of the light pipes, Callow (2003), proposed an equation of calculating light pipe performance in terms of transmittance. This description of performance was used by investigations of light pipe efficiency (Swift and Smith, 1995) and quoted as follows:

$$T = R^{Ltan\theta/d}$$

Where:

T is transmittance

R is the reflectance of the inner surface of the pipe or exterior surface of the PMMA acrylic light rod

L is the length of pipe/rod

d is the of the entrance aperture (nominal diameter of pipe/rod)

Consequently, for a light pipe with 98% reflectance, length of 3000mm, assumed angle of incidence of 50° and a nominal diameter of 300mm, the transmittance is thus:

$T = 0.98^{3000tan30/300}$

T = 0.88990515588

T = 0.8899

Given the same cases, the light rod has a nominal diameter of 100mm, the transmittance is thus:

$T = 0.98^{3000tan30/100}$

T = 0.7047436529

T = 0.7047

The computer model was further used to simulate the same equation with different solar angles of incidences as can be found at different locations of the globe. This can be seen in Table 3.1

Table 3.1 Angle of Incidences and Reflectance Levels
Source: Author (2016)

Angles of Incidence (°)	30	40	50	60	70	80
98% Reflectance for Light Pipe	0.8899	0.8441	0.7860	0.7047	0.5740	0.3180
98% Reflectance for Light Rod	0.7047	0.6014	0.4856	0.3500	0.1892	0.0322

The transmittance of the devices as obtained through the mathematical model similar to that of Callow (2003) and Tukur (2013), shows the solar incidence angle is inversely proportional to the transmittance levels that is, as the solar incidence angle increases, the

transmittance levels decrease. Figure 3.1 shows the superiority of the light pipe over that of the light rod in terms of light transmittance.

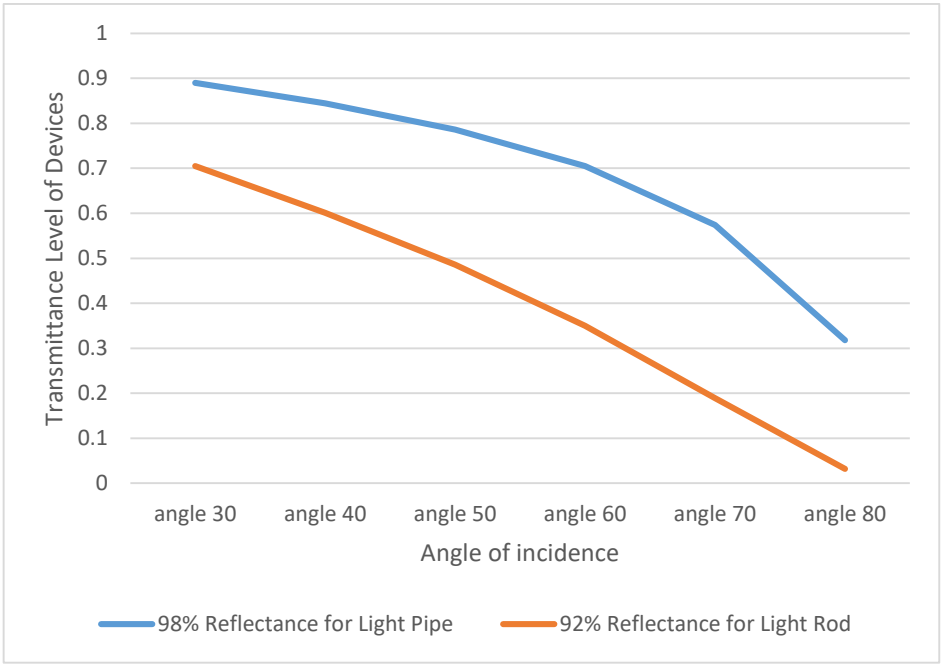


Figure 3.1 Comparative Reflectance for LP and LP at Various Angles of Incidences. Source: Author (2016)

3.9.2 Simulation Form Modelling

The form was modelled in Revit Architecture® 2016 with the light pipe and light rod conforming with the different cases specified in Table 3.3.2. These were then exported as gbxml Files to Ecotect® to perform daylight analysis as shown in Figure 3.2, Figure 3.3 and Figure 3.4 illustrate the steps taken to analyse the models in Ecotect and Radiance.

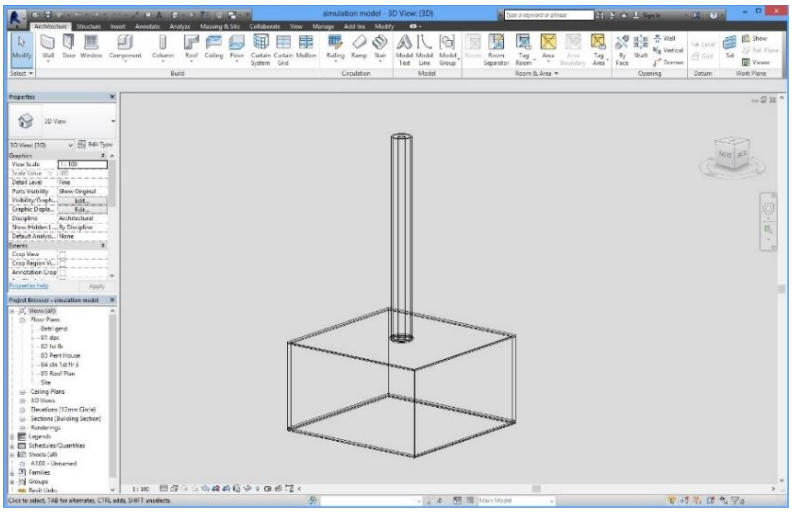


Figure 3.2 Model Drawn in Revit and Exported to Ecotect

Source: Author's sketch (2016)

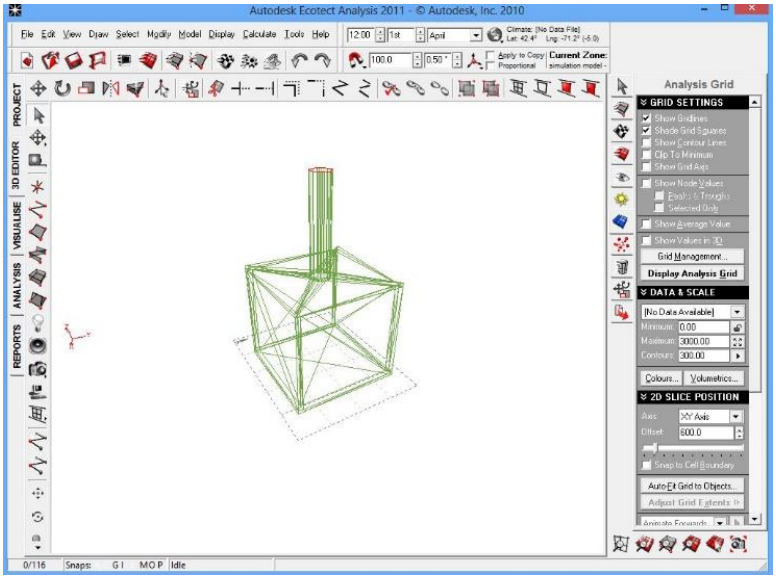


Figure 3.3 Model imported into Ecotect

Source: Author's sketch (2016)

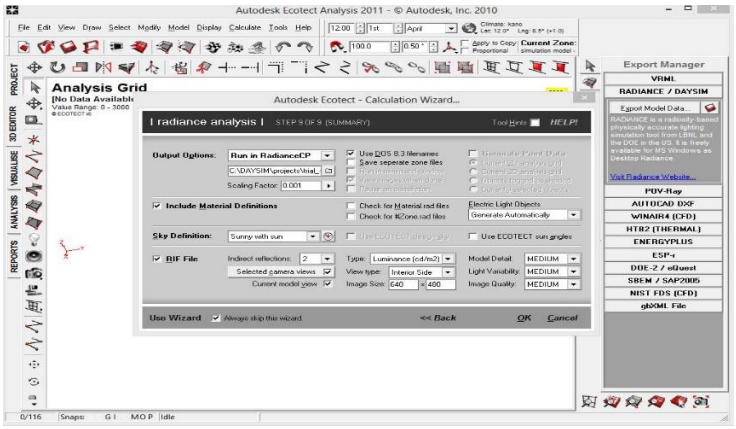


Figure 3.4 Exporting to Radiance for Daylight Analysis

Source: Author's sketch (2016)

3.9.3 Simulation Model

Modelling using the Revit 2016®, Ecotect® software under a set of cases as shown in Table 3.3.2 and sensors position in as shown in Table 3.3 were kept in the same position for all simulations that were carried out in all the cases.

Table 3.3.2 Cases of Simulation.

Source: Author (2016)

Cases	Light pipe Diameter	Light rod Diameter	Height
Case 1	300	100	3000
Case 2	300	100	4500
Case 3	300	100	6000
Case 4	600	150	3000
Case 5	600	150	4500
Case 6	600	150	6000
Case 7	900	200	3000
Case 8	900	200	4500
Case 9	900	200	6000
Case 10	300	200	9000
Case 11	600	200	9000
Case 12	900	200	9000

Table 3.3 Sensor Position in Test Box

Source: Author (2016)

Sensors	Position in Test Box
Sensor 1	Bottom mid-floor of box
Sensor 2	halfway up the middle right-side of the box
Sensor 3	suspended in the mid-centre of the box
Sensor 4	left corner of the box
Sensor 5	top entry of the box

3.10 Data Analysis

Data analysis is a process by which the data collected is transformed into meaningful and useful information. This Research makes use of experimental design approach by evaluating how vertical light pipe can impact the daylighting in a vertical shopping mall.

Descriptive analysis was employed to achieve the first objective and answer research question one. Inferential analysis was adopted to achieve the second, third and last objective and research question.

4.0 RESULT AND FINDINGS

4.1 Introduction

In this chapter, findings from case studies were described, documented and analysed. These findings were presented graphically using plates, table and figures. In addition, simulations were carried out to determine the maximum level which light can be transported optimally using the light pipes and light rods as a dual technology and their efficiency. The results were also analysed and presented graphically using tables and figures. Finally, a model was deduced from the analyses.

4.2 Case Study

A case study is an account of an activity, event or problem that contains a real or hypothetical situation and includes the complexities you would encounter in the workplace (UNSW Australia, 2013). It is a method used to narrow down a very broad field of research into one easily researchable topic (Explorable.com, 2016).

Four international case studies were selected for this study. They are: -

i. Times Square Mall
ii. Zorlu Centre
iii. Fulton Centre
iv. ARG Shopping Mall

They were studied in the order of their number of floors, the first being the tallest, opened in 2009 and the last being the smallest opened in 2016. Aspects studied were: -

i. Types of building materials
ii. Nature of shading devices used
iii. Building orientation

iv. Use of daylighting strategy.

Also in addition, a local case study was conducted at Ado Bayero Mall Kano.

4.2.1 Case Study 1: Times Square Mall, South Korea.

Times Square is a large-scale complex shopping mall composed of a department store, mall, theatre, hotel, large-size bookstore, supermarket, and rental office. It is built in different levels with the mall having nine floors and the highest been twelve floors. It has been receiving favourable comments in diverse media outlets as a space that considers customers and city, while maintaining harmony with the surroundings. It has emerged as a landmark of the south-western zone, with 210,000 daily visitors on average in the month following its grand opening (Arch Daily, 2016).

i. Architects- JUNGLIM Architecture

ii. Location- Seoul, South Korea

iii. Client- Kyungbang

iv. No of Floors – 9 Floors

v. Project Date - 2009

4.2.1.1 Environment and micro-climate

Times Square site setting is well landscaped with so many Architectural features which include plazas, terraces, water fountains and numerous gardens in different level of the mall as it is in Plate I. These architectural landscape improves the microclimate which enhances shopping atmosphere.

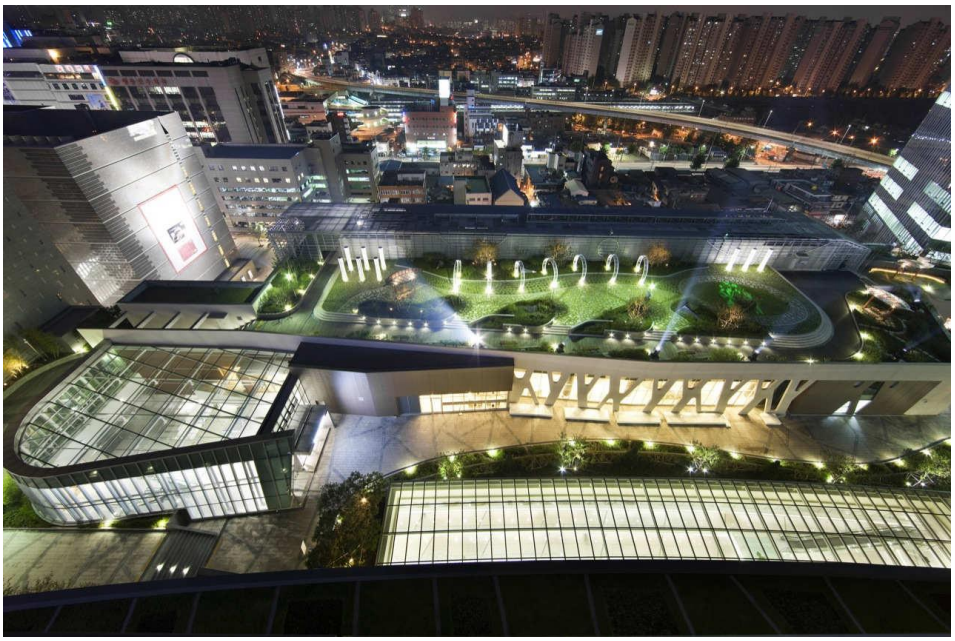


Plate I Site Landscape Overview of Times Square.

Source: (Arch Daily, 2016).

The building is oriented on an E-W axis where by some part of the building was little bit tilted from the E-W there by still longer side facing the North and South side, as shown in Figure 4.1.



Figure 4.1 Orientation of Times Square on the Plan.

Source: (Arch Daily, 2016).

South Korea has a temperate climate with four distinct seasons. Winter are usually long, cold and dry. Summer are very short, hot and humid. Spring and autumn are pleasant but also short in duration. Seoul's mean temperature in January is -5 degrees Celsius to -2.5 Celsius and in July the mean temperature is about 22.5° C to 25° C (World Weather and Climate Information, 2016).

Due to this difference in temperature over a year in Seoul, South Korea, selected building materials are all not vulnerable to this change in the temperature.

4.2.1.2 User behaviour and requirements

Times Square has some unique features which took shopping experience to another all new level during the time it was commissioned, this features includes; Shinsegae. Book Store the country's largest book store chain, the Marriott Seoul Times Square, and two office buildings. The above features enable citizens to fulfil their needs for shopping, cultural activities, wedding, conventional, entertainment, dining, fitness, hotel accommodation and a variety of business, virtually all under one roof.

4.2.1.3 Utility and space enhancement

The spaces within the mall are well connected to each other and standard circulation pattern were used, also the width of the circulation.

4.2.1.4 Form and Function

The idea behind the form is to create a concept landmark of Korea where urban shopping and cultural space form a harmony with nature. To maintain that, the idea of landscaping, terraces, water fountains and numerous gardens came in.

4.2.1.5 Horizontal and vertical circulation

Times Square Mall is design as a modern mall where circulation without interruption is considered, the main horizontal circulation is through walkways, terraces, concourse,

halls and sky bridges, and their width were enough to tackle the traffic within the mall. While the vertical circulations include number of different escalators, ramp, stairways and lifts as shown in Plate II.



Plate II Sky Bridge in Times Square Mall connecting different Functions.
Source: (Arch Daily, 2016).

4.2.1.6 Site Planning and Landscape

Site Planning and landscape in the mall well design which enhances the atmosphere within the indoor and outdoor of the mall as it is shown in Plate I.

4.2.1.7 Parking details and standards

Most of the parking space at Times Square mall are both surface and multi-level basement parking to enable both workers and customers to park conveniently.

Parking Facilities

vi. Night parking (20:00-09:00): 50% discount

vii. Discount parking ticket offered by some stores in Times Square (Korea Tourism Organisation, 2016).

4.2.1.8 Types of Building Material Used

Times square mall was mainly build with concrete, steel, aluminium, and glass.

4.2.1.9 Daylight Strategies

Several daylight strategies have been used in the building, these include side light from store front glazed and top lighting from sky light as in Plate III and atrium which are mostly facing the circulation area of the mall. While the internal partitions were mostly in curtain walls to allow daylight access in the shops to reduce the usage of artificial light though still the artificial light is used during the day time at areas that have less daylight access.

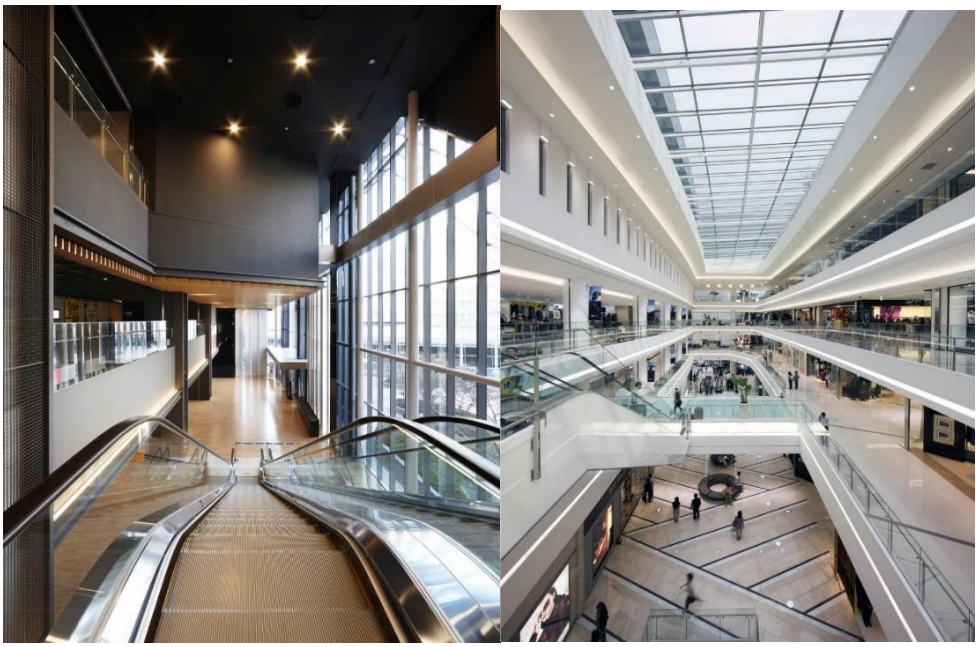


Plate III Top and Side Light as a source of daylight at the Times Square Mall.
Source: (Arch Daily, 2016).

4.2.1.10 Summary of findings from Times Square Mall.

The report above was summarised in form of a checklist Table 4.1, where "1" indicates the availability of the variable and "0" indicates its absence. This ease comparison between the variables documented.

Table 4.1 Summary and checklist of findings from Times Square Mall, South Korea. Source: Visual Survey 2016.

Variables	Type		Scale Factor	Remark
Shading Device	Vertical		0	The building has no shading device except some blinds.
	Horizontal		1	
	Egg-crate		0	
	Overhang		0	
	Fabric		0	
	Blinds		1	
Building Material used	Concrete		1	It is built using modern construction materials, and plain glaze is used to allow natural light into the building.
	Steel		1	
	Wall Clad		1	
	Glass	Plain	1	
		Reflected	0	
Building Orientation	Longer side facing N-S		1	It is oriented with its longer side facing north-south orientation.
Daylight Strategy used	Sidelight	window	1	Most of the façade of the building is either glaze with curtain wall or windows. skylight and atrium were used to allow enough natural light into the building.
		Curtains	1	
	Top light		1	
	Atrium		1	
	Light Pipes		0	

Table 4.1 above doesn't easily indicate any relationship but upon comparing the report in form of chart, it can be easily seen that Time Square Mall uses a variety of building materials, Daylighting strategies, shading devices and it's well oriented.

4.2.2 Case Study 2: Zorlu Centre, Turkey.

Zorlu Centre is the new meeting venue in Istanbul. It features a luxurious shopping centre, a centre for performance arts, a 5-star hotel, offices, and residences. The Shopping Mall includes 12 movie theatres seating 1,600 patrons, a 9,000 sqm anchor store, a 6,000sqm supermarket and 40 cafes and restaurants (Arch Daily, 2014). Zorlu Centre Mall will have a main square measuring 10,000 square meters' gross leasable area of approximately 60,000 square meters and floors each featuring a different concept (Malls. com, 2016).

Zorlu Shopping Mall is open to visitors between 10:00 a.m. and 10:00 p.m. 7 days a week. It is sited at the junction of the Bosphorus Bridge European connection and the glamorous Büyükdere axis that connects the city centre with the great business district Maslak, it also have an amazing façade as its shown in Plate IV (Malls. com, 2016).

i. Architects - Emre Arolat Architects, Tabanlıoğlu Architects
ii. Location - Balmumcu Mh., Zincirlikuyu Sokak, 34398 Beşiktaş/Istanbul Province, Turkey
iii. Area - 639.0 m^2
iv. No of Floors – 7 Floors
v. Project Year- 2013



Plate IV Entrance to Zorlu Centre.

Source: (Arch Daily, 2014)

4.2.2.1 Environment and micro-climate

Turkey is situated in a geographical location where climatic conditions are quite temperate, there are significant differences in climatic conditions from one region to the other. While the coastal regions enjoy milder climates, the inland Anatolia plateau experiences a dryer climate with hot summers and cold winters with limited rainfall (Weather Online, 2016).

The Climate of the Turkey is divided in three different climate zones. A warm temperate Mediterranean climate with dry, warm summers and moderate, wet winters with the warmest month above 22°C, over average; The mountainous regions of Anatolia have an Dsa Climate, a Snow Climate with a dry summer and the warmest month above 22°C and the coldest month below -3°C. The Climate of the central Anatolian plateau can be

classified as BSk Climate, a cold, dry Climate with a dry summer and annual average Temperatures under 18°C (Weather Online, 2016).

4.2.2.2 User behaviour and requirements

Just in the centre, at the Boulevard Level is the Piazza surrounded by the retail units, that strives for creating an alternative public space.

The Concert Hall of 2500 people capacity has an entrance amphi as a continuation of the Public Square and the Piazza, which offers a semi-closed space for alternative performances.

The terrace flats under the shell are equipped with large gardens on the first level, and with large terraces on the upper levels enjoying the Bosphorus view. They are reached through the linear open-air atrium, quite rich, lighted and cheery space that is shown in. The rest of the residential units form three identical towers, detached from the shell with "piloti" and their structural formation continues the horizontal projections of the terrace flats, without turning into symbolic elements of the complex (Arch Daily, 2014).

4.2.2.3 Form and Function

The mall got its form from the terrain as the ground is reconstructed by a topographical interpretation, with a kind of shell that is transformed into an in-between layer for the different functions combined in the complex. The shell starts from the Boulevard Level, with a Public Square at the meeting point with the city, and rises towards south and east. It is split into two arms separated by level differences, in order to overcome the dichotomy between the private and the public. The inner route, the Public Topography reaches to the 28m. Higher Urban Balcony with the marvellous Bosphorus view. The outer ring ends up with a height of 32m creating the Private Topography of the residential units as it is in Figure 4.2. (Arch Daily, 2014).

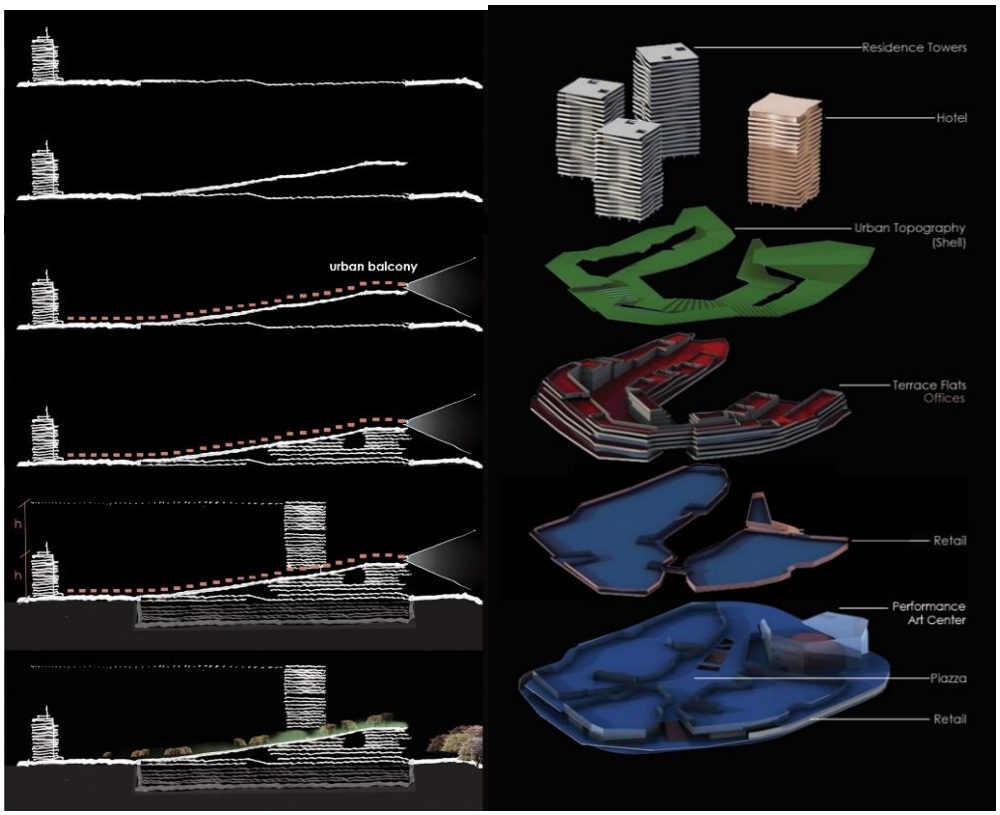


Figure 4.2 Form formation of Zorlu Centre.

Source: (Arch Daily, 2014)

4.2.2.4 Horizontal and vertical circulation

At the Zorlu Centre, the main vertical circulations were escalators and stairways that enable users to move vertically, while at the residential and hotel towers lifts were used to ease the vertical movement. In addition, the horizontal circulation includes terraces, balconies, hallways and walkways

4.2.2.5 Site Planning and Landscape

The site was planned to reach its best eco-friendly environment with well landscape features such as shrubs, water fountains, trees, sit outs, with each floor designed to maintain independent landscape environment.

The 8,000 square meter roof of the performance hall is richly planted with Sedum, Delosperma and rosemary shown in Plate V. The towers are based on a ring of green

construction, which rises from ground level up to 33 meters. Source: Zorlu Property Group in (ZinCo, 2015)

The Zorlu Green Roofs filter dust and pollutants from the air and improve the microclimate, this is illustrated in Plate V. The Zorlu Centre exhibits a stately 120,000 m² of green area. Almost 60 % of the total area (around 72,000 m²) is located on roofs, most noticeably on the topography of the 45,000 m² large ring-formed green space, which rises from ground level up to 33 meters in height. 15 people are now working for the care and maintenance of garden areas. (ZinCo, 2015)

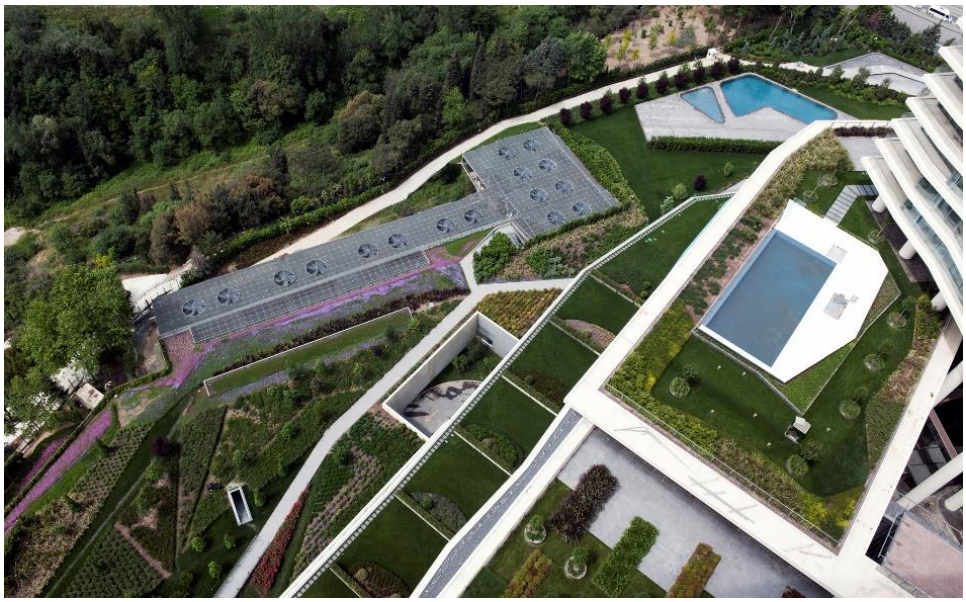


Plate V Landscape elements at Zorlu Centre.
Source: (Arch Daily, 2014)

4.2.2.6 Parking details and standards

In the middle Zorlu Centre, underneath are the basements filled with the five-story underground car park and an underground pedestrian tunnel connecting the Zorlu Centre to Metro and Metro bus public transit systems (ZinCo, 2015).There are 5000 parking lots at the Zorlu Centre which is enough for the number of user (Malls. com, 2016).

4.2.2.7 Daylight Strategies

The lights of Zorlu Centre Shopping Mall will constantly rearrange by the changes of daylight with the new developed lighting technology. The cameras on the towers will detect the light reflected from Bosphorus, and the sky. Computer system will transmute the data received, so the visitors of Zorlu Centre Shopping Mall will feel the daylight inside the building. (Malls. com, 2016).

The excessive use of side light at the Zorlu centre in form of glazed façade makes it easy to generate more natural light into the inner part of the building. This is shown in Plate VI were plain glass was used in the façade and in the restaurant area.



Plate VI Side Light Use as a means of transporting daylight into the mall.
Source: (Arch Daily, 2014)

4.2.2.8 Summary of findings from Zorlu Centre.

The report above was summarised in form of a checklist in Table 4.1, where "1" indicates the availability of the variable and "0" indicates its absence. This ease comparison between the variables documented.

Table 4.2 Summary and checklist of findings from Zorlu Centre, Turkey.

Source: Visual Survey 2016.

Variables	Type		Scale Factor	Remark
Shading Device	Vertical		0	It has overhang in form of concrete deck protruding from the building, also the use of balconies enhances the shading.
	Horizontal		0	
	Egg-crate		0	
	Overhang		1	
	Fabric		0	
Building Material used	Concrete		1	It is built using modern construction materials, and plain glaze is used to allow natural light into the building.
	Steel		1	
	Wall Clad		1	
	Glass	Plain	1	
		Reflected	0	
Building Orientation	Longer side facing N-S		0	Due to the terrain of the site, the form of the building is so complex to the extent that no definite form or shape.
Daylight Strategy used	Sidelight	window	0	The façade of the building is fully glazed with curtain wall to allow enough natural light into the building.
		Curtains	1	
	Top light		0	
	Atrium		0	
	Light Pipes		0	

Table 4.2 above does not easily indicate any relationship but upon comparing the report in form of chart, it can be easily seen that Zorlu Centre uses a variety of building materials, Daylighting strategies and shading devices.

4.2.3 Case Study 3: Fulton Centre, New York. USA

The Fulton Centre is designed to be a catalyst for the redevelopment of the area. It is organised around a large-scale atrium contained within an elegant, transparent façade. Plate VII shows Tapered steel columns draw inspiration from the historic neighbourhood's cast-iron buildings and complement the integration and restoration of the adjacent Corbin Building (ArchDaily, 2016).

i. Architects - Grimshaw

ii. Location - 200 Broadway, New York, NY 10038, USA

iii. Area - 62000.0 sqm

iv. No. of Floor – 6 Floors

v. Project Year – 2014

vi. Total Building Cost (total and square foot) - $1.4B



Plate VII Overview and Interior of Fulton Centre.
Source: (ArchDaily, 2016)

Carefully aligned entrances and exits allow the streetscape to permeate the building, defining clear and efficient pathways to all trains. Once beyond fare control and underground, passengers will encounter brighter, widened passageways with clear signage connecting the complex array of platforms.

4.2.3.1 Form and Function

The main central Architectural concept of the Fulton centre is the interior dome called the Sky Reflector Net that was design to redirect natural light deep into the transit environment. the scheme is organized around a large scale atrium wrapped inside a transparent façade. The section in Figure 4.3 shows the central volume rises to a total height of 36 meters, and is topped with a conical dome structure that is truncated by an angled glass oculus oriented to the southern sky.

The cable net is suspended from 56 connection points round the compression ring of the oculus, and anchored to beams at the bottom as it is in Figure 4.3. The 3.2 mm thick aluminium panels are heavily perforated, not just to reduce weight but also to permit interior air currents to pass through and to control the quantity of light reflected. They are linked by cruciform connectors attached to each corner and fixed to the cable's nodes by swaging – cold-forming to provide a firm connection.

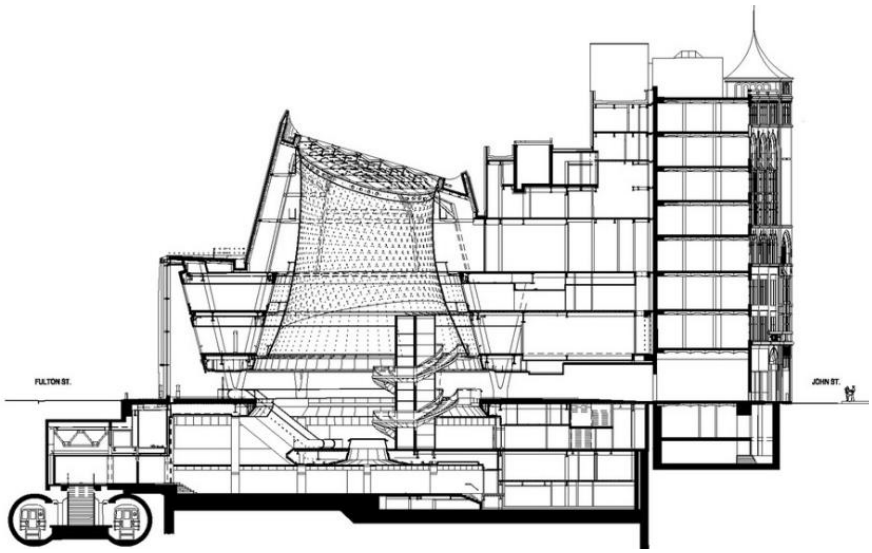


Figure 4.3 Conceptual Form of the Dome at Fulton Centre.

Source: (ArchDaily, 2016)

4.2.3.2 Horizontal and vertical circulation

The concept of the interior of Fulton Centre was designed in a radial form where all horizontal circulations moves around the transparent interior dome through which daylight is used to light the area during day, the main horizontal circulation is through the concourse and the galleries, while the vertical circulation include the central lift with a steel stairway round it, escalators and stairways these links the subways to the malls and the upper.

4.2.3.3 Parking details and standards

No parking space at Fulton centre as it is connected to a train station.

4.2.3.4 Building Material Used

The material used in the interior of the Fulton Centre's dome, is an interdependent reflective lining, offset from to direct sunlight down from the sloping, circular oculus at the top. The walls were all clad in stainless steel while the columns and ceiling all clad in aluminium cover.

4.2.3.5 Daylight Strategies

Both Side and top lighting strategies were used at the Fulton Centre, where the main top light comes from the domes atrium as it is in Figure 4.4 and the side light comes from the well glazed facade of the structure.

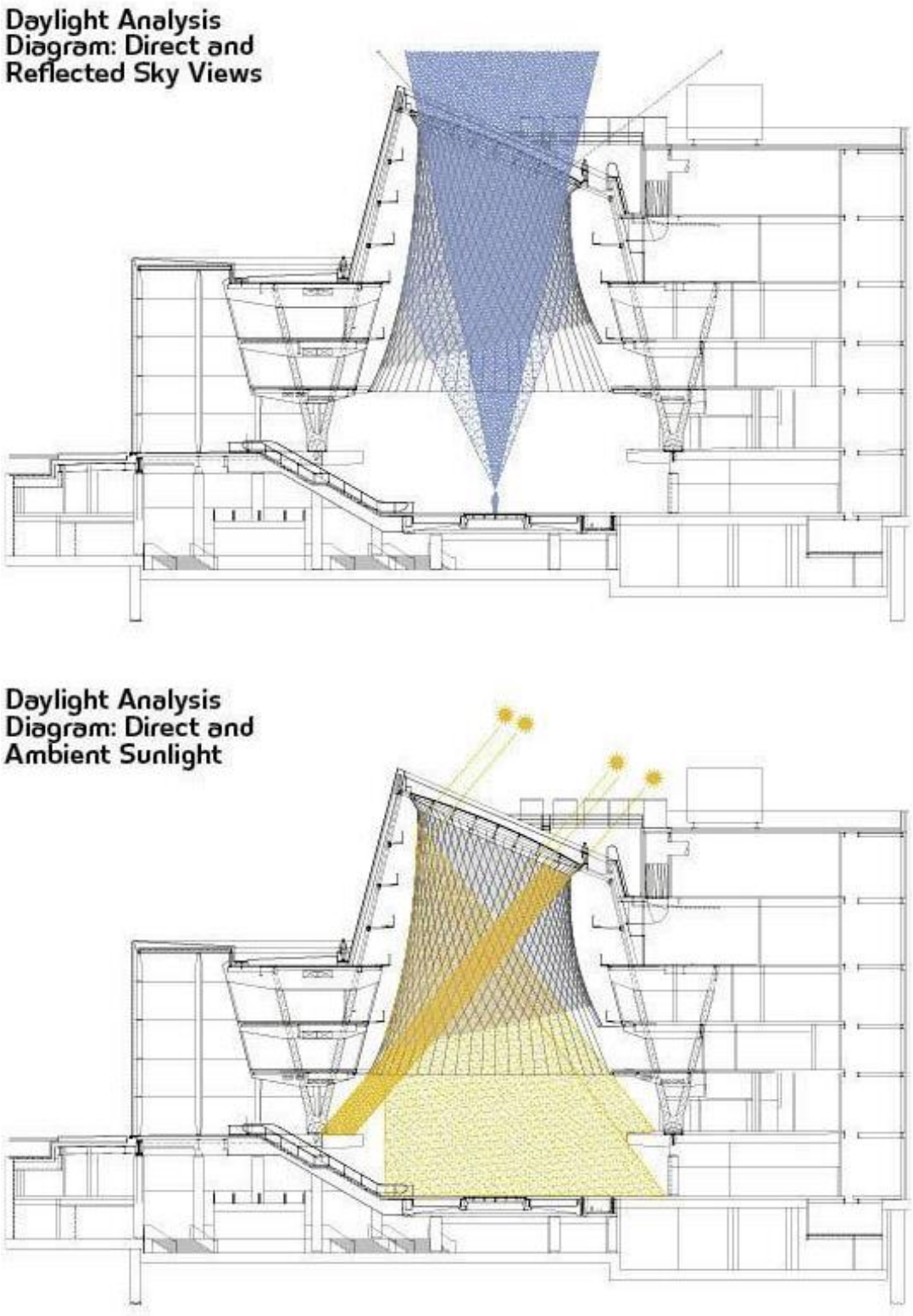


Figure 4.4 Direction and Reflection of daylight into the building.

Source: (ArchDaily, 2016)

4.2.3.6 Summary of findings from Fulton Centre

The report above was summarised in form of a checklist in Table 4.3, where "1" indicates the availability of the variable and "0" indicates its absence. This ease comparison between the variables documented.

Table 4.3 Summary and checklist of findings from Fulton centre, New York, USA. Source: Visual Survey 2016.

Variables	Type		Scale Factor	Remark
Shading Device	Vertical		1	There is a fabric material in the interior of the dome atrium, which controls the level of natural light coming into the building.
	Horizontal		0	
	Egg-crate		0	
	Overhang		0	
	Fabric		1	
Building Material used	Concrete		0	It is built using modern construction materials, and plain glaze are used to allow natural light into the building.
	Steel		1	
	Wall Clad		1	
	Glass	Plain	1	
		Reflected	0	
Building Orientation	Longer side facing N-S		0	The building is cubical in shape but not oriented to N-S.
Daylight Strategy used	Sidelight	window	0	Two façade of the building are glazed with curtain wall, and atrium dome is used to allow enough natural light into the building.
		Curtains	1	
	Top light		0	
	Atrium		1	
	Light Pipes		0	

Table 4.3 above does not easily indicate any relationship but upon comparing the report in form of chart, it can be easily seen that Fulton Centre uses a variety of building materials, Daylighting strategies and shading devices but it is not oriented.

4.2.4 Case Study 4: ARG Shopping Mall, Tehran, Iran.

ARG Commercial complex is a complete collection of the most famous brands in Iran including clothes, cosmetics, home appliances, electronics and kitchen, Perfume, jewellery, carpets and rugs, glasses and Rhinestones, all in a fun & modern environment. The most important features of this big commercial complex include an amusement park, amphitheatre, restaurants, food court, coffee shops and green roof garden (Real Iran, 2015).

A redesign of the new facade, landscape, roofs cape, and interior for the shopping centre was done though at the time, it is under construction and it's due to the client unsatisfactory with the original design. The façade was shown Plate VIII.

i. Architects - ARSH 4D Studio
ii. Location - Tehran, Tehran, Iran
iii. No. of Floor – 5 Floors
iv. Site Area - 115000 m^2
v. Project Area - 78000 m^2
vi. Project Year – 2015



Plate VIII Front Façade of ARG shopping mall.

Source: (Arch Daily, 2016)

4.2.4.1 Environment and micro-climate

Tehran's climatic condition has no significant negative impact on the City's development and its inhabitants. The contrast between mountain and desert, and even between north and south of the City, prevents weather crises from taking shape in any part of the year. When heavy snow obstructs mountain roads, plains in the rim of the desert (Dasht-e Kavir) have often a mild sunny weather. When it is too hot in the desert, one can refuge in the mountain just a few kilometres away. The significant change of weather in different seasons is ultimately pleasing and allows a great variety of activities, either agricultural or recreational, to take place (Tehran Municipality, Public & International Relations Department, 2016).

i. Teheran, Iran is at 35°40'N, 51°19'E, 1191 m (3907 ft). See map.

ii. Teheran has a mid-latitude steppe/ semi-arid cool climate (Köppen-Geiger classification: BSk).

iii. According to the Hold ridge life zones system of bioclimatic classification Teheran is situated in or near the warm temperate thorn steppe biome.

iv. The mean annual temperature is 17 degrees Celsius (62.6 degrees Fahrenheit). See the temperatures page for a monthly breakdown and the fixed scale graph.

v. Average monthly temperatures vary by 28.3 °C (50.9°F). This indicates that the continentally type is continental, subtype truly continental.

vi. Total annual Precipitation averages 229.9 mm (9.1 inches) which is equivalent to 229.9 Litres/m² (5.64 Gallons/ft²) (Climatetemp.com, 2015).

4.2.4.2 Form and Function

Re-composing the facade, the architect decided to simplify the massing and create a smooth and neutral surface to counteract the chaos of the neighbourhood. Glass is used to reflect the old trees of the surrounding area and highlight the mountains to the north (Arch Daily, 2016).

A unique feature of this project is its interactive capability, so that on special nights, people can create an interactive communication with the façade by standing on a special place only by moving their hands as it is in Figure 4.5. The central controller system by its specific software acts in a way to generate random beautiful images and display them on the façade's skin.

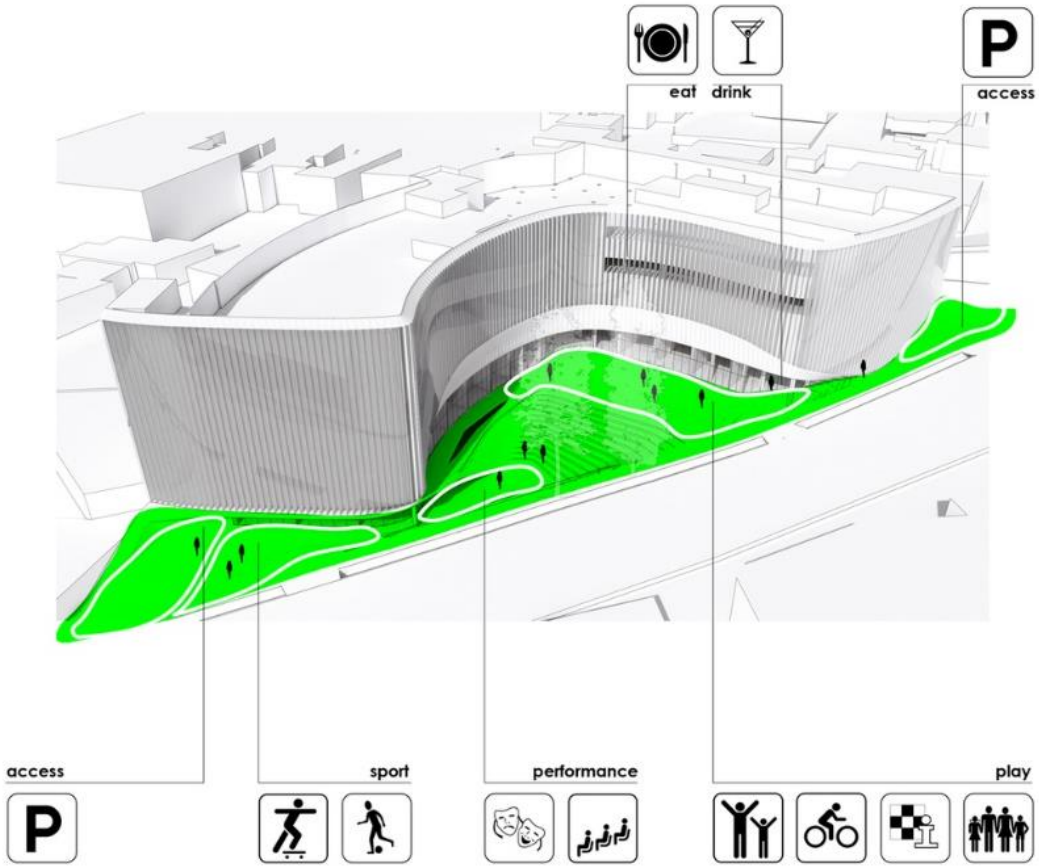


Figure 4.5 Concept development of ARG shopping mall.

Source: (Arch Daily, 2016)

4.2.4.3 Horizontal and vertical circulation

There are three major vertical circulations in the ARG shopping mall, the lift, which is at the core centre and in the atrium of the mall and also close to the entrance, the escalators were placed at the two opposite wing of the mall, and the escape stair way, which were placed at the extreme two end of the mall. And the horizontal been galleries and concourse with passages.

4.2.4.4 Site Planning and Landscape

The topography causes the elevation differences of the site which is solved by landscape - steps turning into long benches provide connections from the sidewalk and create a public outdoor auditorium.

4.2.4.5 Parking details and standards

There are about 1000 number of parking lots spread in a five level basement floors of the ARG Shopping mall for the 200 commercial unit allowing customers to visit and leave the mall safely, and it's all lighted using artificial light shown in Figure 4.6.

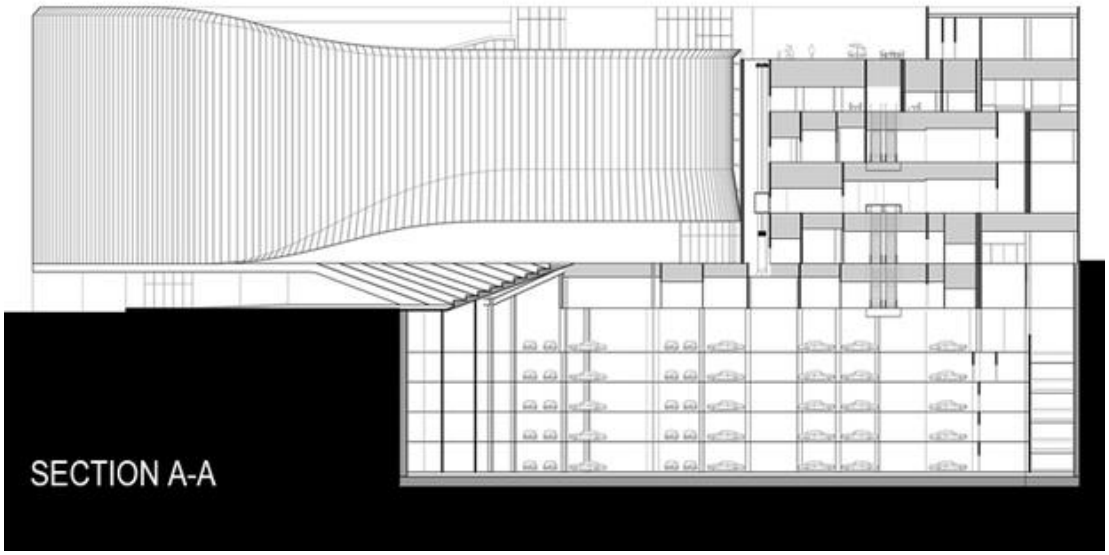


Figure 4.6 Five basement level on the section of ARG shopping mall.
Source: (Arch Daily, 2016)

4.2.4.6 Daylight Strategies

The daylight strategy used is the side light from the fully glazed façade of the mall and also from the atrium at the centre of the mall. While some part of it contains some shading device.

4.2.4.7 Summary of findings from ARG Shopping Mall.

The report above was summarised in form of a checklist in Table 4.4, where "1" indicates the availability of the variable and "0" indicates its absence. This ease comparison between the variables documented.

Table 4.4 Summary and checklist of findings from ARG shopping mall, Tehran.

Source: Visual Survey, 2016.

Variables	Type		Scale Factor	Remark
Shading Device	Vertical		0	Blinds were used inside the building to reduce the effect of the sun.
	Horizontal		0	
	Egg-crate		0	
	Overhang		0	
	Fabric		0	
	Blind		1	
Building Material used	Concrete		1	It is built using modern construction materials, and plain glaze are used to allow natural light into the building.
	Steel		0	
	Wall Clad		0	
	Glass	Plain	1	
		Reflected	0	
Building Orientation	Longer side facing N-S		0	Due to the terrain of the site, the form of the building is so complex to the extent that there is no definite form or shape.
Daylight Strategy used	Sidelight	window	0	All the façade of the building are glazed, and atrium is used to allow sufficient natural light into the building.
		Curtains	1	
	Top light		0	
	Atrium		1	
	Light Pipes		0	

Table 4.4 above does not easily indicate any relationship but upon comparing the report in form of chart, it can be easily seen that ARG Shopping Mall uses a variety of building materials, Daylighting strategies and shading devices but it is not oriented.

4.2.5 Summary and Relationship Between the Four Case studies.

Each variable from the four cases reported were compared to give an overview and ranking in Figure 4.7 and Figure 4.8. illustrates that on average the best variable that was used by all case studies is the building materials used, followed by the daylighting strategies, the least being the orientation.

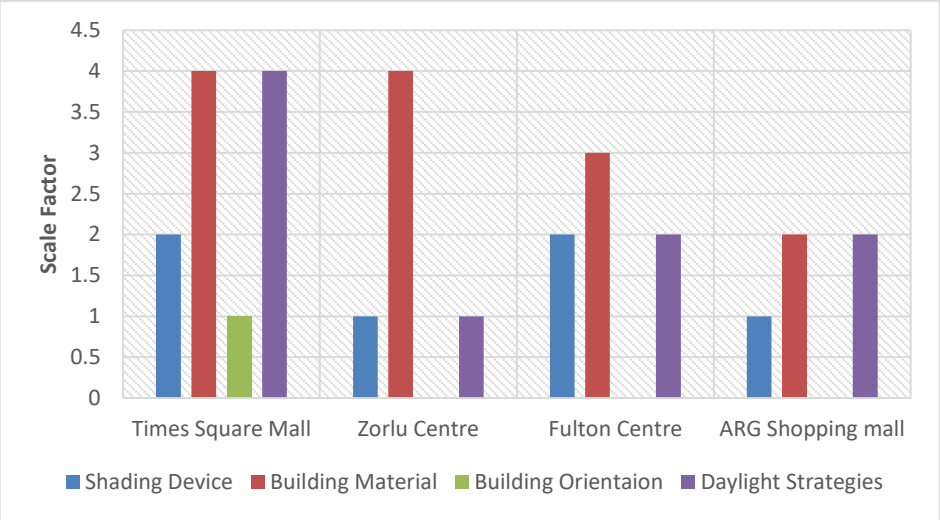


Figure 4.7 Summary of the Case Studies.

Source: Author 2016.

Figure 4.8 indicates that Time Square Mall is the best in terms of the variables checked. This is followed closely by the Zorlu Centre and the lowest is ARG Shopping Mall.

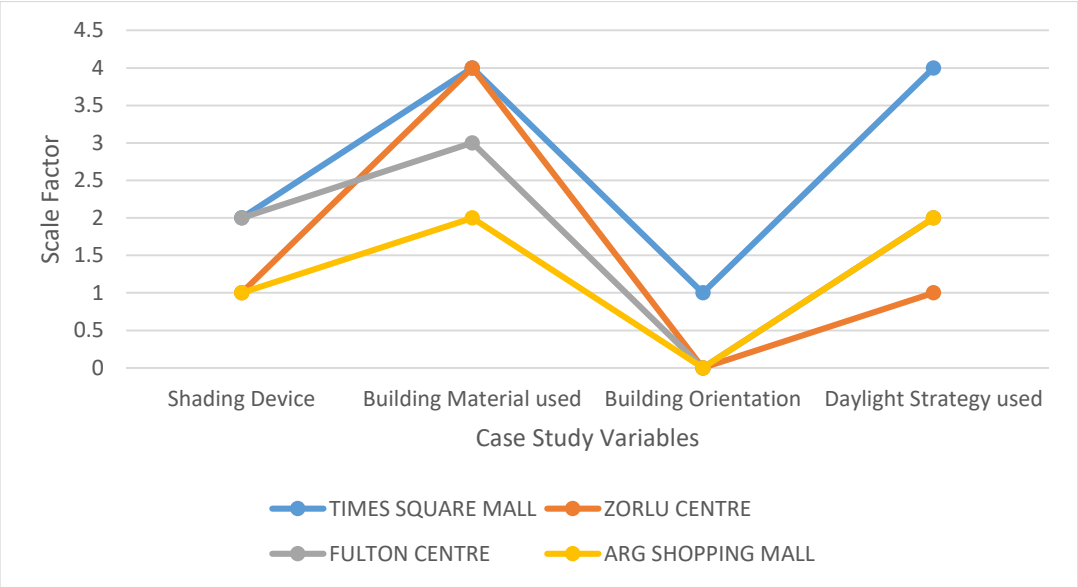


Figure 4.8 Relationship Between the Four Case Studies

Source: Author (2016)

4.2.6 Case Study 5: Ado Bayero Shopping Mall, Kano.

Ado Bayero Mall is the first ultra-modern shopping mall in Northern Nigeria located in the heart of Kano city. Situated in a neighbourhood defined by a well balanced mix of commercial and residential properties, the mall is located near major access roads such as the Zaria –Maiduguri Highways, and is also adjacent to major landmarks such as Kano Trade Fair Complex and the historic Kano Zoo on Zoo road. This high-profile location guarantees easy access and visibility for all tenants and shoppers as shown in Plate IX.

i. Developers - Beverly Development and Realties Limited

ii. Location - Zoo road, Kano.

iii. Area - Spread over 10 hectares

iv. No of Floors – 2 Floors

v. Project Year- 2013



Plate IX Entrance to Ado Bayero Mall.

Source: Field Survey (2016)

4.2.6.1 User behaviour and requirements

Spread over 10 hectares, Ado Bayero Mall offers 24,000 m² of retail and entertainment space comprised of two major international shopping retailers (Shoprite & Game), the largest and modern indoor multi-screen cinema (Film House Cinemas) and a broad range of other offerings including restaurants, media stores and an indoor play area for young children. Furthermore, the mall offers over fifty (50) customisable shop spaces and ample parking for 1000 automobiles.

4.2.6.2 Form and Function

The mall has a simple design with a combination of rectangular forms as it is in Figure 4.9, Figure 4.10.

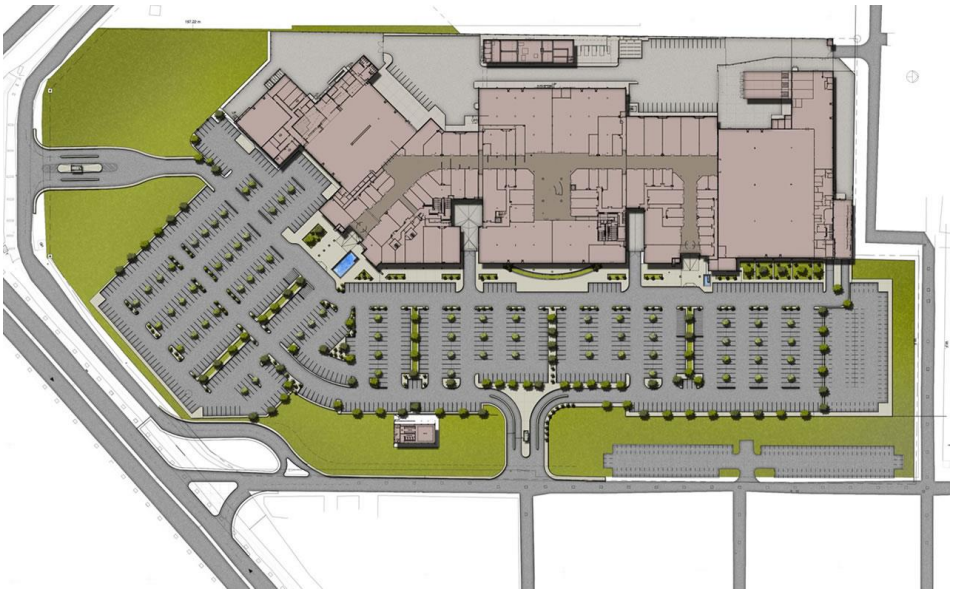


Figure 4.9 Site Layout of Ado Bayero Mall.

Source: Field Survey (2016)



Figure 4.10 Ground Floor Plan of Ado Bayero Mall

Source: Field Survey (2016)

4.2.6.3 Horizontal and vertical circulation

At the Ado Bayero Mall, the main vertical circulation used is the stairways, which enable users to move vertically. Moreover, the horizontal circulation includes terraces, balconies, hallways and walkways.

4.2.6.4 Site Planning and Landscape

The site was planned to reach its best eco-friendly environment with well landscape features such as shrubs, water fountains, trees, sit outs, with each floor designed to maintain independent landscape environment.

4.2.6.5 Parking details and standards

Ado Bayero Mall has an ample parking for 1000 automobiles that will be enough if the ratio of shoppers and floor area is considered.

4.2.6.6 Daylight Strategies

At Ado Bayero Mall there is excess use of artificial light were by most of the inner spaces do not have access to natural light which increase cost of electricity and also contributed to the prices of goods sold. The excessive use of side light at the Ado Bayero mall in form of glazed façade makes it easy to generate more natural light into front shops.

4.2.6.7 Summary of findings from Ado Bayero Mall. Kano.

The report above was summarised in form of a checklist in Table 4.5 where "1" indicates the availability of the variable and "0" indicates its absence. This ease comparison between the variables documented.

Table 4.5 Summary and checklist of findings from Ado Bayero Mall, Kano.

Source: Visual Survey 2016.

Variables	Type		Scale Factor	Remark
Shading Device	Vertical		0	It has overhang in form of concrete deck protruding from the building, also the use of balconies enhances the shading.
	Horizontal		1	
	Egg-crate		0	
	Overhang		1	
	Fabric		0	
Building Material used	Concrete		1	It is built using modern construction materials, and plain glaze is used to allow natural light into the building.
	Steel		1	
	Wall Clad		1	
	Glass	Plain	1	
		Reflected	0	
Building Orientation	Longer side facing N-S		0	Due to the terrain of the site, the form of the building is so complex to the extent that no definite form or shape.
Daylight Strategy used	Sidelight	window	1	The façade of the building is fully glazed with curtain wall to allow enough natural light into the building.
		Curtains	1	
	Top light		1	
	Atrium		1	
	Light Pipes		0	

It can be easily seen that Ado Bayero Mall uses a variety of building materials, Daylighting strategies and shading devices.

4.3 Validation Study

The measured and simulated illuminances from the validation studies were analysed using descriptive statistics and methods from previous daylighting researches. Visually,

the data were analysed using a two-line graph for comparison, while statistical tests for correlation, mean bias error and root mean square were used to analyse the data. Lighting metrics of uniformity ratio and differences in average measured illuminances to simulated illuminances were also applied in the data analysis.

4.3.1 Simulation and Measured Results

The illuminances measured in the aforementioned case studies were recorded based on the Daylighting Monitoring Procedures of IEA 1997 and 2001, while the simulated results were obtained using Autodesk® Ecotect® Analysis and Radiance® Lighting Software by Lawrence Berkeley Laboratories. The material properties, transmittance, work planes, sensor points and time and date for the simulation were all filled out in accordance to what was measured according to the IEA procedure. For the case study these result was presented in Table 4.6 and Figure 4.11 and Figure 4.12 below.

Table 4.6 Measured and simulated illuminances in a typical shop at ABS Mall, Kano.

Field study, 2016

WORKPLANE SENSORS	MEASURED (LUX)	SIMULATED (LUX)	ERROR (SIM-MEA)	ERROR (SIM-MEA)²
1	822	856	34	1156
2	976	920	-56	3136
3	954	922	-32	1024
4	486	570	84	7056
5	525	473	-52	2704
6	473	429	-44	1936
7	213	343	130	16900
8	356	253	-103	10609
9	214	354	140	19600
10	65	85	20	400
11	98	82	-16	256
12	52	76	24	576
AVERAGE	436.167	446.917		
SUM			129	65353

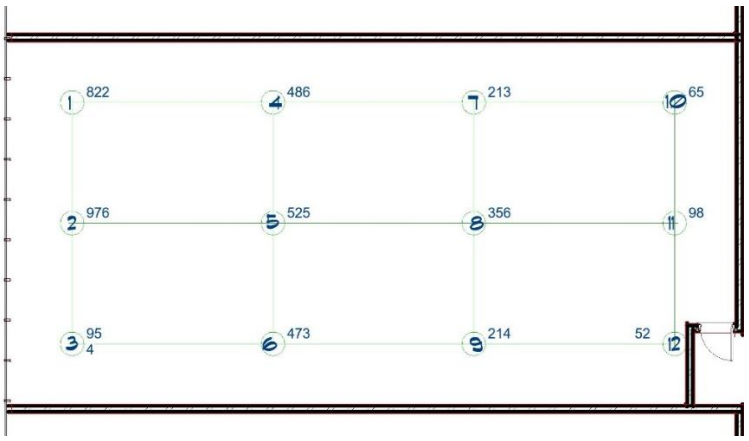


Figure 4.11 Measured illuminances of the shop in ABM

Source: Field study, 2016

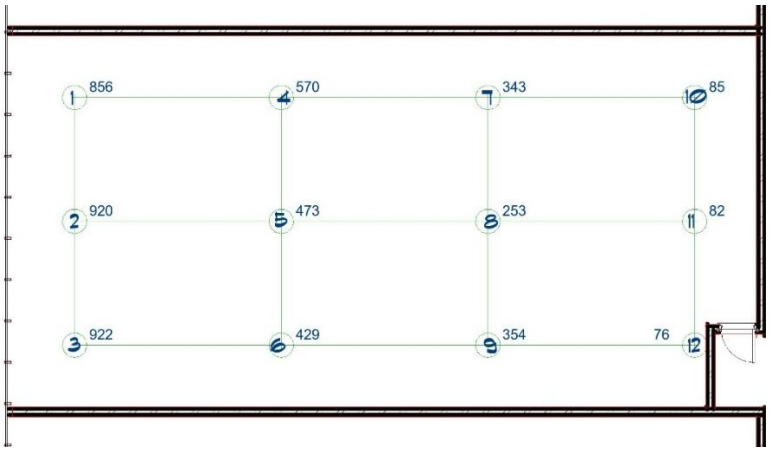


Figure 4.12 Simulated illuminances of the shop in ABM

Source: Field study, 2016

4.3.2 Visual Analysis

The result in Table 4.5 does not show the relationship between the values listed but upon presenting them in charts for visual analysis, the relationship can be seen, compared and understood easier. Figure 4.13 show that the measured illuminances and the simulated illuminances follow the same pattern and are closely related. Although it shows there are variations, this variation will be tested to check if they are within acceptable limits.

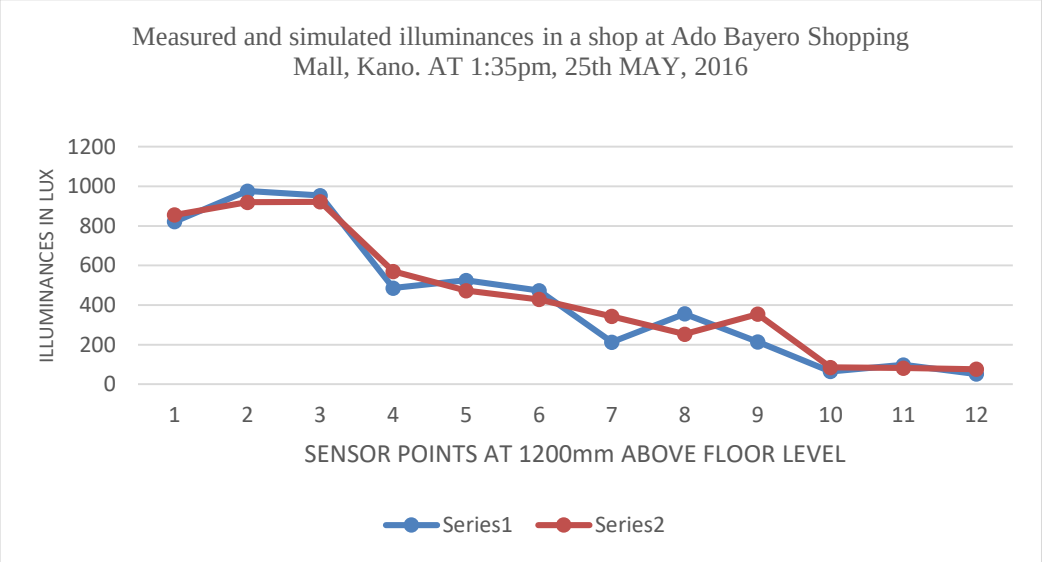


Figure 4.13 Measured and simulated illuminances in a shop at ABS Mall, Kano.

Source: Field study, 2016

4.3.3 Tests of Relationships

The accuracy of the results above will be tested by statistical indicators like Pearson's correlation test, mean biased error (MBE), root mean square error (RMSE) and percentage error (*e*).

Pearson's correlation test is used to test if there is an association between variables and how strong the association is (Pease & Bull, 2010). This test was used to test the strength between the measured and simulated illuminances. Figure 4.14 show that there is a strong relationship between the results.

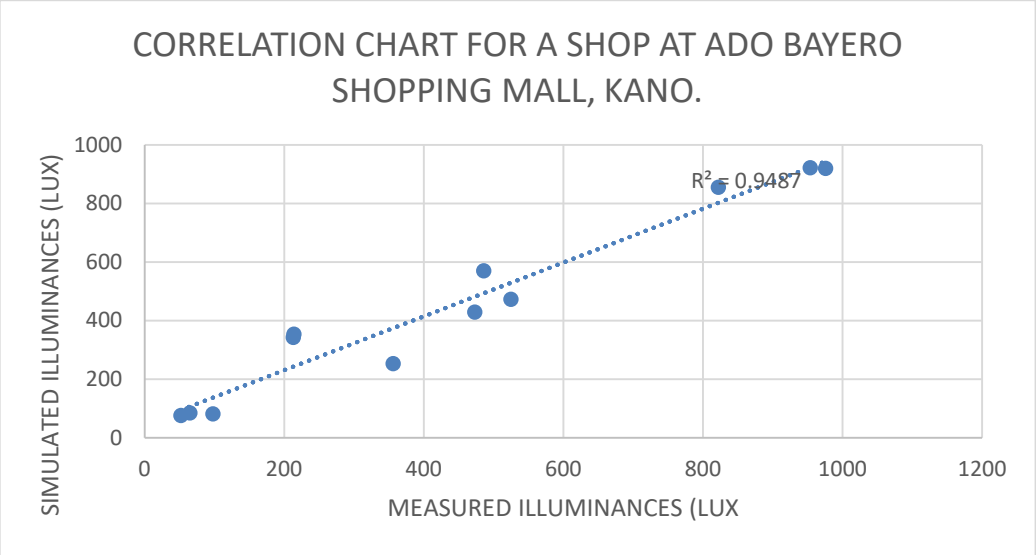


Figure 4.14 Correlation Chart Ado Bayero Shopping Mall, Kano.

Source: Field study, 2016

The coefficient of determination r^2 and the t-test were used to measure the strength of the relationship and to test for significance respectively. The significance was tested in a one tailed test with *p*=0.01. this was calculated using the formula

$$t = r\sqrt{\frac{n-2}{1-r^2}} \quad \text{.....Equation 4.1}$$

Where t= appropriate value to test significance of a correlation

r = coefficient of correlation

n= number of cases

Table 4.7 Test of Significance for a one-Tailed Test with a p =0.01

S/NO.	LOCATION	Coefficient of Correlation (r)	Coefficient of determination (r^2)	Degrees of freedom df = (n - 2)	Critical value of t	Observed value of t	Inference
1	ABM	0.974	0.9487	10	2.764	13.599	tobserved >tcritical SIGNIFICANT

Table 4.7 indicate a strong relationship between measured and simulated illuminances, it also show that the relationship between them is significant. The standard statistical measures used for measuring accuracy of model are root mean square error percentage (RMSE) and mean bias error percentage (MBE) (Gairaa & Bakelli, 2013; Chai & Draxler, 2014; Katiyar, Kumar1, Pandey, & Das, 2010). MBE measure of overall bias error or systematic error while RMSE is a measure of average deviation the *true value* (Cimbala, 2011).

MBE percentage formula is:

$$\%MBE = \frac{100}{x_{mea(av)}} \sum \frac{(x_{sim} - x_{mea})}{N} \quad \text{..... Equation 4.2}$$

While RMSE percentage formula is

$$\%RMSE = \frac{100}{x_{mea(av)}} \sqrt{\frac{1}{N} \sum (x_{sim} - x_{mea})^2} \quad \text{..... Equation 4.3}$$

Where:

x_{sim} is the simulated illumination value

x_{mea} is the measured value of illumination

$x_{mea(av)}$ is the average value of N measured illumination values

Table 4.8 MBE and RMSE Percentage Values for the case studies

S/no	Location	N	$\sum x_{sim} - x_{mea}$	$x_{mea(av)}$	$\sum (x_{sim} - x_{mea})^2$	%MBE	%RMSE
1	ABM	12	129	436.167	**65353**	2.465	16.920

Reinhart (2009) opines that for simulation data to be reliable and worthy, RMSE and MBE have to be less than 35% and between -15% to 15% respectively.

Table 4.8 fall within accepted values as opined by Reinhart (2009).

4.3.4 Average Illuminances Calculations

As shown in Table 4.9, the average illuminance show

$$\%Diff = 100\frac{x_{sim(av)} - x_{mea(av)}}{x_{mea(av)}} \quad \text{…….Equation 4.4}$$

x_{sim} is the average value of N simulated illumination values

x_{mea} is the measured value of N measured illumination values

Table 4.9 Average Illuminances Percentage Differences.

S/No	Location	$x_{mea(av)}$	$x_{sim(av)}$	%Diff
1	ABM	436.167	446.917	2.465

4.4 Simulation Results

Based on the simulation carried out Table 4.10 shows the results gotten from the different sensor positions for each of the cases specified in Table 3.3.2.

Table 4.10 Simulation Result of Different Cases

Source: Author (2016)

Cases of Simulations	Sensor Position 1	Sensor Position 2	Sensor Position 3	Sensor Position 4	Sensor Position 5	Average lux
Case 1	443.5	455.1	473.7	400.4	555.0	465.5
Case 2	408.5	423.4	432.8	388.8	538.4	438.4
Case 3	379.6	409.7	418.3	368.5	506.3	416.5
Case 4	589.1	619.3	622.4	568.4	686.2	617.1
Case 5	543.1	549.2	508.1	543.2	653.9	559.5
Case 6	523.3	552.8	562.3	497.4	620.1	551.2
Case 7	583.1	601.4	633.2	567.2	692.2	615.4
Case 8	578.3	586.3	597.9	543.7	672.5	595.7
Case 9	538.2	546.4	566.0	521.3	647.4	563.9
Case 10	398.9	417.2	470.7	374.3	531.9	438.6
Case 11	429.1	448.8	491.6	398.7	555.8	464.8
Case 12	485.3	497.2	513.5	428.3	596.5	504.2
Average	491.7	508.9	524.2	466.7	604.7	519.2

Table 4.10 above, show that for cases 1 to 9, the length of the pipe is inversely proportional to the illumination meaning as the length of the pipe increase by 1500mm, the illumination reduces by 6%.

Contrarily, for cases 10-12, the diameter of the pipe is directly proportional to illumination that is, as the diameter increases by 300mm, illumination also increases by 6.8%. Finally, as the diameters of the pipe and rod increases in cases 1 to 6 and the illumination increases by 2%.

4.4.1 Results Analysis and Discussion

The results from Table 4.10 were presented in charts and graphs for visual analysis to ease understanding and comparison between the cases.

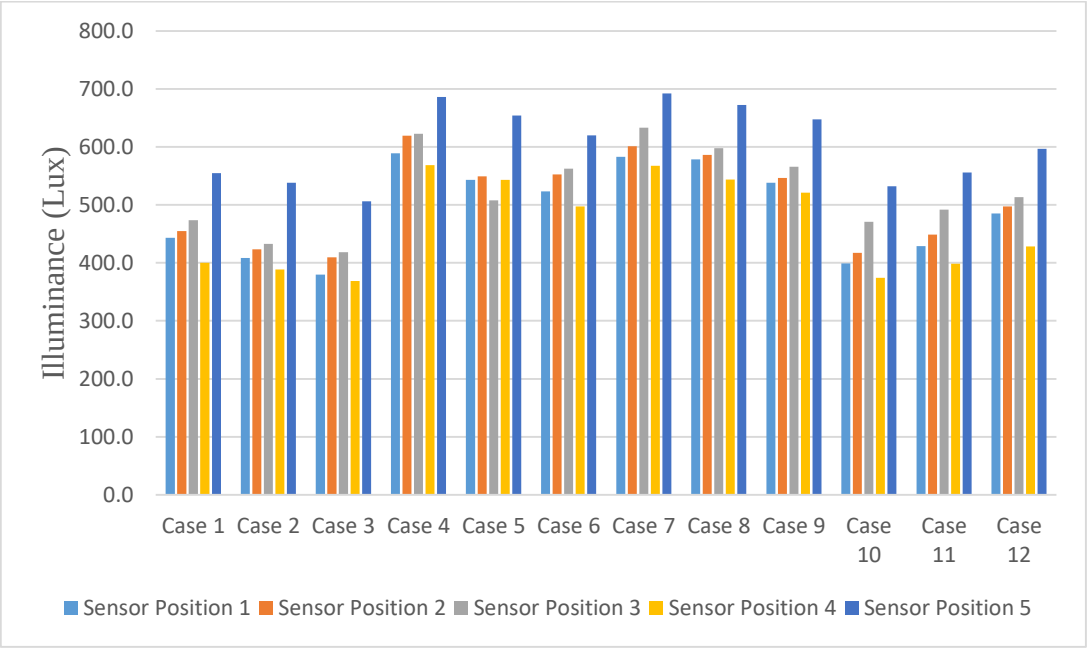


Figure 4.15 Illumination Quality for all Cases at all Sensor Positions

Source: Author (2016)

Figure 4.15 shows that the best average case having the best illuminance in the box is case 7.

The sensor at position 5 always has the highest illumination for all the cases because it shows illumination as light enters the box.

The sensor at position 3 (middle of the box) gives the best illuminance within the box the and that of position 4 gives the worst illuminance.

The relationship between illumination and light pipe height and diameter were shown in Figure 4.16 and Figure 4.17.

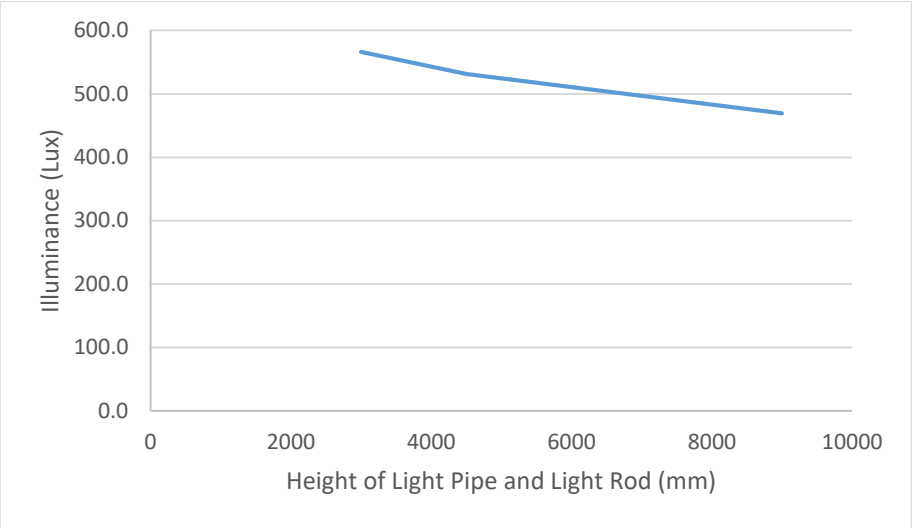


Figure 4.16 Illumination Levels for Change in Height of Light Pipe and Light Rod

Source: Author (2016)

Figure 4.16 illustrates that as the height of the light pipe and light rod increase by 1500mm, level of illuminance decrease by 6%.

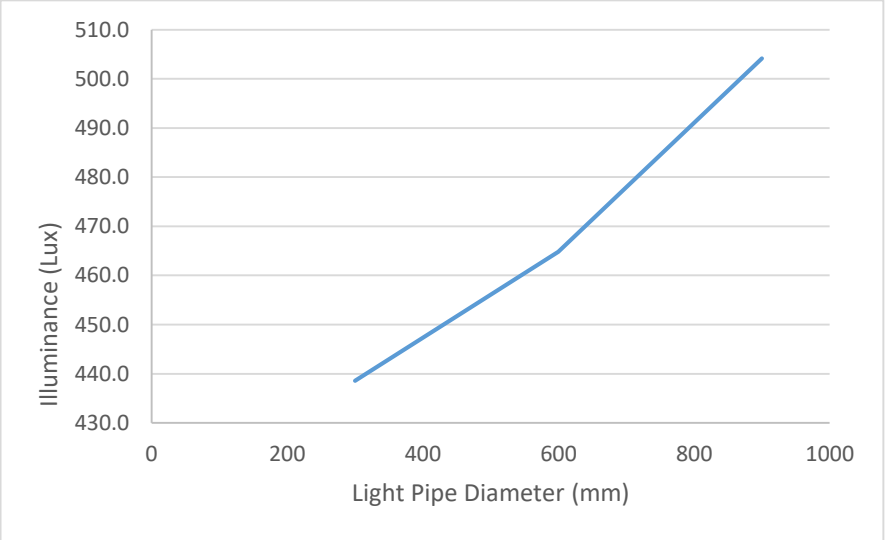


Figure 4.17 Illumination Level with Change in Diameter

Source: Author (2016)

Figure 4.17 shows as the diameter of the light pipe increases by 300mm, the illuminance in the box increase by 6.8%.

5.0 DESIGN REPORT

5.1 Introduction

In this chapter design report is discussed which include site location, site selection criteria and features on the selected site.

5.2 Site Location

Kano State is a state located in North-Western Nigeria. The capital of Kano State is Kano. Kano's once booming manufacturing sector has been stagnant over the last 15 years. Largely due to epileptic power. Kano State has been a commercial and agricultural state, known for the production of groundnuts as well as for its solid mineral deposits. It is arguably within the first five states in terms of commercial activity within Nigeria. The location is shown in Plate X.

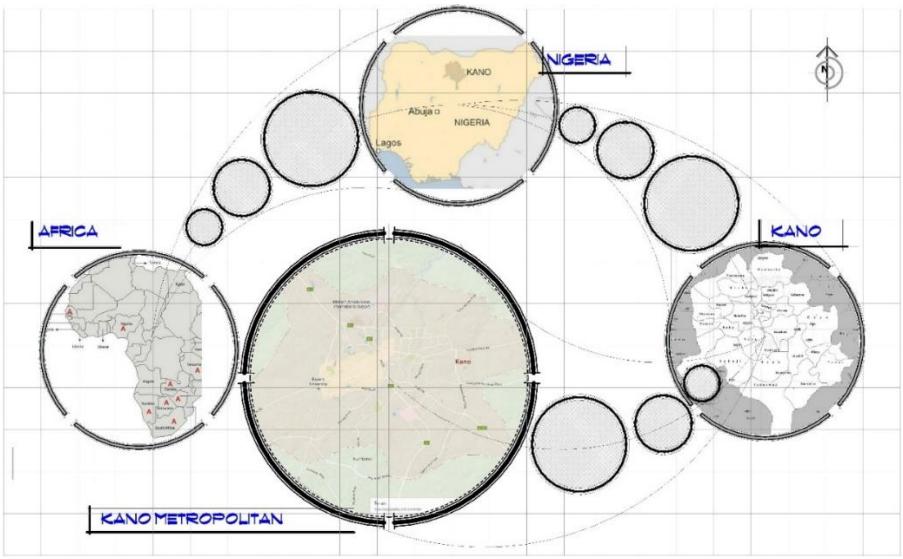


Plate X Map location.

Source: Author's sketch (2016)

5.3 Site Selection Criteria

Muhammad, Al Katheeri and Salam (2015), state that a shopping mall should be located in an area that is far away from existing malls, near major roads, in a commercial area, near a fire and police station and has high population density. Kano has limited land due to its high population density, but there still sites for commercial activities.

Within the perimeter circle, is the proposed central area of Kano municipal which is suitable for the location of a shopping mall, hence three sites were chosen from this area as seen in Plate XI and will be weighed based on the above considerations in order to select the most appropriate site.

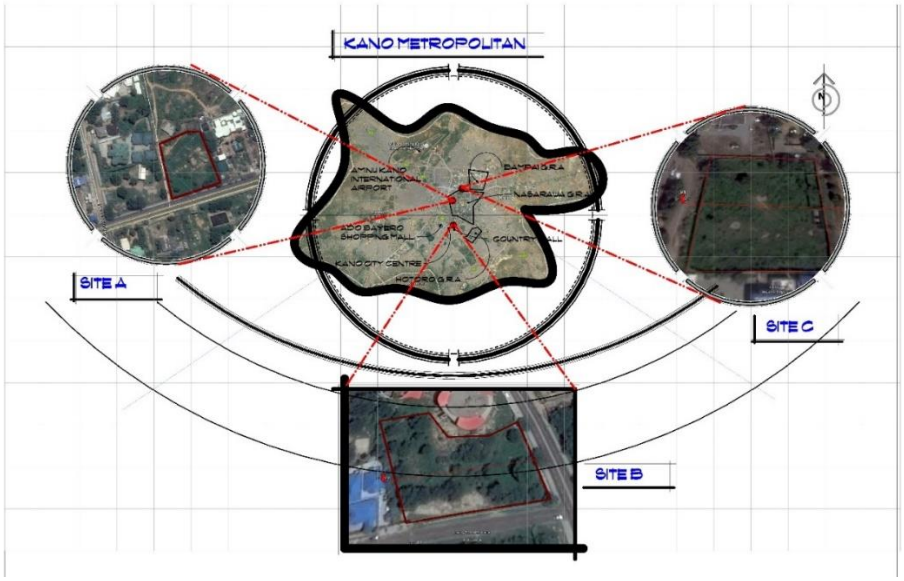


Plate XI Sites Location

Source: Author's sketch (2016)

5.3.1 Site A (Magwan Audu Bako Way, Kano.)

This area is located along Audu Bako Way. It is in Nasarawa GRA and also in close proximity to state government house, Magwan water resort. The site is accessible by road through Audu Bako.

5.3.2 Site B (Audu Bako Way, Kano.)

This area is located in Farm Centre along Marhaba Cinema Road. It is in close proximity to the Ado Bayero mall, Country mall, Marhaba Cinema, Farm centre Phone Village. Access route that branches off the Marhaba Cinema.

5.3.3 Site C (Murtala Muhammad way, Kano)

This area is located along Murtala Muhammad Way, near Zainab House opposite Kano Golf Course. It is in close proximity to Nasarawa G.R.A. and Bampai G.R.A. The site is accessible by road through Murtala Muhammad way, which also has a secondary lane, and another access route Tiga road. Based on the criteria researched, a quantitative result was derived leading to the selection of the best site among the three. The rating was based on 1 and 0, 1 denoting the presence of a criteria and 0 denoting its absence. The result is shown in Table 5.1 below

Table 5.1 Site Selection Criteria

Source: Author (2017)

Criteria	Site A	Site B	Site C	Remark
Legally Defined	1	1	1	All the Site are legally defined
Adequate size	1	1	1	All sites are adequate.
Owner	1	1	1	The sites are owned by Kano state.
Zoning	0	1	1	A and B are within commercial area
Road Access	1	1	1	All sites have major road access
Secondary Lane	0	0	1	Site C has a secondary lane access
Topography	1	1	1	The sites slope gently, will ease drainage
Infrastructure	1	1	1	All sites have electrical, water and sewage.
Total	6	7	8	

5.4 The Proposed Site

The site is located within commercial area, close to public buildings. It is adjacent to first bank and Kedco Yard towards the left and right respectively, and opposite Golf Course and some shops It slopes gently towards the North which will ease drainage in that direction, it is easily accessible through Murtala Muhammad Way which is a major road and Bompai Road which is a secondary Road. The site is shown in Plate XII below.

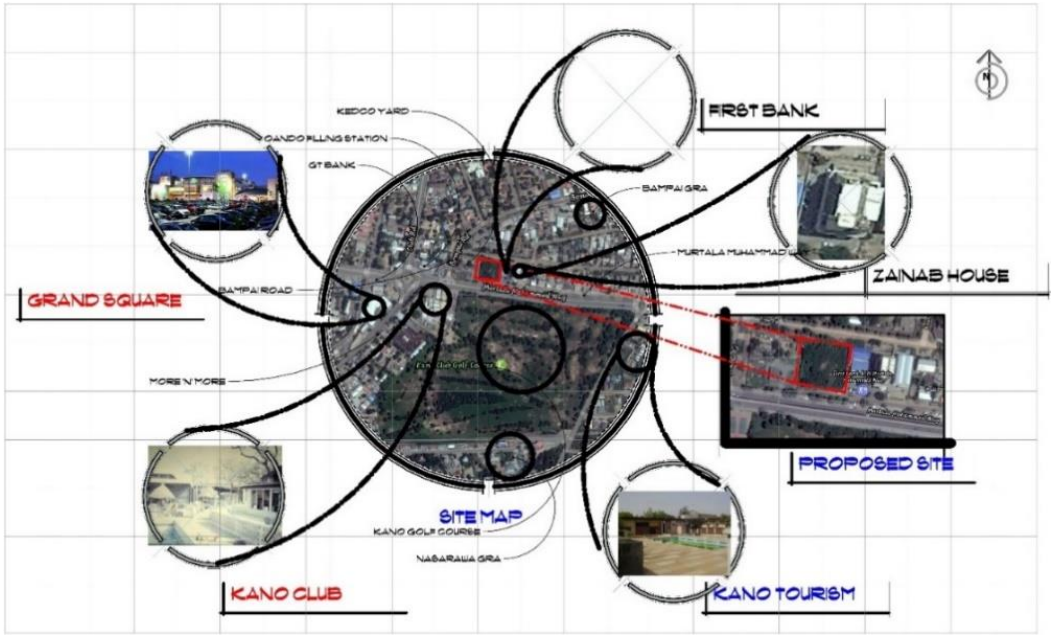


Plate XII Proposed Site

Source: Google maps (2016), Author (2016)

5.4.1 Features on Site

The site has both manmade and natural features. The natural features are the geology and topography, climate and wind shown in Plate XIII and Plate XIV while the manmade features are the roads and existing infrastructure.

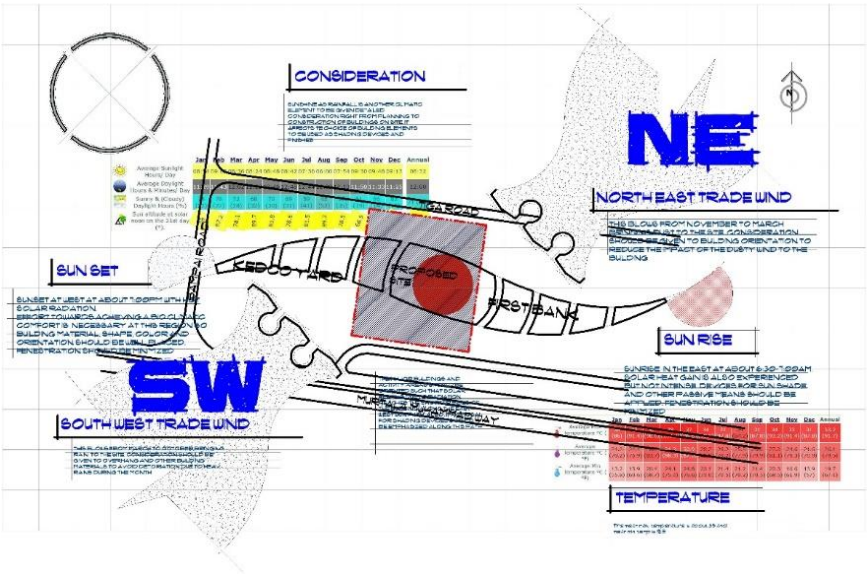


Plate XIII Site Features

Source: Author's sketch (2016)

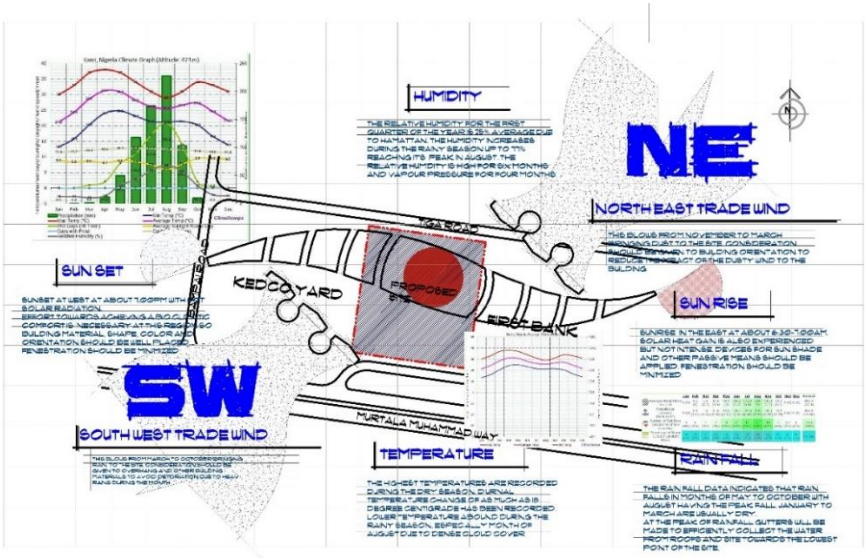


Plate XIV Site climatic Analysis

Source: Authors sketch (2016)

6.0 BRIEF FORMULATION

6.1 Introduction

The design brief was gotten from the requirements of a vertical shopping mall with respect to the location, and scope of the research. The site was zoned into five parts according to function covering the main building, the parking, the security accommodation, the services building and the storage.

The main building contains

i. Administrative area- These are the facilities in charge of running all other units of the shopping mall. It includes the managing director, directors, personnel, account, and advertisement.
ii. Staff Facilities- These are the facilities mainly used to support the day-to-day activities of the staff of the shopping mall. These services include restroom, locker room, prayer room, washing facility, staff entrance, canteen and service lift
iii. Restaurant- These are all the facilities that prepare or serves food and drinks for customers. These include mini restaurant, coffee, ice cream, chocolates and snack bars.
iv. Kitchen- This facility prepares the food to be served in the restaurants and event centres
v. Cinema- It is a place where movies are shown for public viewing. it includes managers office, refreshment kiosk, ticket room, projection room, cleaners store, film store, control room, main theatre
vi. Leisure- it offers services where people go to unwind stress and to relax. It includes game centre, kids centre, gymnasium and events centres.

vii. Food- these facilities offer edible items like fresh fruits and vegetables. It include mini restaurant, fresh food, gourmet and fresh market, hypermarket, food court, fine dining.

viii. Retail- these shops sell consumer goods to customers in small quantities. It includes pharmacies, boutique, jewellery, beauty and fashion accessories, electronics, kitchenware, garments, children boutique, and furniture.

ix. Other Services- These are all other services that can be offered in this facility like the make-up studio, photo studio, bank, rental offices and so on.

The storage contains

x. Storage- These are those facilities where the departments in the shopping mall store their goods. It includes warehouse, stores and offloading bay.

The parking/ workers facility

i. Parking- These refer to spaces provided where customers keep their cars within the premises of the shopping mall.

ii. Workers facility- This facility houses

The security zone consists

i. Security- These refer to all the services provided in the shopping mall to ensure the safety of the mall, customers, staff and goods.

ii. Security Accommodation- These are the accommodation provided for the security personnel in the shopping mall

6.2 Design Consideration

The design was produced taking into consideration the daylighting principles discussed in previous chapters.

6.2.1 Structural Elements

The major structural elements were reinforced concrete columns were erected from the basement to the atrium, two-way reinforced concrete beams on ceilings to accommodate large span area without intermediate support, lattice frames which supported the curved side of the building form.

6.2.2 Entrances and Exits

Four entrances and exits were provided to reduce congestion: One main entrance and exit for customers and visitors, Service entrance and exit for staff, basement entrance and exit for parking and underground access into the building.

6.2.3 Circulation

Vertical circulation in forms of lifts, escalators, service lifts, ramps and staircases to ease movement between floors of the mall.

Stair escape routes were provided for the basement and cinema.

Horizontal circulation was also provided like verandas and concourse

6.2.4 Material

Double-glazed glasses were provided facing the North and south to maximized daylight access into the building while reducing glare. Aluminium to cover the lattice frame in the curved part of the building form.

6.2.5 Services

Rooms were provided Mechanical and electrical central control and distribution. These services are transported to the vertical duct in the main building through main duct which is then transferred to and distributed between the various floors using the service floor.

6.2.6 Daylighting strategies used

6.2.6.1 Orientation

The building was oriented with its longer side on East and West axis to maximize daylight intrusion while reducing glare in the building.

6.2.6.2 Shading

Monocoque shading device (structural skin), perforated walls were also used to shade some parts of the building and at the same time provide aesthetics.

6.2.6.3 Light redirecting device

Light shelves were provided on the sidelight apertures to reduce glare and distribute light deeper into the interior of the building.

6.2.6.4 Side lights

Glazing was provided as Sidelight apertures facing north and South

6.2.6.5 Toplight

Atrium and monitor roof were used as toplighting to provide uniform light to the core of the building.

6.2.6.6 Light pipes

Light pipes were used to improve daylighting within the windowless part of the building. Twenty light pipes of 600mm diameter and 9000mm height were provided on the curved part of the building form. Those spaces showed a 20% illuminance level which met the illuminance required for a shopping mall space.

7.0 SUMMARY AND CONCLUSION

7.1 Summary

To achieve the research aim, an in-depth literature was undertaken, this aided in establishing the benefits of daylighting, its principles and strategies. The strategies were grouped into either toplighting or sidelighting with toplighting providing more uniform and brighter light into a space.

For the first objective, international case studies were carried out to establish the current trend in vertical shopping mall design and to collect and analyse data on variables related to design in general and daylighting provision in terms of orientation, shading and daylighting strategies used. This further influenced the design requirements, building materials, and daylighting strategies used in the proposed building.

To achieve the second objective, light pipes and light tubes of varying lengths and diameters were tested in a windowless box (3m x 3m x 3m). These were then modelled in Ecotect® Radiance® simulated and the results of the illumination received at five positions in the box were analysed. In the first instance, the lengths of the light pipes and light rods were increased in multiples of 1.5m while keeping their diameters constant. The results show that the illuminance within the box reduces by 6% in every 1.5m length, this means the illumination decreases by 30lux for every 1.5m length. It can be deduced that the height of the light pipe and light rod should not exceed 9.5m in order to meet the illuminance requirement (300-500 lux) within a shopping mall.

To achieve the third objective, a suitable site was chosen in the proposed study area and site analysis was carried out on the selected site. The proposed design was reported with respect to its structural elements, entrances and exits, circulation, materials, services and daylighting strategies used.

To further validate the study, two tests were carried out on a space in the design the first instance had side light as the only source of daylight and the second instance had side light with vertical light pipes. The results showed that the vertical light pipes added 20% daylight to the space.

7.2 Conclusion

The main problem of daylighting in a building in the hot semi-arid zone is the glare it comes along with; this causes discoloration and visual discomfort the inhabitants of a space. Shopping malls also encounter these problems along with poor distribution of the light within a space. Deductions from literature, case studies conducted and simulations led to the following conclusions.

Due to the width of a space in a shopping mall, side light and exterior toplight is inadequate to provide daylight within the space

As daylight travels in a straight path, the shelves and merchandise provided within a space obstructs its transfer deeper into a space.

Orientation determines the shading to be provided for sidelight apertures to further exclude glare from reaching interior of a shopping mall.

The fenestration material used also determines the quality and quantity of daylighting within the space.

Light pipes transfer more daylighting to lower floors than other toplighting strategies like skylights.

7.3 Recommendation

Finally, this study could be said to have achieved its objectives and answers its research questions. Furthermore, some recommendations are given as follows;

Based on the simulation results, it is recommended that vertical light pipe should not exceed a height of 9.5m for effective and efficient light transmission.

Although vertical light pipes improved the interior daylight up to 20%, it cannot be used on its own. Other daylight strategies should also be considered during the design stage of any project.

7.4 Contribution to Knowledge

This study provides an additional way of optimizing daylight using vertical light pipes in the hot semi-arid zone, where additional 20% daylight was achieved in an interior of a shopping mall.

It also proves that illuminance within a space reduces by 6% in every 1.5m length of vertical light pipes.

7.5 Limitation

Inability of the researcher to have access to current daylighting simulating softwares such as Photopia®.

Lack of indigenous work on the study climate area on similar topic. Inability of the researcher to have access to a live model of the light pipe so that live testing will be conducted.

REFERENCES

Adaji, E. E. (2015). *Use of Daylight Strategies for Lighting Energy Cost Reduction in a Metropolitan Library Design.* Zaria: Unpublished work.

Adesina, M. O. (2011). *Application of Daylighting Strategies in Civic Centre Design.* Zaria: Unpublished work.

Agarwal, R. (2015). *Your Article Library*. Retrieved June 1, 2016, from yourarticllibrary.com

Aizenberg, J. B. (2003). Light & Enngineering. *Integral lighting systems for rooms with insufficient daylight*.

Ander, G. D. (2014, October 23). *Whole Building Design Guide.* Retrieved May 19, 2016, from National Institute of Building Science: http://energy.gov/eere/femp/federal-energy-management-program

Arch Daily. (2014, June 12). *Zorlu Centre / Emre Arolat Architects + Tabanlioglu Architects.* Retrieved from Arch Daily: http//www.archdaily.com/514825/zorlu-center-emrearolat-architects-tabanlioglu-architects

Arch Daily. (2016, March 11). *ARG Shopping Mall / ARSH 4D Studio.* Retrieved from Arch Daily: http//www.archdaily.com/783535/arg-shopping-mall-arsh-4d-studio

Arch Daily. (2016, July 28). *Parc Central / Benoy.* Retrieved from Arch Daily: http//www.archdaily.com/parc-center-boney

ArchDaily. (2016, January 14). *Fulton Center / Grimshaw*. Retrieved from Arch Daily: http://www.archdaily.com/780271/faulton-center-grimshaw/

Austrian Standards Institute. (2013). Standard values for indoor and outdoor lighting. In Z. Lighting, *The Lighting Handbook* (pp. 27-43). AUSTRIA: Austrian Standards Institute.

Autodesk Education Community. (2015). *Autodesk Sustainability Workshop*. Retrieved June 14, 2016, from Autodesk Education Community: http://sustainabilityworkshop.autodesk.com/buildings/apertures-daylighting

Boubekri, M. (2008). *Daylighting, Architecture and Health.* Burlington: Elsevier Ltd.

Brain, J. (2015, May 19). *Ciralight Global*. Retrieved July 13, 2016, from What Are the Benefits of Tubular Daylighting Devices?: http://www.ciralight.com/blog/what-are-the-benefits-of-tubular-daylighting-devices

Bristolite Daylighting Systems. (2016). *Basics of Daylighting in a Green Environment*. Retrieved June 20, 2016, from Bristolite Daylighting Systems: http://www.bristolite.com/Interfaces/lesson2.3.aspx

Callow, J. M. (2003). *Daylighting Using Tubular Light Guide Systems.* Nottingham: Unpublished work.

Chai, T., & Draxler, R. R. (2014). Root mean square error (RMSE) or mean absolute error (MAE)? – Arguments against avoiding RMSE in the literature. *Geoscientific Model Development*, 1247.

Cimbala, J. M. (2011, August 26). Basic Statistics. Penn State.

Climatetemp.com. (2015). *Tehran*. Retrieved from http//www.tehran.climatemps.com

Craven, J. (2016). *What is a Clerestory Window?* Retrieved June 27, 2016, from Architecture About .com: http://architecture.about.com/od/structural/g/clerestory.htm

EHI Retail Institute. (2011). Shopping mall lighting . *licht.wissen 06*, pp. 40-43.

Energy Efficient Technologies. (2015). *HK EE NET*. Retrieved May 20, 2016, from Energy Efficient Technologies: http://ee.emsd.gov.hk/english/other/oth_tech/oth_tech.html

Environmental Building News. (1999, October 1). *Daylighting with Windows and Skylights: A Checklist for Action*. Retrieved June 20, 2016, from Environmental Building News 9-99: www.buildinggreen.com

Explorable.com. (2016). *Case Study Research Design*. Retrieved from Explorable: https://explorable.com/case-study-research-design

Gairaa, K., & Bakelli, Y. (2013). A Comparative Study of Some Regression Models to Estimate the Global Solar Radiation on a Horizontal Surface from Sunshine Duration and Meteorological Parameters for Ghardaïa Site, Algeria. *ISRN Renewable Energy*.

Gelfand, L. (2010). *Sustainable School Architecture.* New Jersey: John Weley & Sons, Inc.

Green Building Technology. (2007). *Minimizing Building Energy Consumption.* Retrieved May 18, 2016, from Green Building Tech HK: http://gbtech.emsd.gov.hk/english/minimize/minimize.html

Groat, L., & Wang, D. (2002). *Architectural Research Methods.* New York: John Wiley and Sons Inc.

Idris, H. A. (2015). *Passive Solution to Increase Energy Efficiency in The Design of a Shopping Mall Abuja.* Zaria: Unpublished work.

Ikuh, I. C. (2011). *An Application of Daylight Design Principle for Energy Efficiency in the Design of Energy Centres.* Zaria: unpublished work.

International Energy Agency. (2010). *Daylight in Building.* Hertfordshire: AECOM Ltd.

Kallet, & Richard, H. (2004). "How to Write the Methods Section of a Research Paper.". *Respiratory Care 49*, 1229-1232.

Kano State Government. (2013). *Kano State Investors Handbook.* Kano: Ministry of Commerce, Industry, Cooperatives & Tourism. Kano State. Nigeria.

Katiyar, A. K., Kumar1, A., Pandey, C. K., & Das, B. (2010). A comparative study of monthly mean daily clear sky radiation over India. *INTERNATIONAL JOURNAL OF ENERGY AND ENVIRONMENT, Volume 1*(Issue 1, 2010), 179. Retrieved 09 2016

Kitson, M. (2016, February 25). *Hilson Moran.* Retrieved May 20, 2016, from Designing high-impact mall façades that drive footfall and enhance shopper comfort: http://www.hilsonmoran.com/News/Articles/Designing_high-impact_mall_fa%C3%A7ades_that_drive_footfall_and_enhance_shopper_comfort/

Koh, B. B., & Meyer, P. (2015). *Daylighting Principles (and design) and Recent Standard Changes.* Raleigh, North Carolina, United States of America.

Korea Tourism Organisation. (2016). *Imagine your Korea.* Retrieved from Destination by Rigion: http//english.visitkorea.or.kr

Ladan, H. (2011). *Application of Daylighting Techniques to Improve Energy Efficiency in the Design of Faculty Buildimgs.* Zaria: Unpublished work.

Malls. com. (2016). *Zorlu Center*. Retrieved from Malls. com: http//www.malls.com/tr/malls/zorlu_center.html

Mohamad, M. Y., Al Katheeri, F., & Salam, A. (2015). A GIS Application for Location Selection and Customers' Preferences for Shopping Malls in Al Ain City; UAE. *American Journal of Geographic Information System*, 79,80.

National Association of Rooflight Manufacturers . (2003). *Natural Daylight Design Through Rooflighting.* Bedfordshire: National Association of Rooflight Manufacturers .

New World Encyclopedia. (2015, September 15). *New World Encyclopedia*. Retrieved June 1, 2016, from http://www.newworldencyclopedia.org/entry/Main_Page

Nigerian National Petroleum Corporation. (2016, June 23). *NIgeria Profile*. Retrieved June 23, 2016, from Nigerian National Petroleum Corporation: http://www.nnpcgroup.com/NNPCBusiness/BusinessInformation/OilGasinNigeria/NigeriaProfile.aspx

Obadote, E. D. (2009). Energy Crisis in Nigeria: Technical Issues and Solutions. *Power Sector Prayer Conference*, (pp. 1-3). Abuja.

Olatunji, O. A. (2014). *Beauty and Fashion Centre Abuja: Exploring The Use of Daylight to Enhance Visual Comfort.* Zaria: Unpublished work.

Pease, C. M., & Bull, J. J. (2010). *Chapter 18. Correlations are hard to interpret*. Retrieved 09 21, 2016, from Interpretations: https://bio301d.com/.../interpretation.../chapter-18-correlations-are-hard-to-interpret

Phillips, D. (2004). *Daylighting;Natural Light in Architecture.* Burlington: Architectural Press.

Polit, D., & Hungler, B. F. (1999). *Principles and Methods (6th Ed.).* Phildelphia,: Lippincott Williams & Wilkins.

Real Iran. (2015, October 08). *Top 10 Most Luxurious Shopping Malls in Iran*. Retrieved from http//realiran.org/top-10-most-luxurious-shopping-malls-in-iran/

Reinhart, C. (2011). Natural Light in Design. *Static Daylighting Metrics* . Sydney, Australia: National Research Council of ...

Reinhart, C. F. (2009). *Experimental validation of autodesk 3ds max design2009 and daysim 3.0: Technical report submitted to Autodesk Canada Co. Media and Entertainment.*

Richman, E. E. (2010). Requirements for Lighting Levels. In E. E. Richman. Pacific Northwest National Laboratory.

Ruck, N., Aschehoug, Ø., Aydinli, S., Christoffersen, J., Courret, G., Edmonds, I., . . . Selkowitz, S. (2000). *Daylight in Buildings.* Washington: the Lawrence Berkeley National Laboratory.

Ruya, D. (2015, December 27). *Lighting theory*. Retrieved June 20, 2016, from LumenHub: 2016

Salisu, A. S. (2015). *Optimising Fenestration for Daylight Provision in the Architecture of Secondary Schools in Nigeria Using Climate-Based Daylight Modelling.* Zaria: Unpublished.

Salisu, A. S. (2015). *Optimising Fenestration for Daylight Provision in the Architecture of Secondary Schools in Nigeria Using Climate-Based Daylight Modelling.* Zaria: Unpublished work.

Tandon, U. (2015, August 26). EzineArticles. *The Different Types of Shopping Malls*.

Tehran Municipality, Public & International Relations Department. (2016). *Tehran Climate*. Retrieved from en.tehran.ir/default.aspx?tabid=106

Tukur, R. B. (2013). *Harnessing daylight potentials as a tool for visual and thermal comfort in residential buildings.* Nottingham: Unpublished work.

University College Dublin, Energy Research Group. (n.d.). *Daylighting in Buildings.* Ireland: University College Dublin, Energy Research Group.

UNSW Australia. (2013, June Thursday 20). *UNSW Library*. Retrieved from UNSW Australia Current Student: https://student.unsw.edu.au/what-case-study

VELUX Group. (2014). *Daylight, Energy and Indoor Climate Basic Book.* Hørsholm.

Weather Online. (2016). *Weather Online*. Retrieved from Weather Online ltd: http//www,weatheronline.co.uk/reports/climate/turker.htm

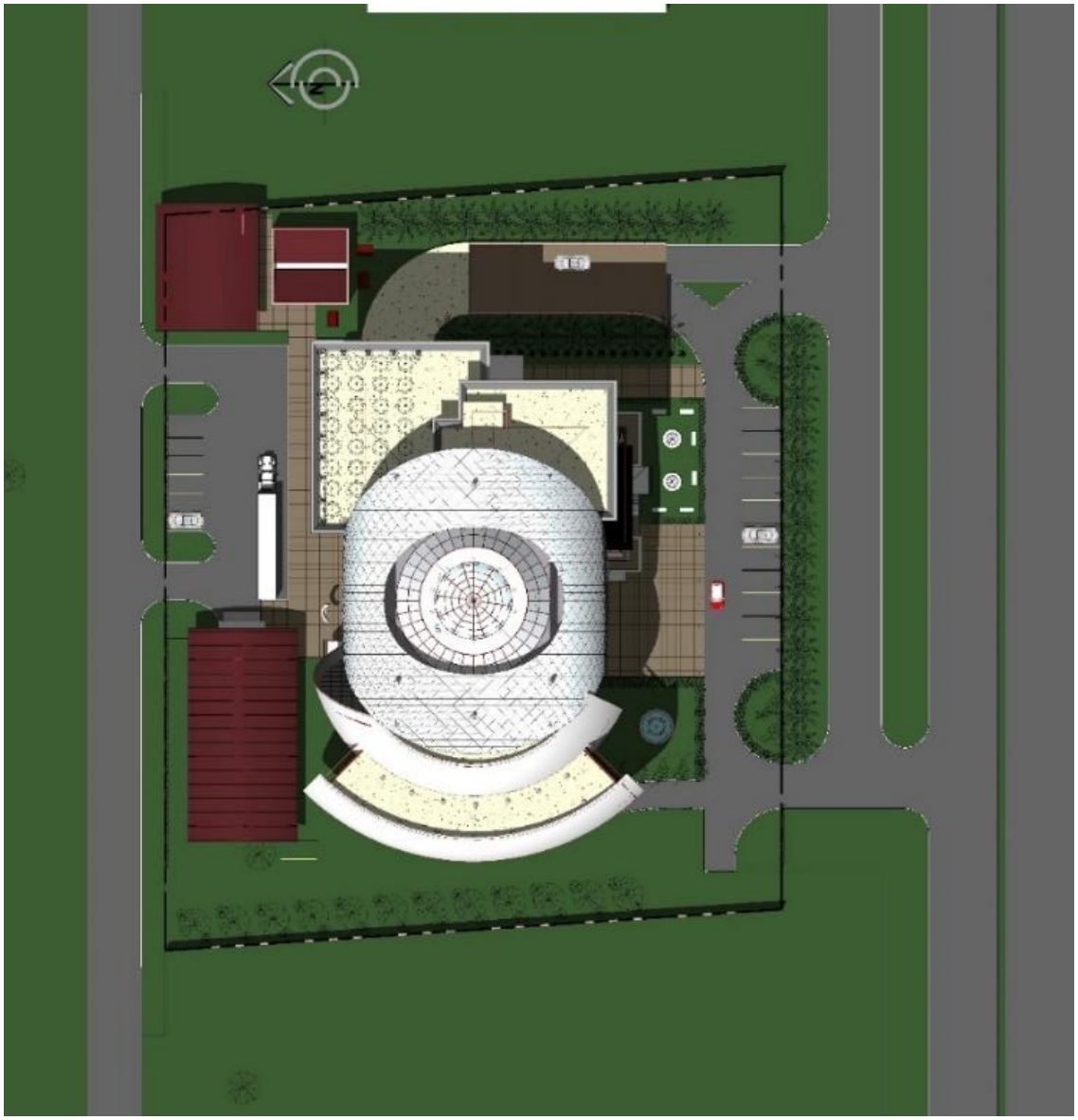
World Heritage Encyclopedia. (2015, September 15). Super-regional mall. *World Heritage Encyclopedia*.

World Weather and Climate Information. (2016). *Climate in South Korea.* Retrieved from World Weather and Climate Information: https//weather-and climate.com/average-nonthly-rainfall-temperature-sunshne-in-South-Korea

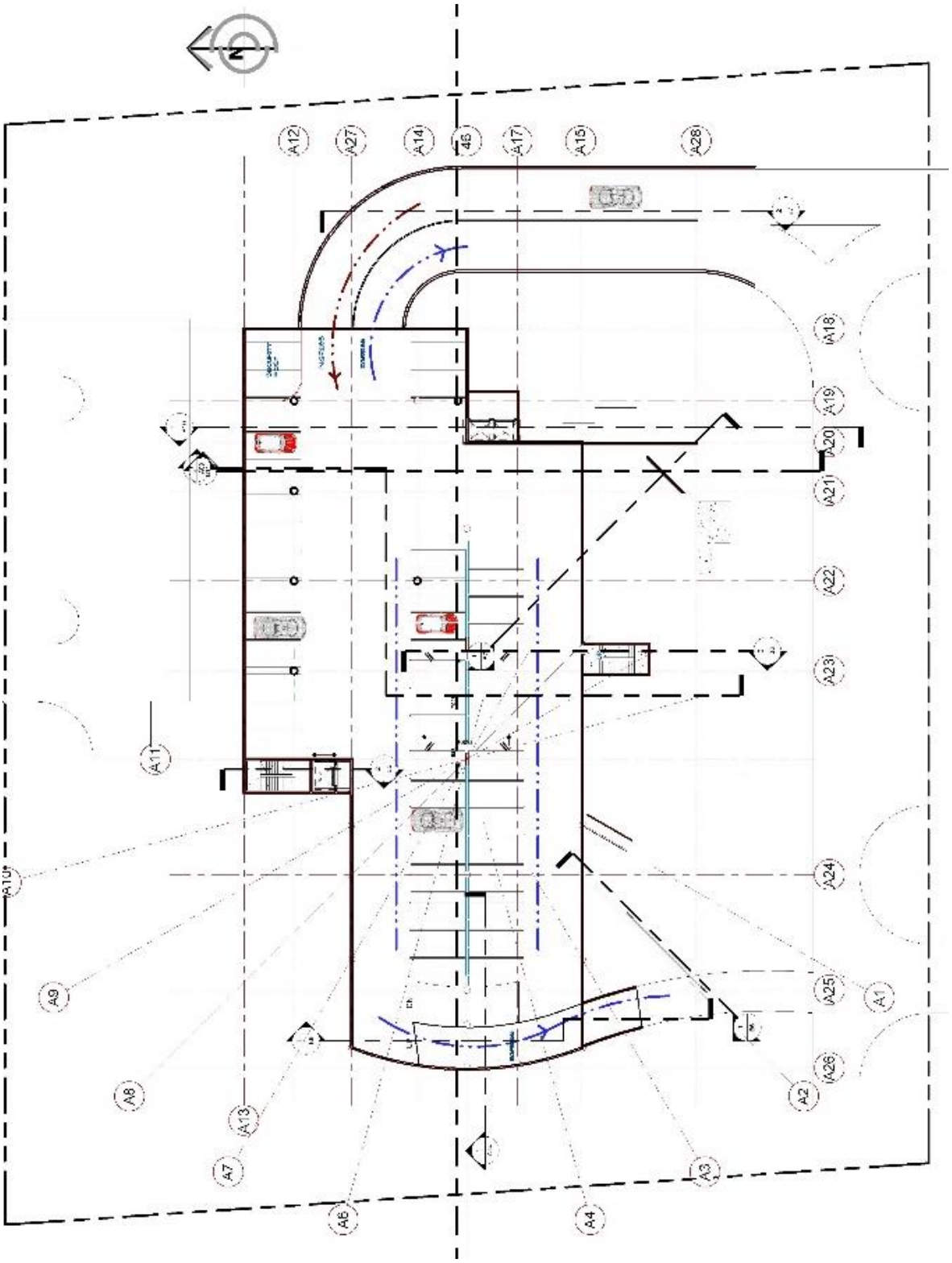
ZinCo. (2015, August 10). *Zorlu Center Istanbul - green superlatives.* Retrieved from Zinco Green Roof: http//www.zinco-greenroof.com

APPENDICES

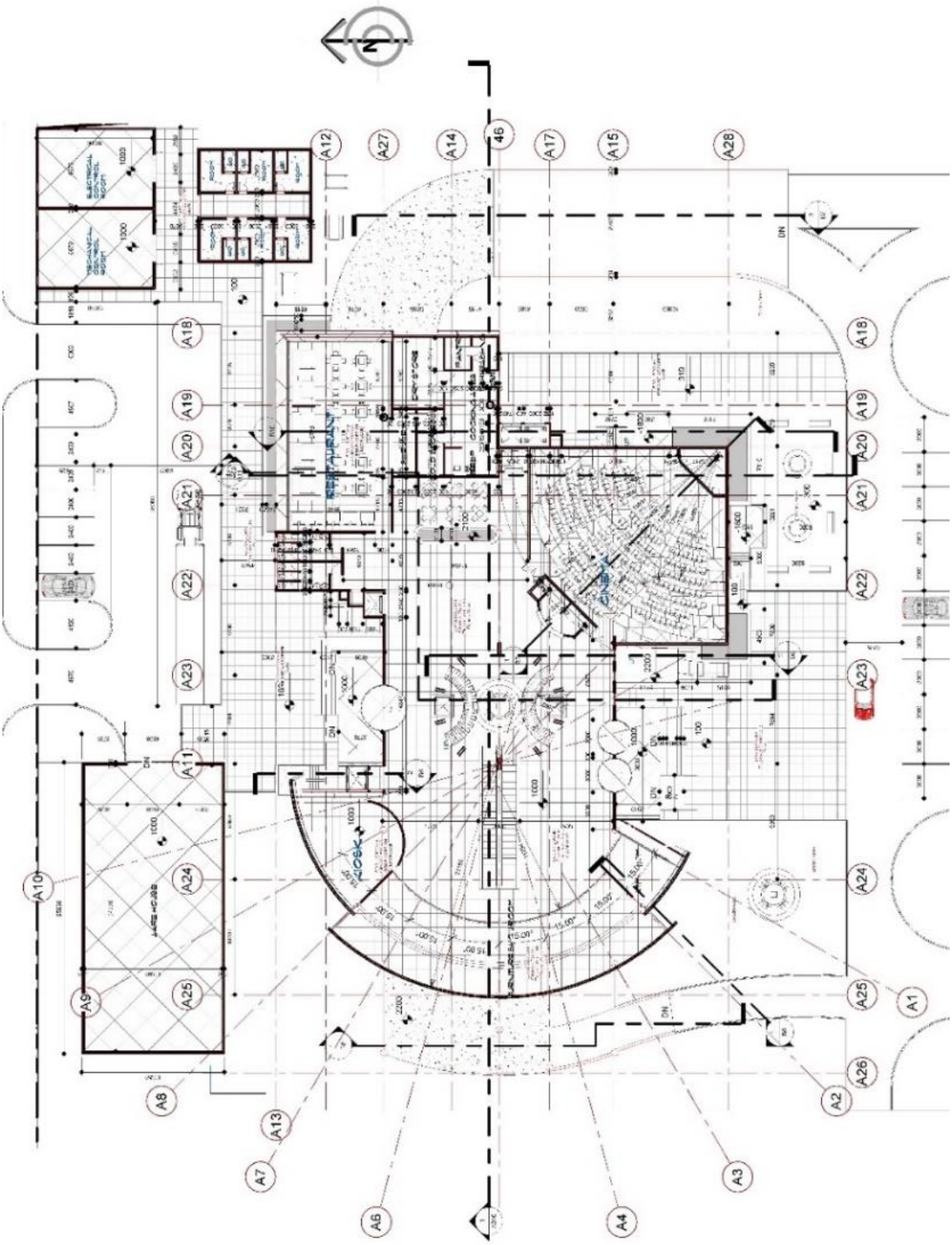
APPENDIX I: DESIGN



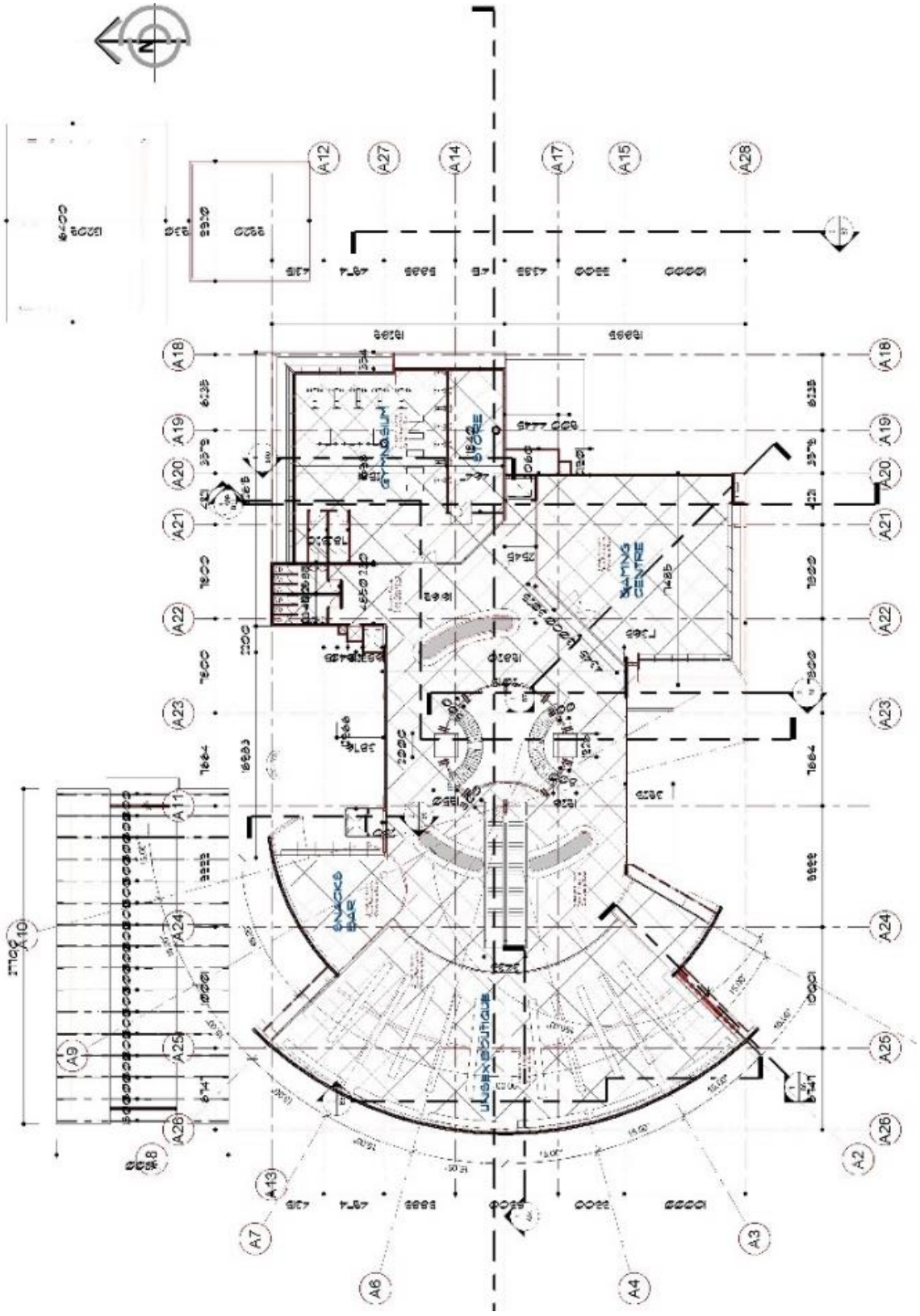
Appendix I Site Plan of the proposed building



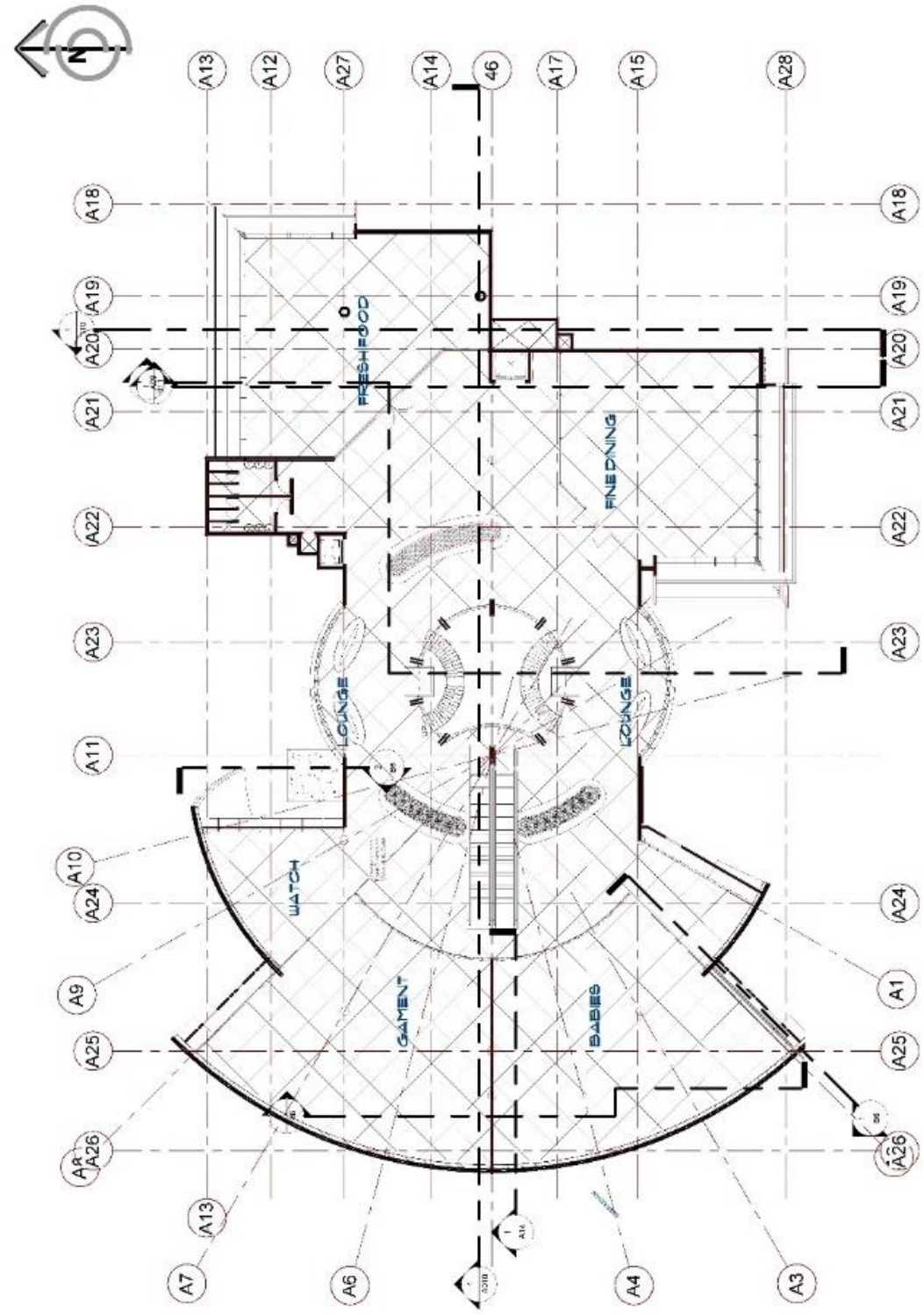
Appendix II Basement Plan of the proposed building



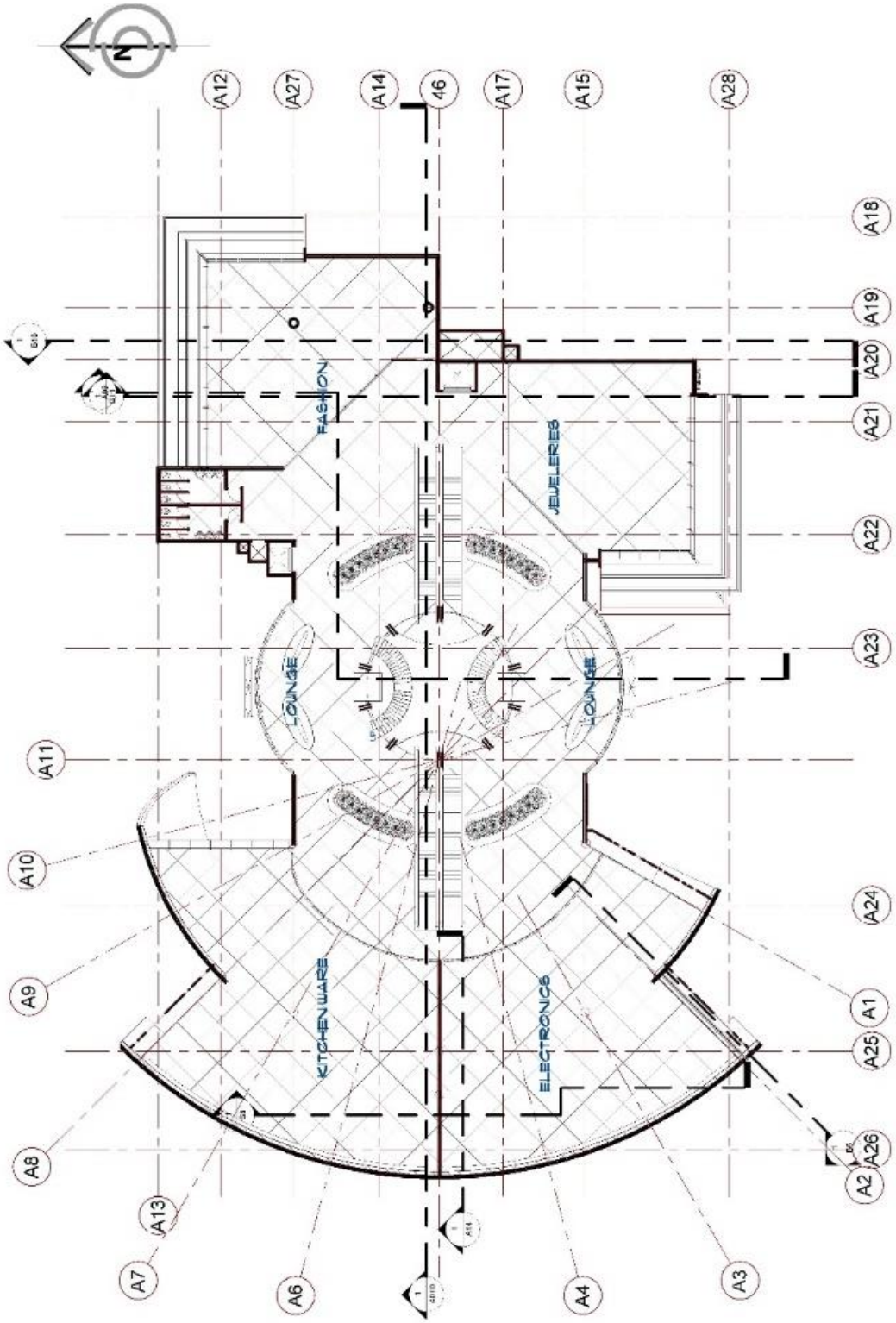
Appendix III Ground Floor Plan of the proposed building



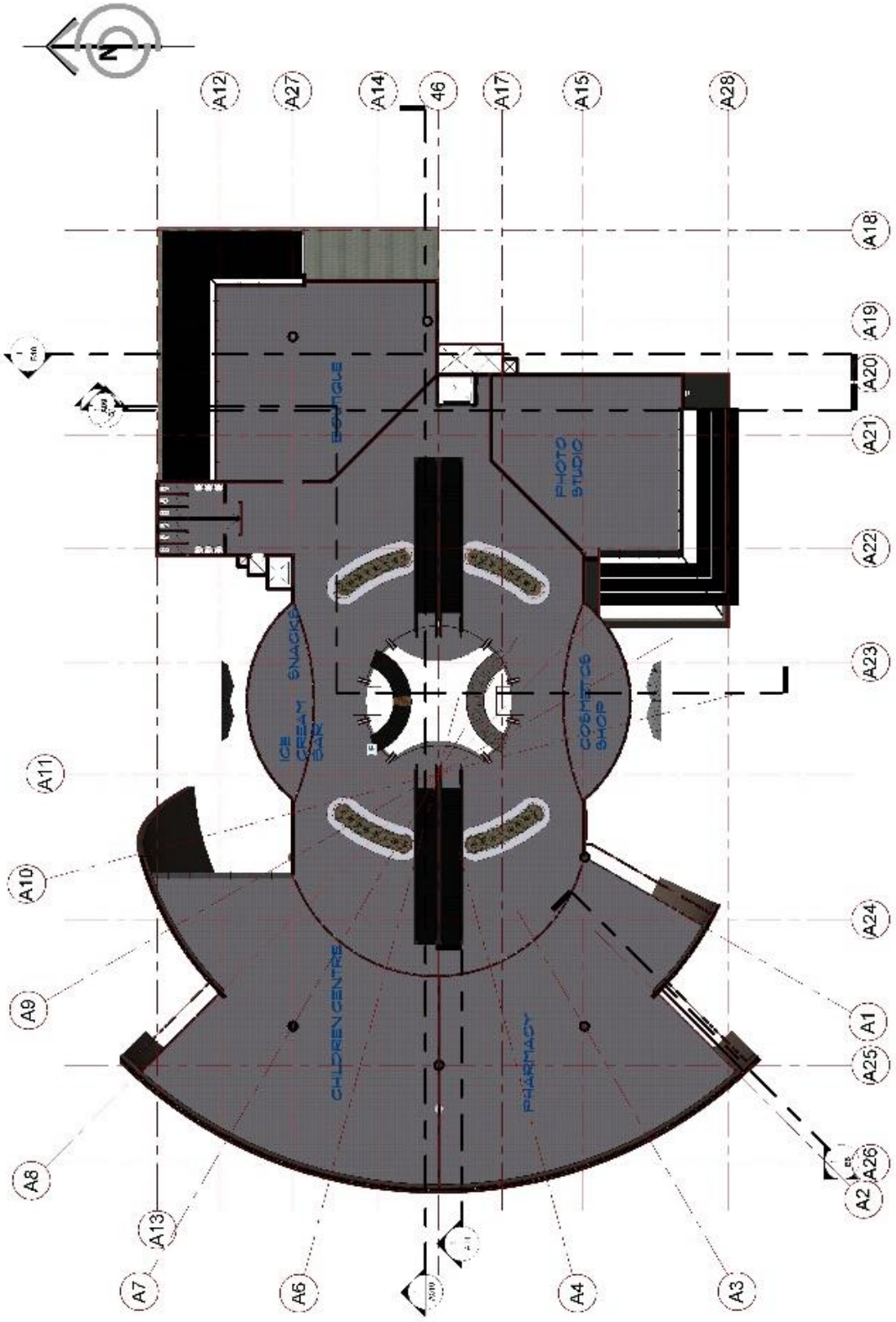
Appendix IV First Floor Plan of the proposed building



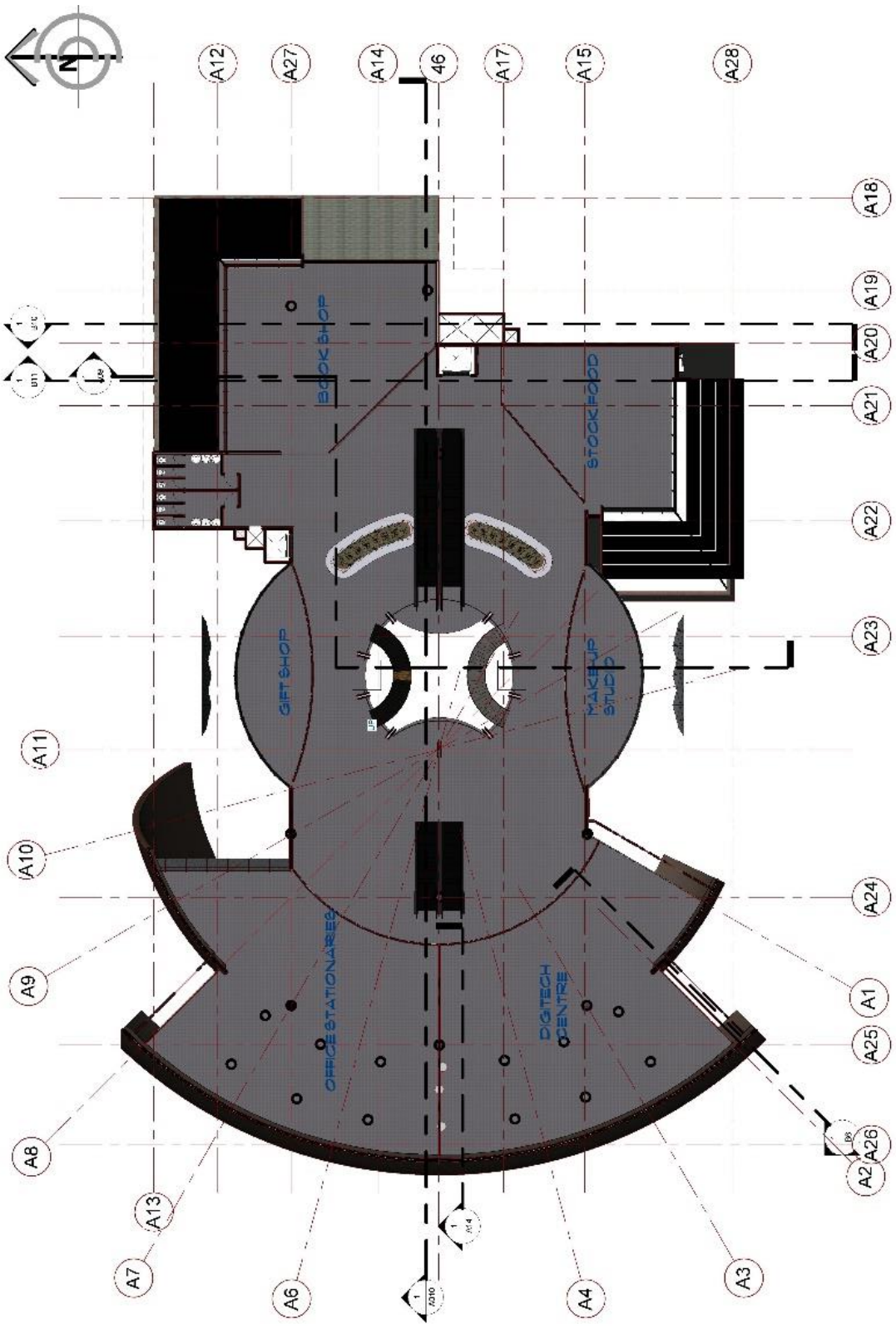
Appendix V Second Floor Plan of the proposed building



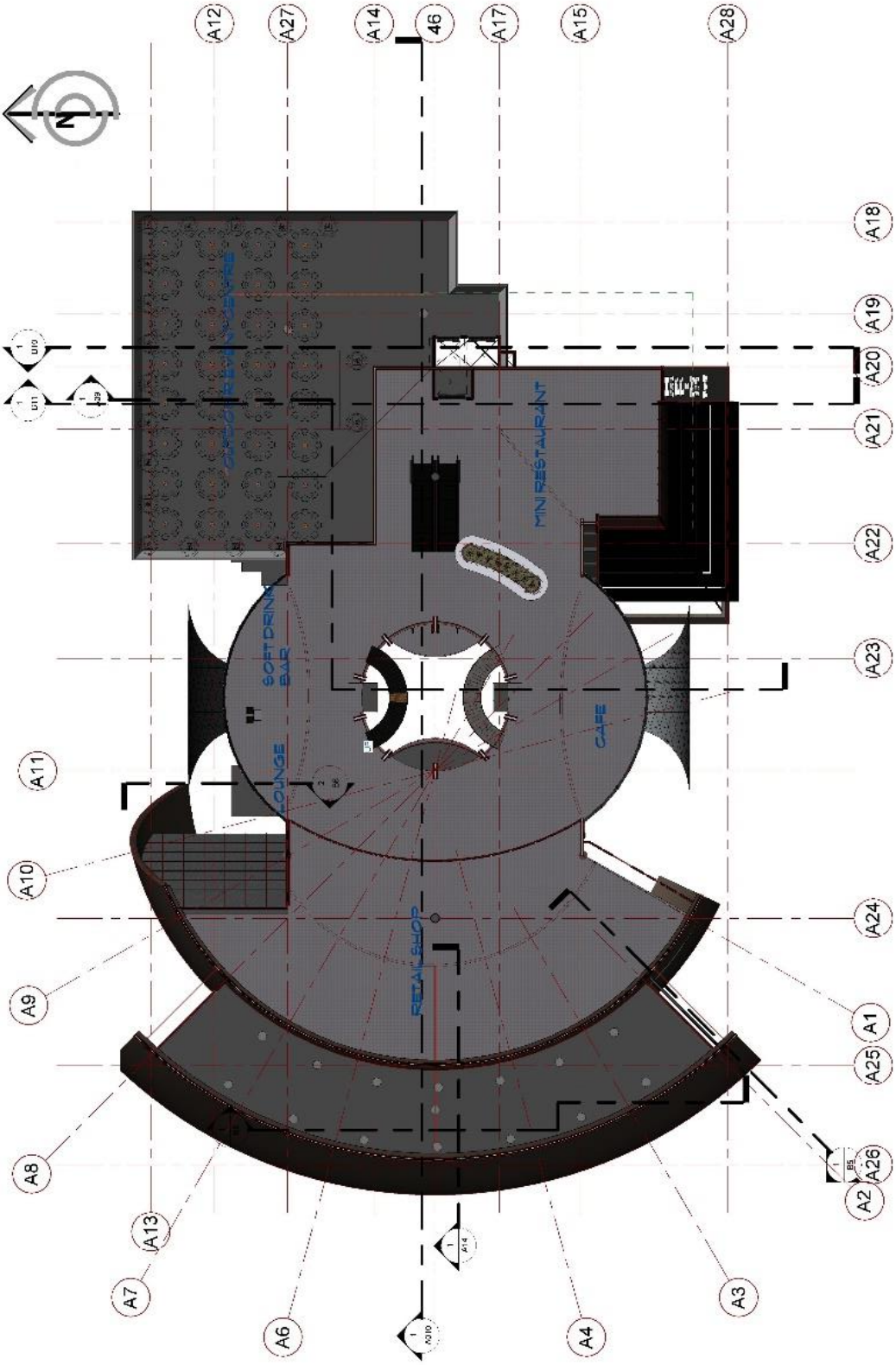
Appendix VI Third Floor Plan of the proposed building



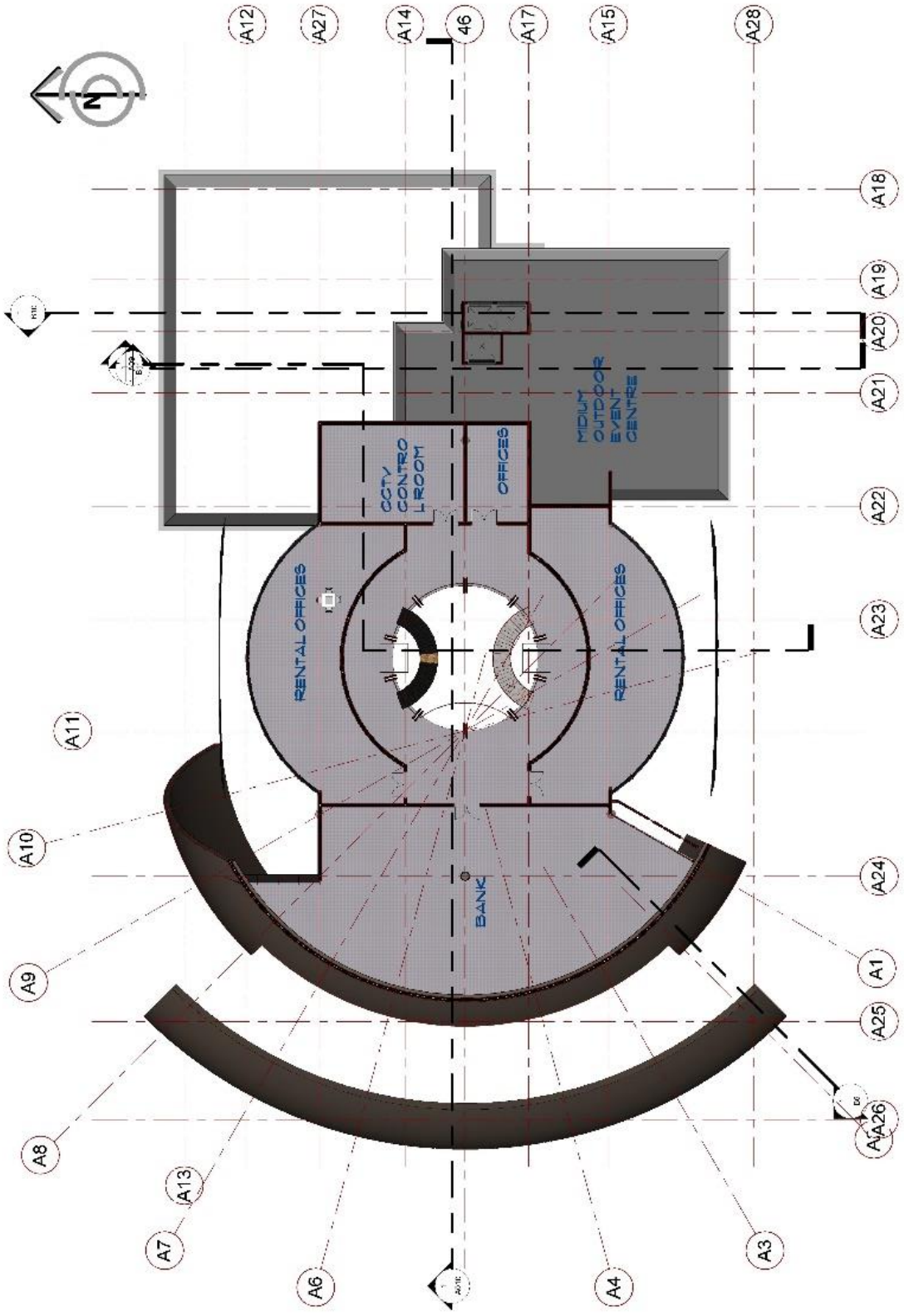
Appendix VII Forth Floor Plan of the proposed building



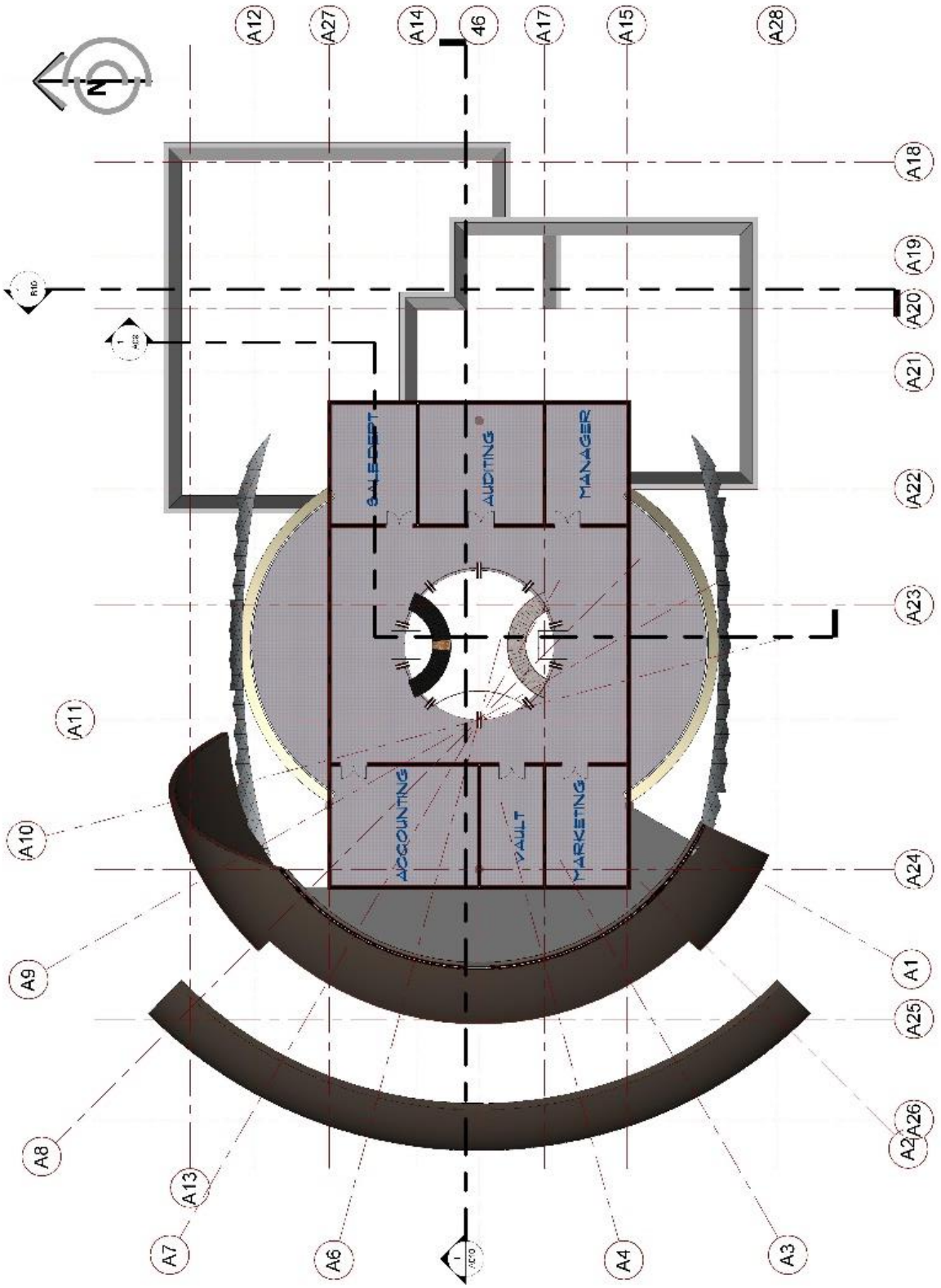
Appendix VIII Fifth Floor Plan of the proposed building



Appendix IX Sixth Floor Plan of the proposed building



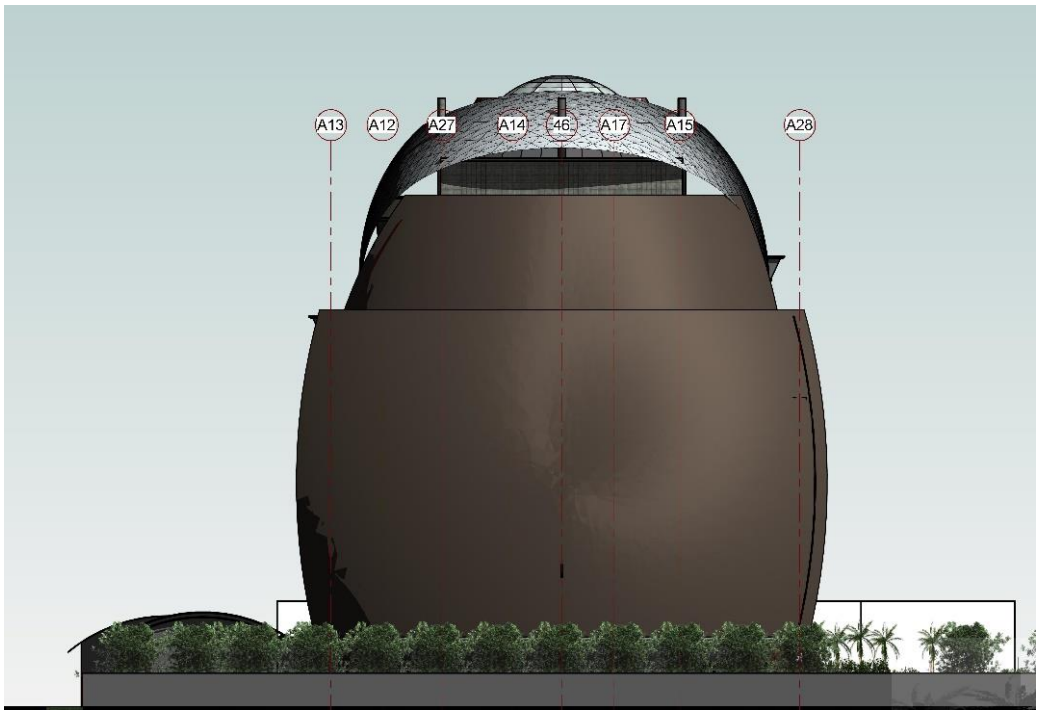
Appendix X Seventh Floor Plan of the proposed building



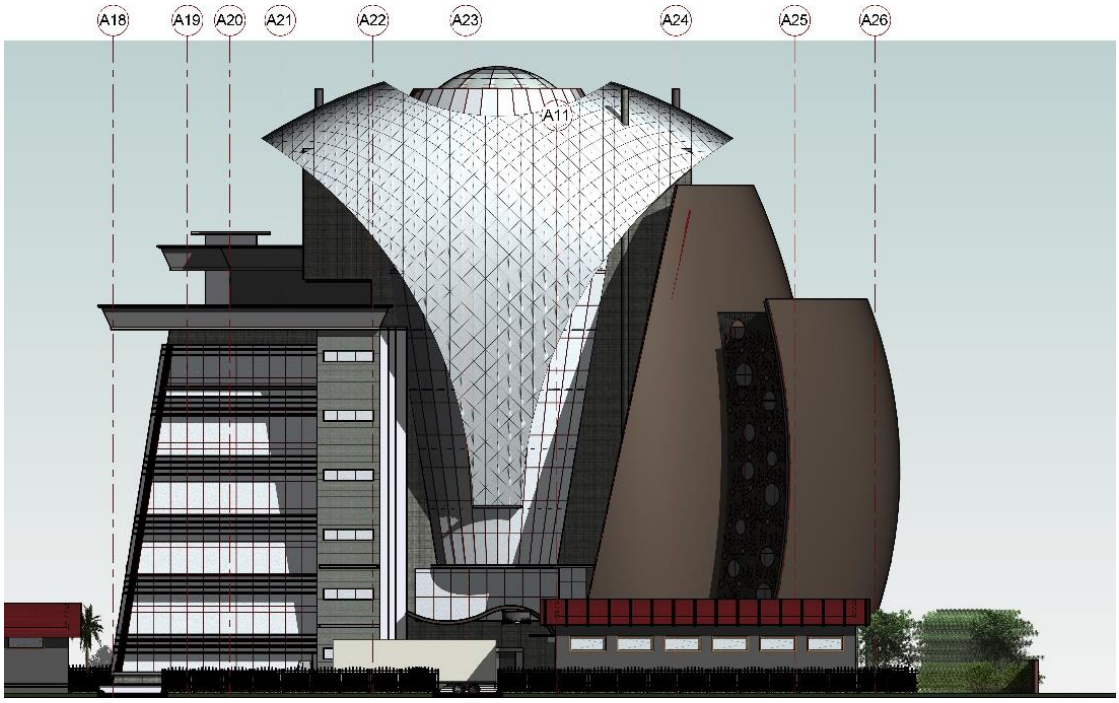
Appendix XI Eighth Floor Plan of the proposed building



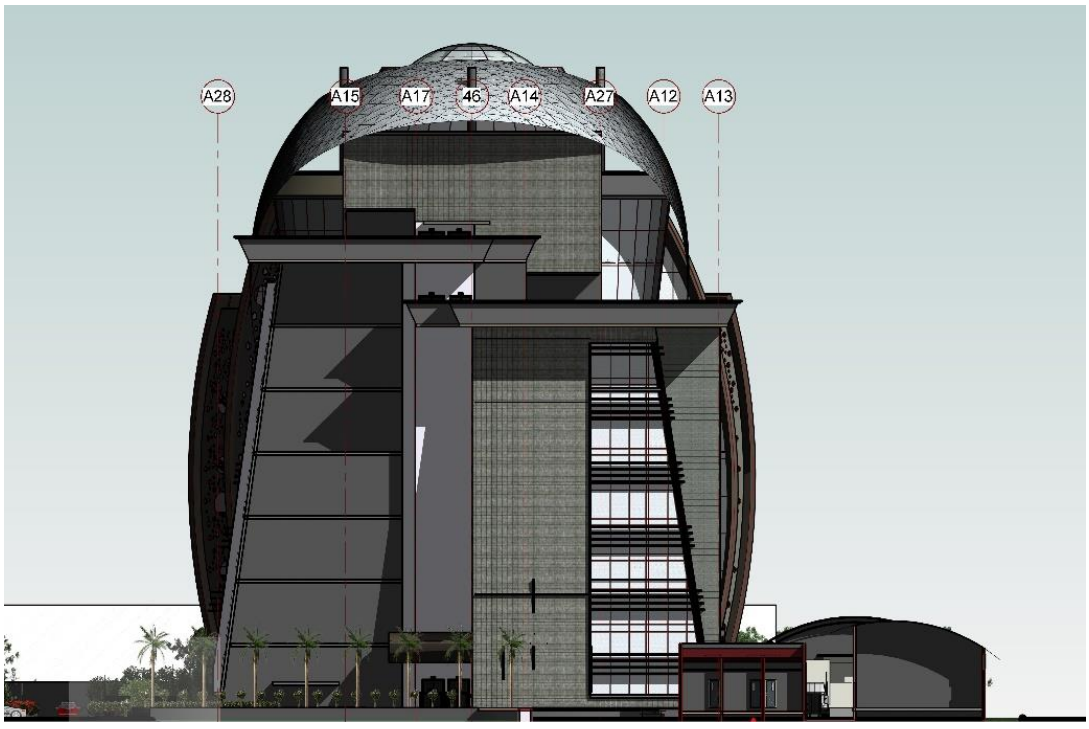
Appendix XII South Elevation of the proposed building



Appendix XIII West Elevation of the proposed building



Appendix XIV North Elevation of the proposed building



Appendix XV East Elevation of the proposed building



Appendix XVI Approach View



Appendix XVII Aerial View