THE UNIVERSITY OF NAIROBI
DEPARTMENT OF ARCHITECTURE
FACULTY OF THE BUILT ENVIRONMENT & DESIGN

TRENDS OF SUN-SHADING DEVICES IN NAIROBI SINCE 1900

A project report presented to the Department of Architecture in partial fulfilment of the requirements for the degree of Master of Architecture, Environmental Design.

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DECLARATION

This project report is my original work and to the best of my knowledge, has not been presented, either in whole or in part, for the award of a degree in this or any other institution.

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Signature.. Date 04.08.22.......................................

This project report is submitted in partial fulfillment of the examination requirements for the award of the Master of Architecture degree, Department of Architecture, University of Nairobi.

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Chairman, Department of Architecture.

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To my family and friends who supported me, thank you seems not nearly enough. May the good Lord ensure your cups never run dry and your hearts are always full.

DEDICATION

To my daughter and husband,

“ Who being loved is poor?”

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ABSTRACT

Thermal comfort can affect the living and working conditions of individuals within buildings. To harness maximum comfort, a conducive environment should be created. The use of a sun shading device is considered to be one of the best means to achieve this. With the increased use of glazing globally, which comes with thermal discomfort, and with increased expectations of comfort at more efficient levels, there is a need for further exploration into the design and use of sun shading devices to achieve thermal comfort.

Sun-shading devices have changed over the years making direct comparison of each device's efficiency nearly impossible and as a result of advancements in technology, new materials, and construction methods, the design of shading devices has been constantly evolving. This study critiques the implementation and transformation of sun-shading devices in Nairobi over time from the traditional to the present and the factors that have led to the variations over time. The scope of the study is limited to buildings in Nairobi designed between 1880 - 2020 in order to establish a timeline of the transformation brought about by changes in architectural styles, economic development, industry leaders as well as advancement in technology and materials. Using temporal trend analysis as a research strategy, Nairobi's timeline is categorised according to the different architectural styles and the selected case studies are analysed according to their form, construction, function, and design. The research finds that a key trend is the approximate two decades-long time lag between the sun shading device types in the Western world and their implementation in Nairobi. At the moment the western world is geared towards kinetic or adaptive sun shading devices which this thesis predicts will be implemented in Nairobi in the future.

CHAPTER 1 - INTRODUCTION

1.1 BACKGROUND OF THE STUDY

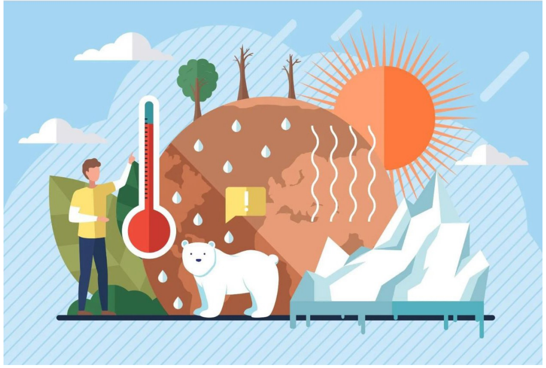

Fig1.1 Info-graphic on the various impacts of climate change on the world.
Source: https://www.news-medical.net

Climate is defined as how the humidity, atmospheric pressure, wind, temperature, precipitation, and other meteorological variables change in a specific region over a long span of years. Over the past 100 years, the change in climate associated with global warming is a result of the earth's average temperature increase from 0.4°C to 0.8°C. Scientific consensus on climate change reveals that by the year 2100 it is expected to increase from 1.4°C to 5.8°C causing melting ice caps and endangering the flora and fauna worldwide as shown in fig1.1. To achieve thermal comfort within our buildings, several strategies have been documented as means for passive cooling and prevention of heat gain within buildings.

Since the 1990s, countries around the world have recognized the seriousness of climate change and taken considerable measures to prevent global warming. As a part of these efforts, the Kyoto Protocol was established to set emission-reduction targets for each country. This is because energy consumption in buildings accounts for 30–40% of the world's total energy consumption. In particular, commercial buildings account for 35% of building energy consumption, and 50% of building energy is used for heating and cooling.

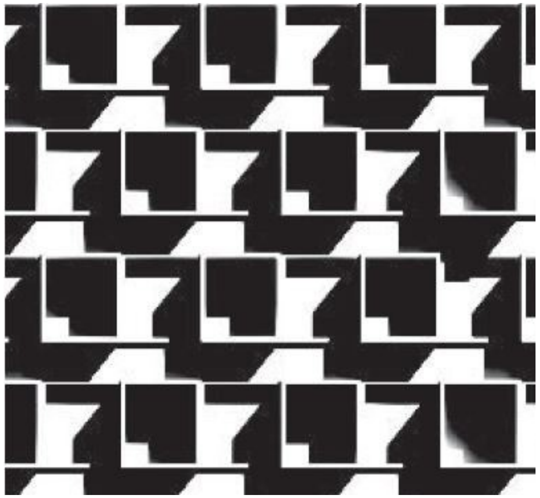

Fig1.2. Shadow study of Chai House sun shading devices.
Source: ETH Studio Basel (2000)

Sun shading devices have been proven to be a key passive design strategy in the prevention of heat gain through the elimination of direct solar heat gain through glazed window openings which are the single greatest source of heat gain in buildings. Therefore, these devices contribute significantly to the reduction of the overall energy consumption of buildings.

Design of sun shading devices has been a key factor in architectural and environmental design strategies over the years for their aesthetic value and efficiency in the prevention of solar heat gain yet its execution varies significantly over time. Fig 1.2 shows one of the hundreds of variations of sun shading devices in Nairobi that through a shadow study shows its efficiency while highlighting its aesthetic value.

1.2 PROBLEM STATEMENT

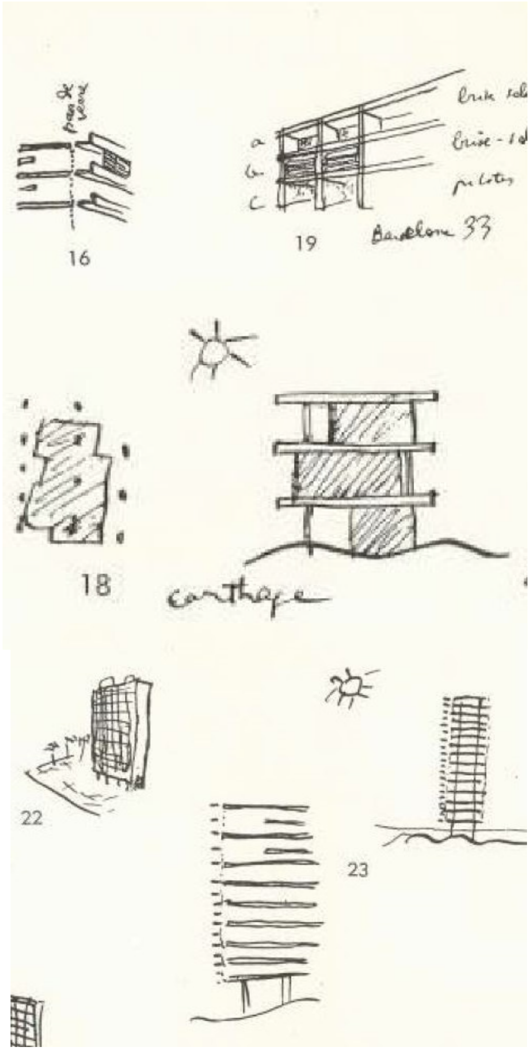

Fig1.3. Images of Le Corbusier's explorations of sun-shading devices .
Source: Olgyay & Olgyay, 1957

The importance of studying history is to help us understand the successes and failures of an area of interest as it gives us the tools to analyse the past, it highlights patterns that might not be visible in the present thus can provide an arena for the understanding of current problems and potential solutions for the future. Understanding the history of the built environment offers a lens for understanding our environmental future and will help us move forward thinking critically about how we live.

> "History is not everything, but it is a starting point. History is a clock that people use to tell their political and cultural time of day. It is a compass they use to find themselves on the map of human geography. It tells them where they are but, more importantly, what they must be."
> John Henrick Clarke

As is seen in fig 1.3 showing LeCorbusier's explorations with sun shading devices, different types of solar shading devices have been designed, depending on building orientation, location, window characteristics, etc., and have contributed to the improvement of a building's thermal and visual comfort. There is a difficulty in directly comparing the different sun shading devices in Nairobi to each other therefore the research is historical and critiques the implementation and transformation of sun-shading devices in Nairobi over time from traditional to innovative and the factors that have led to the variations over time to predict the future of sun shading devices visible through these trends.

Banham (1969) demonstrates the importance of considering the environmental-control systems of buildings to create a new understanding of the history of architecture. In his research, he states his intention is purely architectural history that considers what is taken to be the proper use and exploitation of mechanical environmental controls and to show how this had manifested itself in the design of buildings by various architects. This research aims to undertake a similar study with a focus on the manifestation of external sun shading devices in Nairobi.

1.3 OBJECTIVES

1. To identify factors affecting sun shading device design and implementation in Nairobi since its formation to 2020.
2. To analyse the historical trends of sun shading devices in Nairobi.
3. To predict future trends of sun shading devices in Nairobi.

1.4 RESEARCH QUESTIONS

1. What are the factors affecting sun shading device design and implementation in Nairobi?
2. What are the historical trends of sun shading devices Nairobi?
3. What type of sun shading devices are likely to be in trending in Nairobi in the near future?

1.5 JUSTIFICATION OF THE STUDY

The research seeks to analyse the design of sun shading devices in the Nairobi Central Business District, the factors that influenced it, and how the character of these devices has evolved over the years through an analysis of the existing buildings and the work of influential architects of the day. In doing so, with the advent of facade engineering as a discipline, the research will provide those designing for similar conditions with the factors to consider given the many choices in the design of shading devices.

1.6 SIGNIFICANCE OF THE STUDY

This research will benefit architectural historians, academics as well as different practitioners looking to understand what determined the design of Nairobi facades and encourage more practitioners to adopt a creative approach to the design of sun shading devices as a means for the prevention of heat gain in buildings. It also contributes to the body of knowledge on the history of architecture in Nairobi and environmental design.

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Fig1.4. Images of buildings showing the evolution of sun-shading in Nairobi.
Source: http://www.sikh-heritage.co.uk, Google earth and author

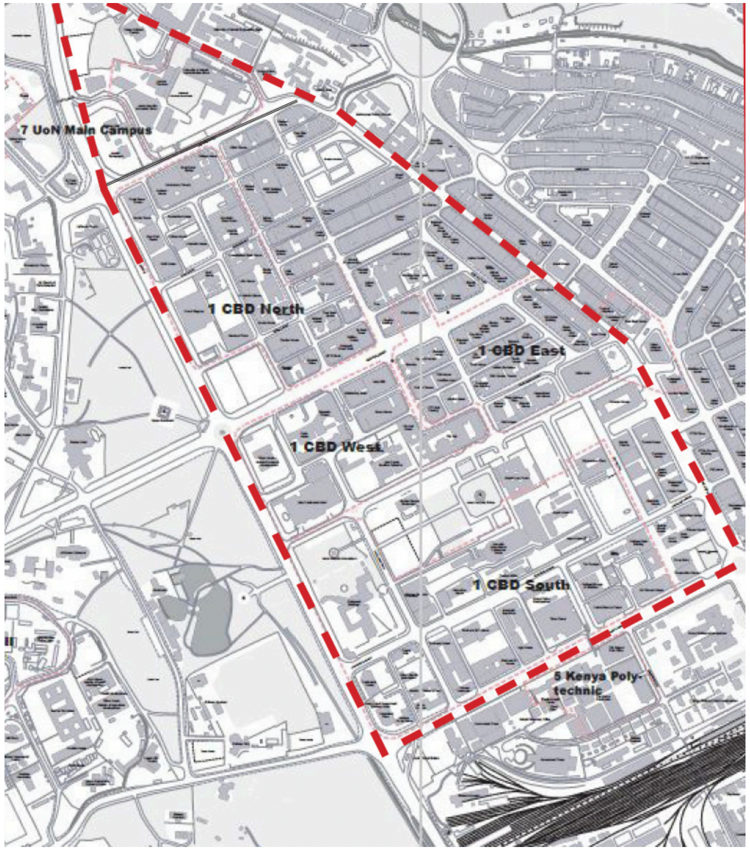

Fig1.5. Map defining the scope of the study within the highlighted zone.

Source: ETH Studio Basel (2000). Author modified.

1.7 SCOPE OF THE STUDY

1. The study is limited to buildings within Nairobi city and further focus on buildings within the Nairobi Central Business District whose boundaries for this research are Uhuru highway to the West, Haile Selassie Avenue to the South, Moi Avenue to the East and University of Nairobi Main Campus to the North as shown in fig 1.5.

2. Field work is in terms of building typology is limited to commercial buildings. For purposes of this research, all buildings within the Central Business District whether housing religious, institutional or hotel activities are considered to be commercial buildings by virtue of their location.

3. The study will be limited to fixed external sun-shading devices only. If the sun is not stopped before reaching the interior of the glazing then, in terms of heat gain, the shading device has not performed. This means the shading device is, by nature, a façade element hence the choice to focus on external shading devices.

4. Although shading of the whole building is beneficial, shading of the windows is crucial, so the research focuses on the shading of windows and openings. The following typologies have not been considered in this analysis: internal solar shadings, self-shading buildings and solar film coatings on fenestrations.

1.8 LIMITATIONS OF THE STUDY

1. Case study selection is limited due to inaccessibility of some buildings, limited documentation of the building or access to drawings.
2. Time constraint in the number of buildings that can be analysed.

1.9 DEFINITION OF TERMS

1. The tropics - Refers to regions located between the Tropic of Cancer in the Northern Hemisphere at $23^0$26’13.3”N and the Tropic of Capricorn in the Southern Hemisphere at $23^0$26’13.3”S. These areas all have the sun directly overhead at least once during the year.

2. Tropical Climate - This is the climate typically found in the tropics. It is classified as a non-arid climate in which all twelve months of the year have a mean temperature of at least 18^0C.

3. Thermal Comfort - This is defined as a condition of mind that expresses satisfaction with the thermal environment.

4. Visual Comfort - This is defined through a set of criteria based on the level of light in a room, the balance of contrasts, the colour ‘temperature’ and the absence or presence of glare.

5. Sun Shading devices - This is a building element on the external side of the window including awnings, canopies and projecting horizontal and vertical fins. These devices when correctly designed are effective in prevention of heat gain through reduction of solar radiation.

6. Building skin - This is the defining characteristic of a building and the part of the building that interacts with the world at large as it is the first layer that confronts us. It is a design element that is integral to thermal comfort as well as the structural system.

7. Building facade - This is the side of a building, usually the front, that provides the opportunity to create the building’s character. This is the face that is given special architectural treatment.

8. Tropical modern architecture - Modern architecture adapted to tropical climate that arose after the second world war, prompted by post colonialism and globalisation.

9. Colonial architecture - An architectural style from a mother country that has been incorporated into the buildings of settlements in distant locations.

1.10 ORGANIZATION OF THE STUDY

Chapter 1: Introduction

Chapter one serves as an introduction to the area of study. It explains the problem statement which is the importance of history to help understand the successes and failures of sun shading devices in Nairobi to analyse trends that can be used by future designers in the wake of facade engineering as a new discipline in the industry. It further highlights the scope of the area of study as well as the sun-shading devices being limited to external sun shading devices due to the effectiveness of its performance compared to other sun shading methods.

Chapter 2: Architecture and Sun-shading Devices

This chapter introduces all types of sun shading devices with further detail regarding varieties of external shading devices and means of calculation. It further interrogates the genesis and history of sun-shading devices at a global level and the factors that led to the transformation and spread of these devices over time worldwide. Chapter two further establishes key factors for consideration in the design of external shading devices that determine the design of a device. These factors form the basis of analysis in Chapter Four.

Chapter 3: Research Methodology

Chapter three discusses the process and tools used to collect data in the field. The field of study being the Nairobi Central Business District. It outlines the selected cases and justifies the selection of each case study. Lastly it explains how the data is collected and analysed.

Chapter 4: Sun shading Devices in Nairobi.

In this chapter, all the data collected is explained and analysed. The history of construction in Nairobi is divided into distinct architectural periods that highlight a shift in sun-shading devices. The devices are further analysed to highlight visible trends and through case studies showcase this evolution. Chapter four summarises the evolution, impact, and extent of sun shading devices in Nairobi.

Chapter 5: Conclusions and Recommendations

It outlines and summarises the findings from each chapter of the study on sun-shading devices and answers the research questions in Chapter one. It also gives recommendations on the future of sun shading devices.

CHAPTER 2: ARCHITECTURE AND SUN-SHADING DEVICES

2.1 ARCHITECTURE & SUN-SHADING

Fig2.1. Sun shading device on the exterior of Unesco House.
Source: Yao(2021)

Fig 2.2. Le Corbusier's drawing showing the path of the sun above and below the horizon and to the left a building showcasing the heat being most profound in the late afternoon and to the west.
Source: Antoniou (2017)

For architects, the sun is one of the main tools that affects the spatial organization and shape of buildings. Unprotected glass is the single greatest source of heat gain in a building and as such, the most effective way to reduce the solar heat gain on fenestrations is to intercept direct radiation from the sun before it reaches the glass. "The sun control device has to be an element of the facade, an element of architecture." Marcel Breuer (1955) Where used, the shading devices are an integral part of the building envelope and thus influence thermal and daylighting performance yet also offer many possibilities for architectural expression.

Shading against solar heat gain is the most flexible and easily applicable method of cooling a building's interior and can be applied in all climates to almost all buildings irrespective of latitude. The effectiveness of all types of shading devices depends on their design, taking into account the climate of the area, geographical characteristics, the course of the sun across the sky at different times of the year, and the orientation of the facade of the building amongst other parameters.

2.1.1 SOLAR CONTROL IN BUILDINGS

The design, installation, and operation of solar shading may be achieved in many ways. These can be split into natural and built options. Natural sun-shading methods refer to those design techniques which prevent or moderate heat gain by manipulating the building form, layout, and site design. This can be achieved through the designer's manipulation of the following variables.

1. Orientation and aperture geometry.

According to Koeningsberger (1975) Solar heat gain on the western side can be particularly troublesome as its maximum intensity coincides with the hottest time of the day. In equatorial locations, the main windows should face north and south to avoid solar heat gain whereas at higher altitudes further away from the equator, heat may be desirable during the winter when the sun is low so an orientation towards the equator may be desirable.

2. Control of solar- Utilisation of optical properties of opaque and transparent surfaces.

3. Urban Design – A compact urban layout can provide mutual shading by neighbouring buildings. This is determined by the distance between the building and the building's height. An example would be streets with parallel rows of buildings.

4. Vegetation - Planting of trees, vines, shrubs, and ground cover for shading and daylighting purposes. The trees filter sunlight before it reaches the building's interior therefore reducing glare and direct heat gain as shown in fig 2.3. This is only suitable for low buildings and during early mornings and evenings when the sun is at a low angle as it casts long shadows against the facade.

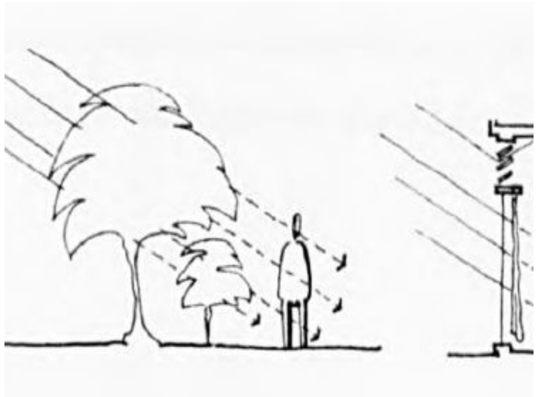

Fig2.3. Use of vegetation for shading.
Source: Stack et.al

Built sun-shading devices refer to devices placed on the building and can be categorised into the three categories below.

1. External shading devices. - By intercepting solar radiation before it reaches the building, external devices are the most effective at preventing the build-up of solar heat gain inside.

2. Internal shading devices - Internal devices with a reflective external coating can reflect solar radiation to the outside, but transfer some of their solar heat gain to the room by convection. Examples include blinds, curtains etc.

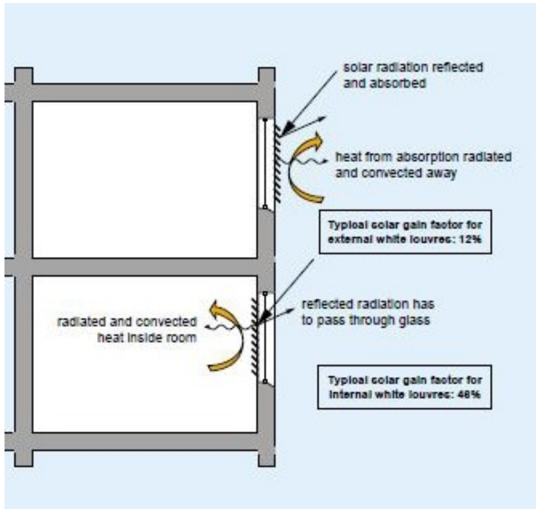

Fig 2.4. Internal shading devices versus external shading and its effect on glazing.
Source: Stack et.al

3. Glazing- Treatment of glazing to reduce glare is a method of solar control commonly used now. This includes double glazing, tinting, coloured glass etc.

2.1.2 TYPES OF EXTERNAL SUN-SHADING DEVICES

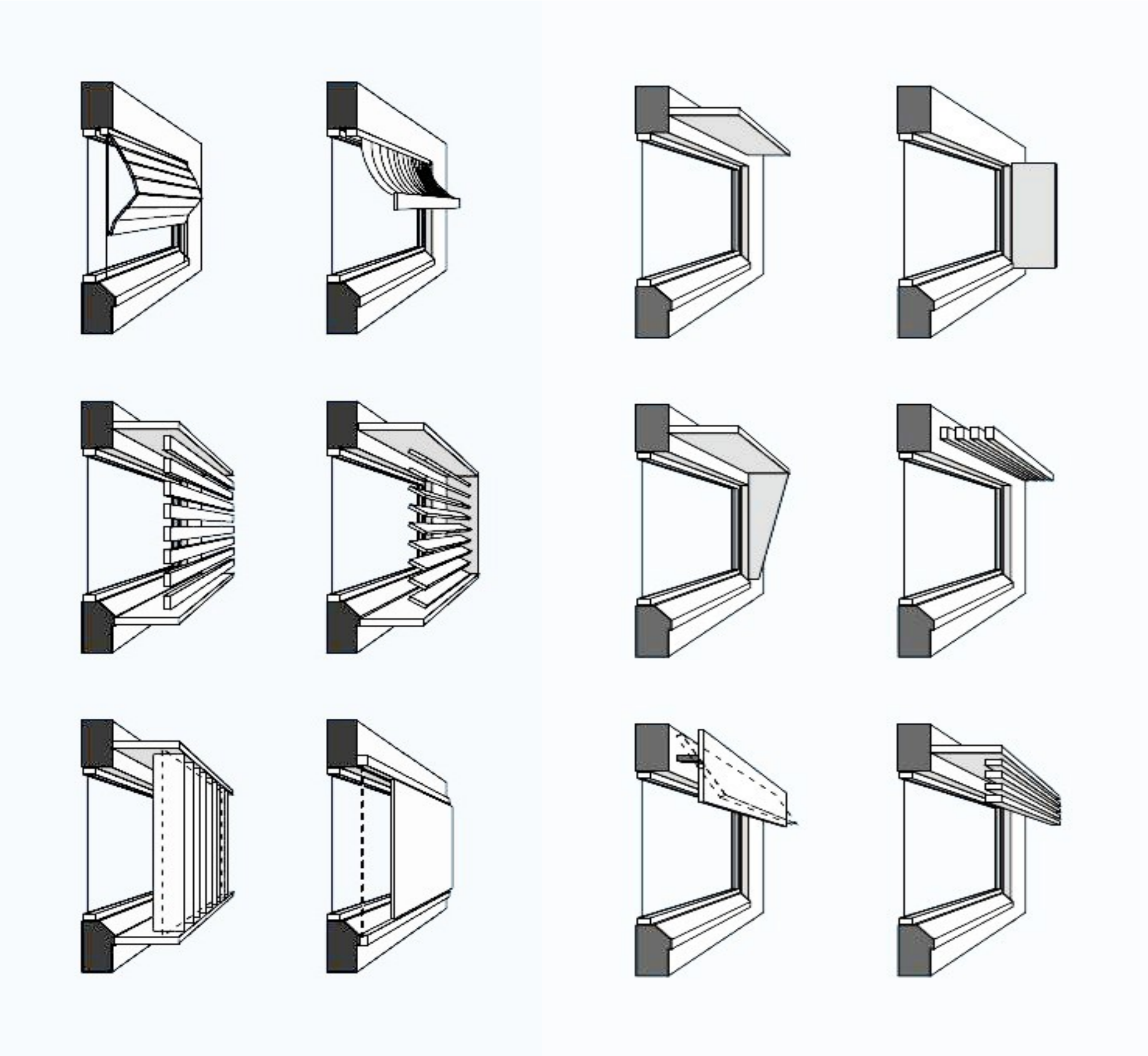

Fig 2.5 shows a few of the various varieties of sun shading devices worldwide. They differ in the installation location, fin orientation, manual or automatic control and in the type of materials used.

They can vary in size without changing their shading characteristics, as long as the ratio of the depth to the spacing of the elements or height of the window to be shaded (projection factor) or the cut-off angles (Vertical Shadow Angle and Horizontal Shadow Angle) remain constant.

They are categorized into three broad categories based on the shading and shadow cast which can be further subdivided depending on the design of the device. These are Horizontal, Vertical, and Egg-crate sun shading devices.

A. Horizontal Sun-shading devices

Horizontal shading devices provide effective shading when the sun's altitude is high. The depth of the device determines the length of the shadow on the window wall. Generally, a deeper projection over the window provides a larger shading mask and therefore improved shading. They block the high-altitude sun but admit the lower-angle sun. The performance of these devices is measured by the calculation of the vertical shadow angle.

Horizontal shading devices can be proportioned to shade while still admitting sun to help heat the building in the cooler seasons. Overall illuminance levels in the interior of the building are reduced by deep horizontal shading devices but the uniformity of light distribution can be improved by breaking the horizontal overhang into several shorter projections evenly distributed. This problem can also be resolved by making the shades seasonally adjustable. Moveable shading may be operated manually or automatically. Manual control relies on the discomfort of an individual and is therefore not fully efficient compared to automated shading systems.

Fig2.6. Horizontal shading on Maendeleo House, Nairobi Source: Google Earth.

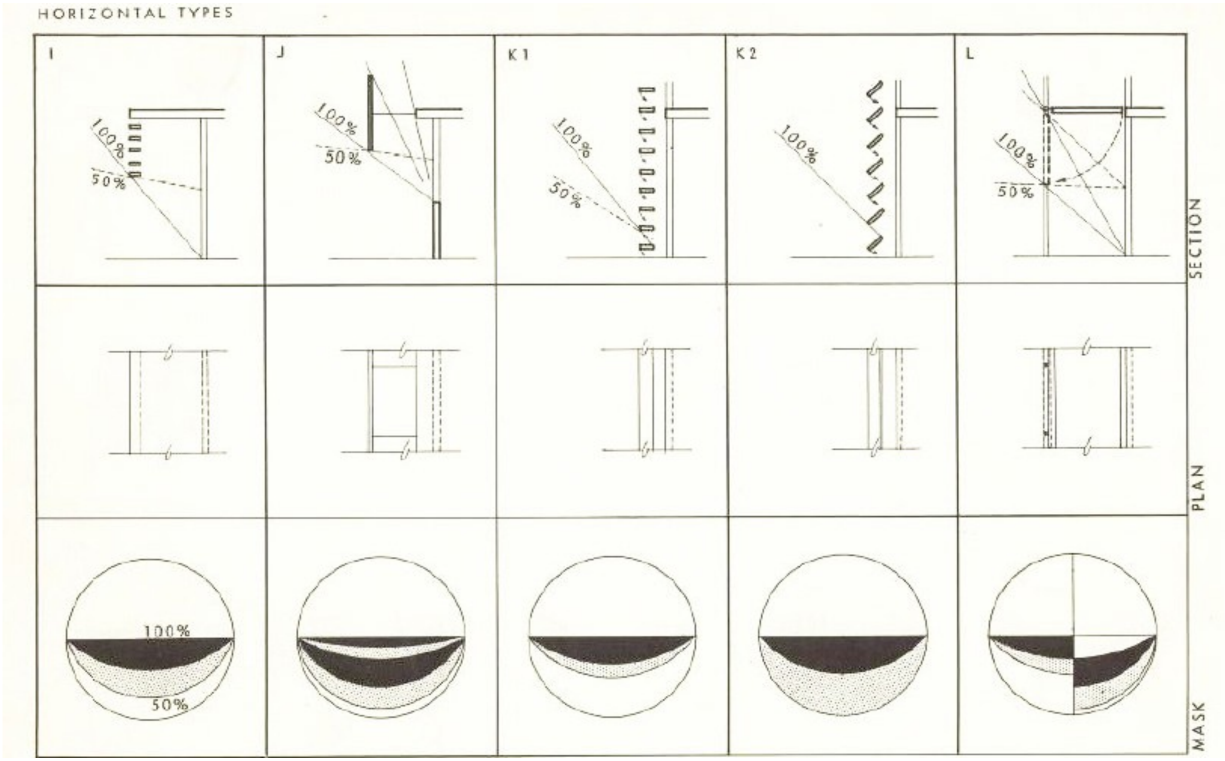

Fig 2.7. Types of horizontal sun shading devices. Source: Olgyay & Olgyay (1957)

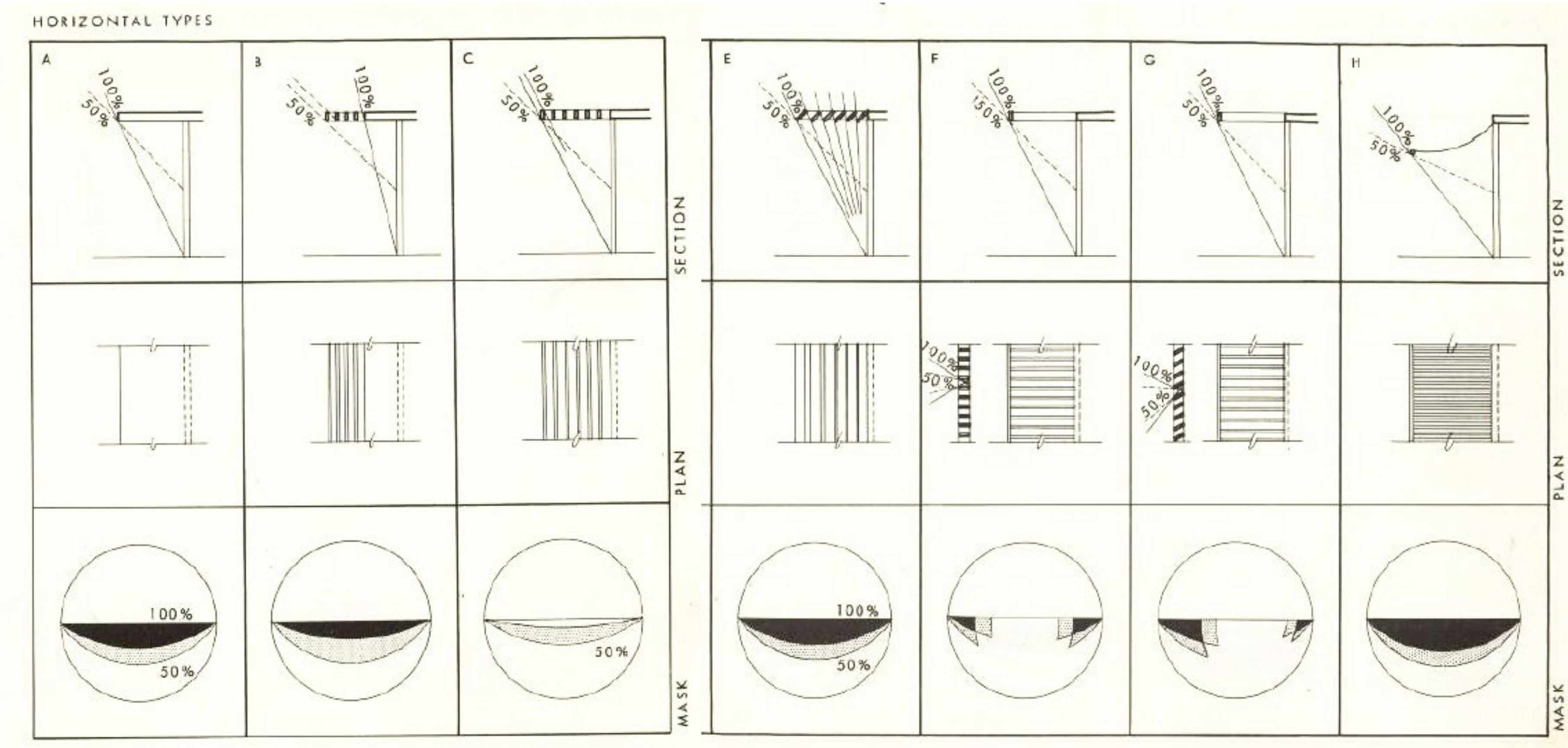

Fig 2.8 Types of horizontal sun shading devices.
Source: Olgyay & Olgyay (1957)

Fig2.9. Horizontal sun shading devices at Finance House, Nairobi. Type J according to fig. 2.7 Source: Flickr.com

Fig2.10. Horizontal sun shading devices at City Market, Nairobi. Type A according to fig 2.8. Source: Author

B. Vertical Sun-shading devices

Vertical sun shading devices consist of projecting fins or louvres in a vertical orientation. The performance of these devices is measured by the calculation of the horizontal shadow angle. The spacing of the blades affects the projected depth of the device for instance closely spaced fins may require shorter fins than their widely spaced counterparts to provide adequate shading.

Vertical shading devices are effective when the sun is low and the broad side of the vertical elements faces the sun. This makes the most efficient during early mornings and in the evening. Vertical sun shading devices perpendicular to the window is most effective on the northern and southern side, where no horizontal element is needed. At tropical latitudes where the sun is much higher, vertical shading devices are not very effective.

Fig2.11. Vertical shading on Jogoo House B
Source: Google Earth.

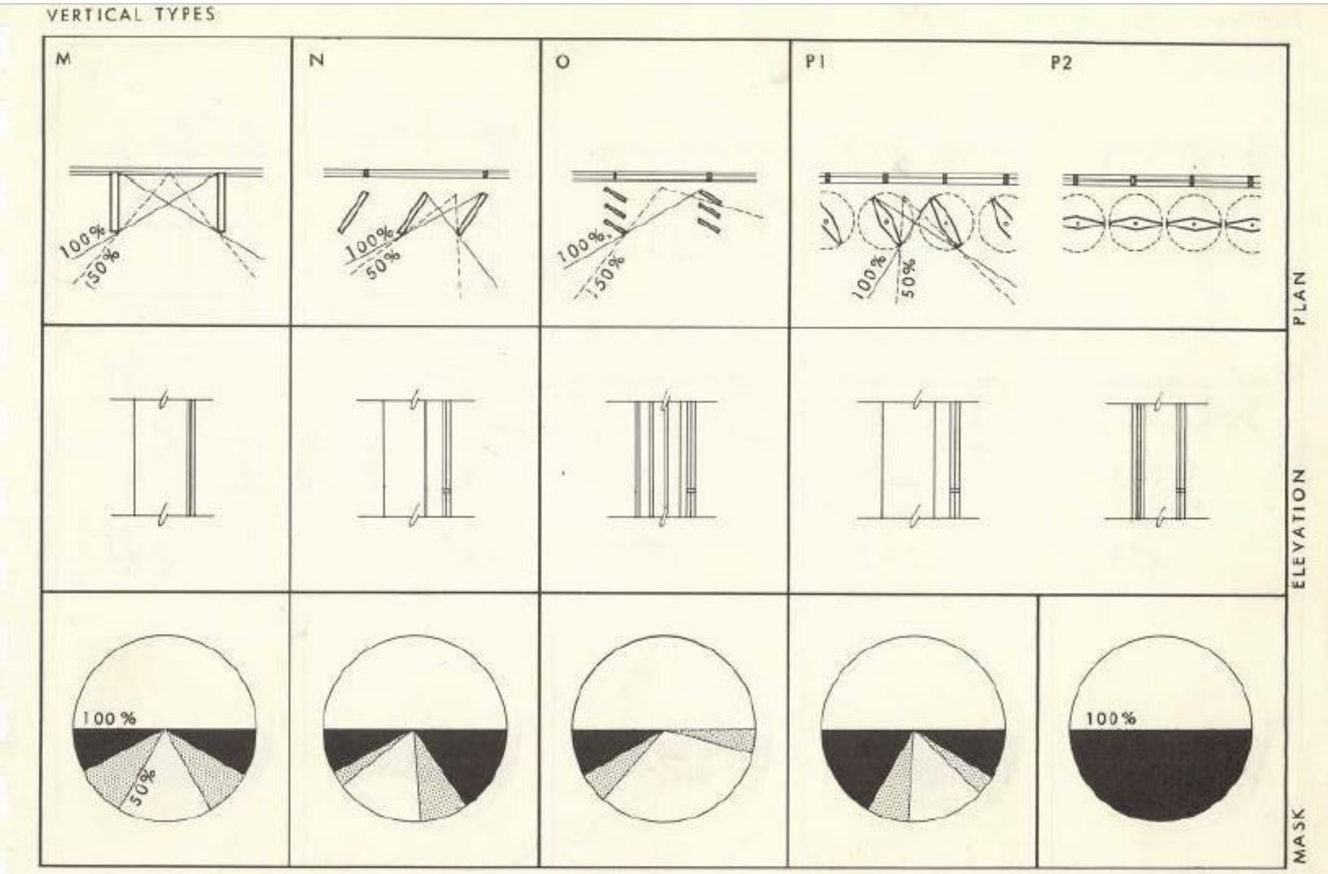

Fig 2.12. Types of vertical shading devices
Source: Olgyay & Olgyay(1957)

C. Egg-crate Sun-shading devices

Egg crate shading devices are considered the most efficient type of sun-shading device as they combine the advantages of both horizontal and vertical shading devices. They are particularly effective on east and west facing facades. These devices provide both indirect sunlight as well as privacy. The degree of privacy is determined by the distance between each horizontal and vertical member. Depending on the shading requirements, the slats can be either slanted or perpendicular to the window.

Some designs have distinct vertical and horizontal projections such as the west façade of the Millowners' Association Building, in Ahmedabad, India, by Le Corbusier, the horizontal elements provide shade in the early afternoon when the sun is high and the angled vertical elements shade in the late afternoon when the sun is low and in the west. Others have more geometric patterns that give a distinct architectural aesthetic to the building's facade. An example is Uganda National Theatre as shown in fig 2.13.

Fig2.13.Circular egg crate shading on Uganda National Theatre and Cultural Centre in Kampala Uganda designed by Peatfield & Bodgener in 1956.
Source: https://3rdworldarchitecture.wordpress.com

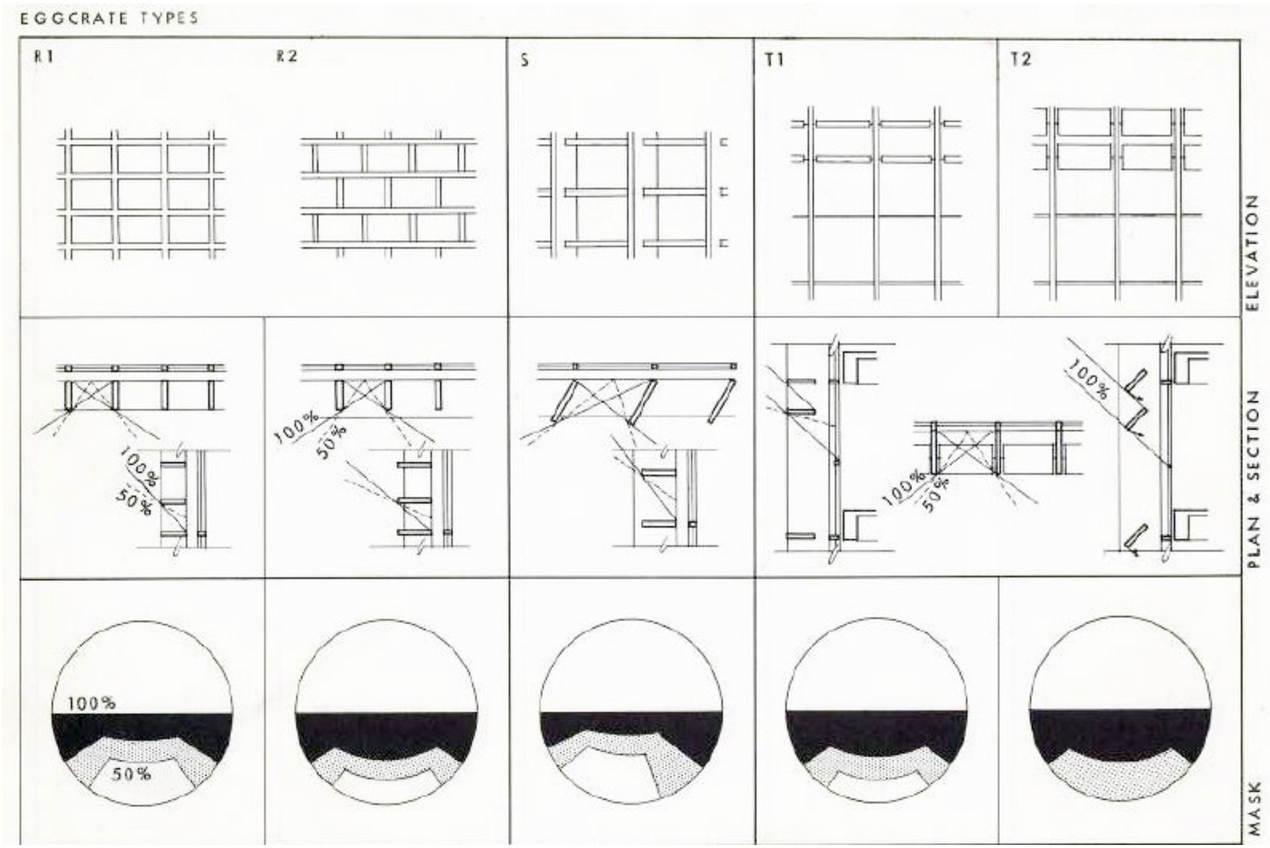

Fig 2.14. Types of egg crate shading devices.
Source: Olgyay & Olgyay(1957)

D. Moveable Sun-shading devices

Fixed shading devices have limitations, the most crucial being their inability to adapt to the external conditions variations as well as blocking the view to the outside. Moveable shading systems in buildings are a high performing shading solution that selectively and optimally control daylight and heat gains. They are also known as active, kinetic or dynamic shading systems. They try to achieve a balance between sufficient daylighting levels, providing solar protection, and energy balance while allowing the occupants the flexibility to control the shading devices according to their evolving needs.

Active shading devices change their properties in response to exterior climate and interior requirements and according to Aldakheel & Aoul(2017), may be categorized into three classes: smart glazing, kinetic shading, and integrated renewable energy shading. "The active systems can be within the glazing of the openings or as an exterior shading system." (Aldakheel & Aoul, 2017) This is achieved through the use of smart glazing technologies, sensors, and control systems, or through the application of smart dynamic shading devices.

The widespread use of active sun shading devices is hindered by numerous challenges According to a study done by Aldakheel & Aoul (2017), the biggest hindrance to the uptake of active sun shading devices is the high initial costs. Research by Voight et al (2021) concluded that the challenges in implementation are due to the higher complexity when compared to traditional designs. Firstly, the technical complexity in terms of designing/realizing the product itself and, secondly, the process-related complexity, including the management and coordination of the stakeholders involved. With developments in technology and more research, there is the emergence of a new type of active sun shading device materials such as photovoltaic (PV) integrated devices and stimulus-responsive materials for folding devices.

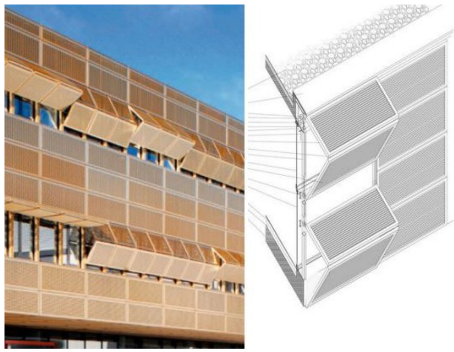

Fig2.15. Vertically folding shutters ta University of Potsdam, Germany.
Source: Dakheel et al.(2017)

Fig2.16. Perforated metal rotating shading system at Zurich airport.
Source: Dakheel et al. (2017)

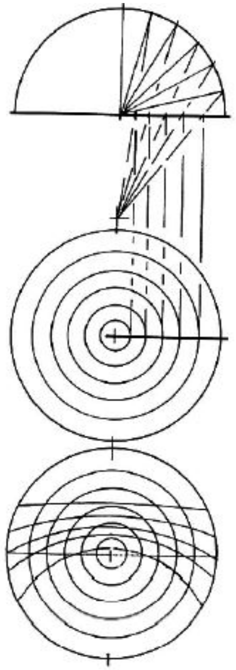

Fig2.17. stereographic projection method Source: Szokolay (2004)

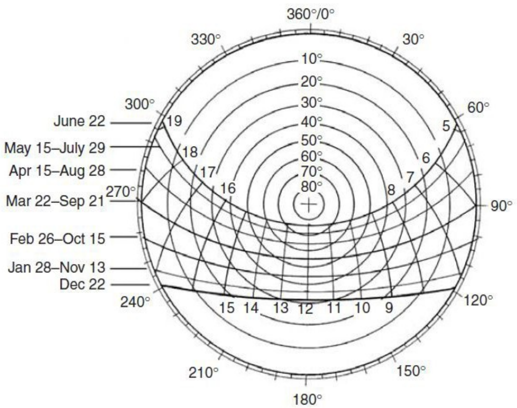

Fig2.18. 36⁰ sun path diagram.

Source: Szokolay (2004)

2.1.3 DESIGN OF SUN SHADING DEVICES

Design of a shading device is a complex task that is linked to the function of the building as well as its geographical location. The building's function determines the lux levels to achieve visual comfort as well as thermal comfort whereas the geographical location determines the depth of the sun shading device based on the facade's orientation.

Some rules of thumb in design of sun-shading devices according to Munyao (2017) are:

1. North facing windows in the North pole and South facing windows in the south pole require no shading as direct sunlight will only reach these windows in the early morning and late hours in the evening.
2. Equator facing windows require horizontal shading devices to protect the windows from high angle sun during the day while still allowing low angle morning and evening sun.
3. East facing windows in the Northern and Southern hemisphere require fixed vertical shading devices but along the equator require horizontal or eggcrate shading devices.
4. West facing windows receive the most exposure to heat in the afternoons and would be best with movable or egg crate sun shading devices.

When designing an external sun shading device, the sun's movement and influence can be predicted using the following methods.

1. Sun path diagrams.

In sun path diagrams, "the sky hemisphere is represented by a circle(horizon). Azimuth angles(direction of the sun) are given along the perimeter and altitude angles ad shown by a series of concentric circles with 90^0 (zenith) being the centre." Szokolay 2004. This is shown in Fig 2.18.

Sun path diagram types are namely the orthographic projection, the equidistant chart, and the stereographic projection. The stereographic projection shown in Fig 2.17 is the most commonly used method. The shadow mask created using this method are used to assess the impact of the shadow on the building's interior.

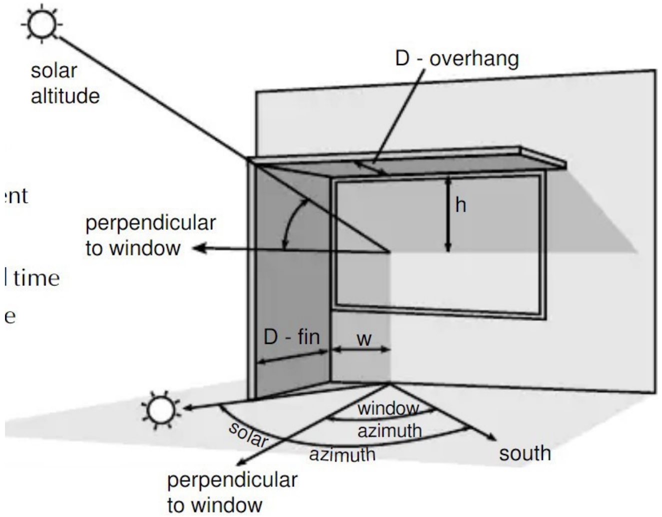

Fig2.19. Solar altitude and azimuth for calculation of sun shading projection
Source: Szokolay (2004)

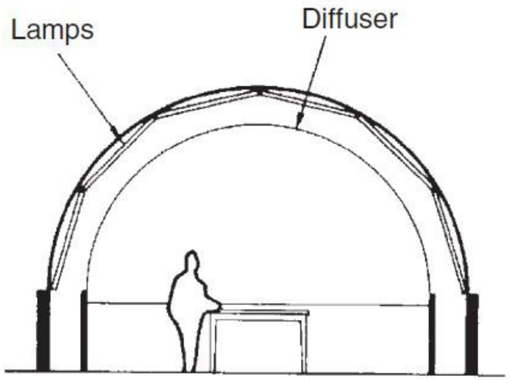

Fig2.20. A sketch of the artificial sky. The model would be placed on the table in the centre.

Source: Szokolay (2004)

The the sun path diagram method is that the ability to shape and size the different typologies of sun shading devices is based solely on the Horizontal and Vertical Shadow Angle thus restricting the architectural form of the device and the expression of the architect or designer.

According to Landis (2017), the limitation of this method is it tends to result in rectilinear forms but does not work efficiently for complex, non-conventional forms and as such is useful for off the shelf solutions.

2. Physical model.

These are tested in a laboratory under artificial and natural sunshine condition in a heliodon or a model mounted sundial. This method is used for complex geometries and a scale of 1:20 is usually used as is important that the internal surface reflectance should match the reality as near as possible. (Szokolay 2004.)

3. Computer simulations.

The thermal performance of any building entails complex interactions between the exterior environment and the internal loads that are constantly changing from hour to hour and season to season. 3D modelling programs include algorithms for the sun's movement throughout the year. According to Kirimtat, Koyunbaba, Chatzikonstantinou, and Sariyildiz (2016), these simulation programs are used by architects and engineers to analyse, designate and evaluate the daylight value, natural ventilation, indoor thermal and visual comfort. A few examples of such tools are DAYSIM, DIVA for Rhino Ecotect, Energy Plus, and IES-VE.

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Computer simulations are a practical way to predict the dynamic energy and energy cost performance for a large number of design solutions. At this stage, the design team can manipulate the building massing, zoning, siting, orientation, internal organization, and appearance of the facades without adding significantly to the cost of design. This is through a comparison of the alternatives to a base or best-case building simulation to understand the alternatives.

According to Olgyay& Olgyay (1957) whichever the method used to design sun shading devices, the following steps should be taken:

1. Determine the overheated period when shading is needed.
2. Determine the position of the sun when shading is needed.
3. Determine the type and position of a shading device.
4. Design a shading device from the shading mask.

In summary, when designing a sun shading device, many devices though different in appearance might have the same shading mask therefore there will be many possible solutions for each situation. The designer's task is to choose between the various technically correct possibilities or develop new variations. This is the line where technical method ends and creative expression takes over. (Olgyay & Olgyay 1957)

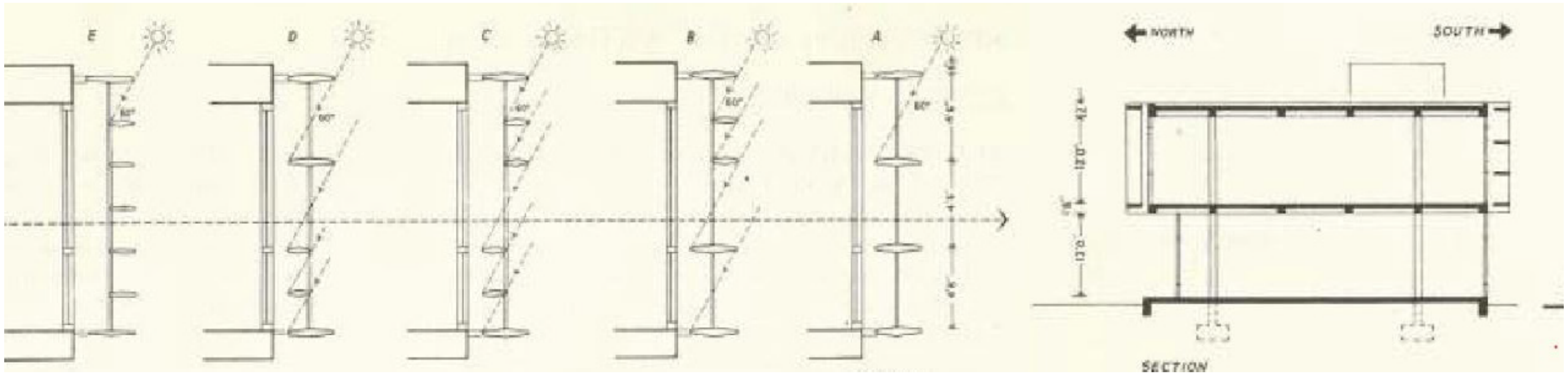

Fig2.21. Analysis of different arrangements of horizontal devices to be used on a building. The section shows variation of the sun shading device to the North and Southern facade.
Source:Olgyay & Olgyay (1957)

2.2 EVOLUTION OF ARCHITECTURE AND SUN SHADING

The benefit of shading buildings from the sun cut across various cultures in history. Throughout time, the implementation of shading devices varies from traditional vernacular buildings to classical architecture and later in modern architecture. The design, development, and progression vary from one geographical location to another yet a clear timeline can be drawn based on fundamental shifts in global architectural, political, and social factors. This distribution of the sun-shading devices throughout history can be viewed according to specific architectural styles and their key proponents. Aside from this, the sun-shading devices vary according to types, character, functions, and building materials indicating the global distribution and spread.

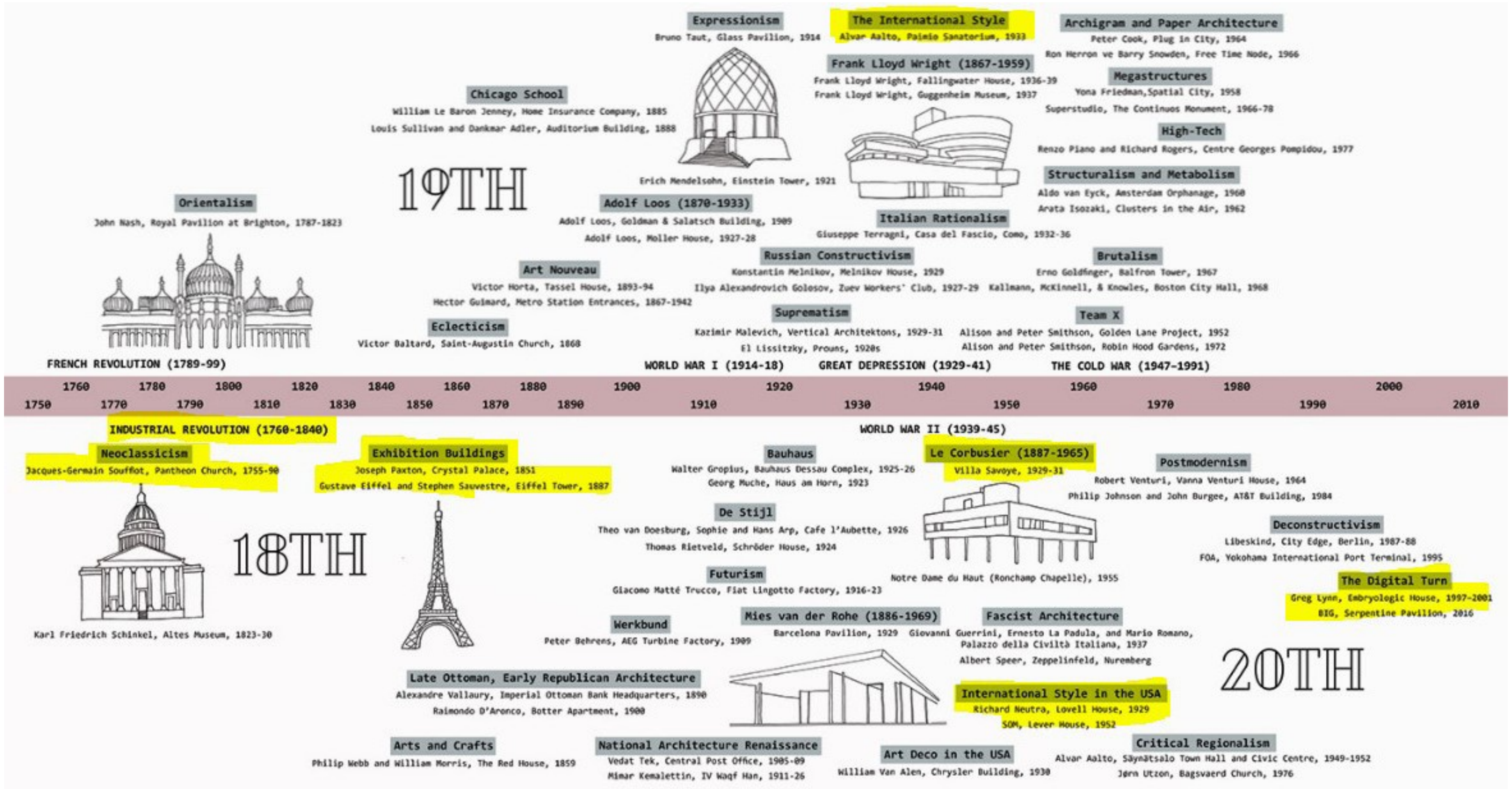

Fig 2.22. Timeline of architectural history.

Source: https://www.behance.net/gallery/62655491/Architectural-History-and-Theory-Timeline. Author modified

2.2.1 VERNACULAR ARCHITECTURE

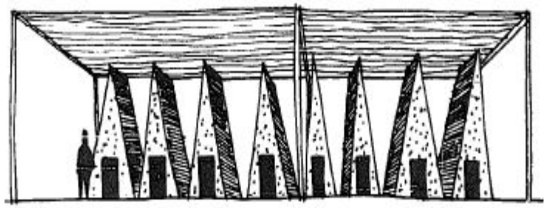

Fig2.23. Yokut settlement. Source: Rapoport,1969

Fig 2.24. Swahili House in Lamu. Source: Martin 1969

Fig 2.25. Engawa in Japanese House. Source: https://www.interactiongreen.com/ engawa-gallery/

Vernacular architecture refers to local or regional architecture and from region to region the design of traditional buildings varied as a response to climate. According to Rapoport (1969), we build houses to keep in consistent climate, and to keep out predators making thermal comfort, through sun-shading, a key concern in the design of shelter. Sun shading in response to the need to reduce the surface area exposed to the sun and increase shading appears different depending on the climatic variables.

There are several types of traditional sun-shading devices globally. Some examples are the Indians of the Yokut Tribe of Southern California shaded the whole settlement with brushwood thus providing for thermal comfort and shaded communal areas as shown in Fig 2.23(Rapoport,1969)

Verandahs and overhangs are types of sun-shading devices used in Japanese, Swahili, and Ancient Greek architecture to name a few cultures. Fig 2.24 shows a Swahili house in Lamu town that employs the use of balconies as a sun-shading device for the windows and baraza below. The traditional Japanese veranda called the 'engawa' shown in Fig 2.25 protected the walls that offer protection from glare and solar radiation. This is similar to the traditional Malayan houses that have low eaves and wide verandahs.

Another instance is the widespread use of screens known as mushrabiya and jaalis amongst the Swahili and Indians respectively. Aside from shading the users from direct heat and glare in hot and humid climates, this type of shading device played a major role in providing privacy and aesthetics of the building.

Traditional architecture was all done by the users, whether individual or communal, depending on the culture, and the shading devices were often designed using locally available materials. Examples include bamboo, tree branches, clay, thatch amongst several others.

Age of Classical Architecture	Year
Ancient Greece	700 – 480 BCE
Hellenistic Period	323 – 31 BCE
Roman Empire	27 BCE – 476 CE
Byzantine Period	330 – 467 BCE
Romanesque Period	1000 – 1150 CE
Gothic Period	1100 – 1450 CE
Italian Renaissance	1400 – 1600 CE

Table 2.1 Years of the ages of classical architecture.
Source: https://artincontext.org/classical-architecture/

2.2.2 CLASSICAL ARCHITECTURE

Classical architecture encompasses all architecture that is derived from the ancient Greeks and Romans and is characterized by symmetry, columns, pediments, rectangular windows, and marble. It includes all the styles in the periods shown in Fig 2.22 alongside. The designs and construction during this period were done by master builders and master masons.

At first, building skins were oriented towards fulfilling a function but later people began to decorate their buildings just as they did their clothing such as the Greek Frescos, Temples, Palaces, and Mosques. The proportions, fenestrations, divisions by columns, architraves, and ashlar stone first provided the aesthetic purpose but also created a means of horizontal shading through large overhangs that were supported by columns which is a key aesthetic feature of the period. As shown in Fig 2.26 and Fig 2.27 the larger shading elements of the Greco –Roman period as well as the porticoes and colonnades of ancient Greek and Roman buildings had the purpose of shading both the building and an outdoor living space.

Sacral buildings such as cathedrals and churches began to have translucent, coloured glass which allowed light to penetrate but obscured vision while lighting images from behind. The glazed windows remained small until the Industrial Age with an emphasis on the window treatment and the structural frame.

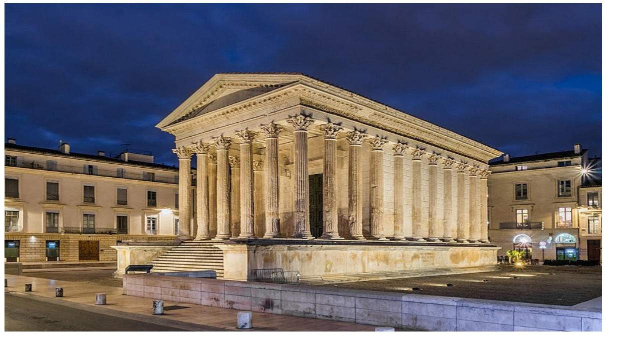

Fig 2.26. Image of Roman Temple . Source: Forbes.com

Fig 2.27. Image of Greek Revival Building . Source: hgtv.com

Colonial style buildings were later adopted by several communities and were known as Greek revival. Aside from the colonnaded porch at the front, they also provided sun-shading even when it was not a conscious goal through the windows which were usually set back into deep load bearing masonry walls. This created the effect of a shallow egg-crate shading device depending on the size of the window.

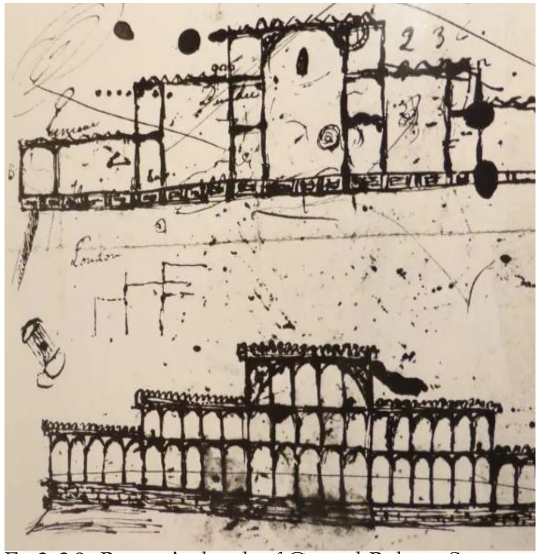

Fig2.28. Paxton's sketch of Crystal Palace. Source: https://intriguing-history.com/the-crystal- palace/

2.2.3 INDUSTRIAL REVOLUTION

Olgyay (1957) links sun shading device directly to introduction of glazing in buildings. "The architectural appearance of the sun control is not an effect in itself-it is the result of several other developments. It is the direct consequence of the glass pane, which in turn was born from structural possibilities during the Industrial Revolution." Olgyay (1957). As architecture was liberated from the load bearing walls so was an appreciation for interior light.

The Industrial revolution between 1800-1900 brought with it more methods of producing and using glass which was once a preserve of the wealthy due to high manufacturing costs and the window tax introduced in 1696 by William III. The term daylight robbery stems from this period when people were forced to brick over their windows to avoid paying the annual window tax which was in place for 156 years.

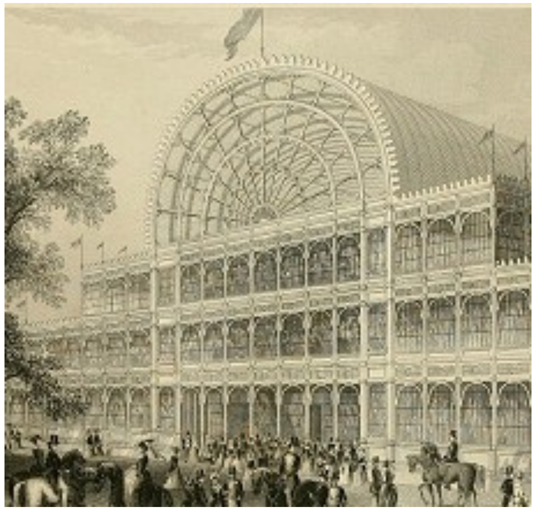

Fig 2.29. Crystal Palace exterior. Source: https://study.com/academy/lesson/history-uses-of-glass-in-architecture.html

The Crystal Palace shown in fig 2.29 designed by Joseph Paxton was the first large-scale glass construction of its time and its presence at Hyde Park in 1851 at the great exhibition sparked a new era in architecture. It showcased the structural possibilities such as moving the structure off walls and pre-fabrication and as such was a major influence on modern architecture. The lack of sun-shading devices in favour of transparency was a key influence on future design by architects. Notably, Joseph Paxton was not an architect but was instead a gardener and therefore he was able to casually negate the formal canon of classical architecture at the time. Visionary designs were led by engineers and non-architects who worked on train stations and large shopping arcades.

2.2.4 LE CORBUSIER AND MODERN ARCHITECTURE

Fig2.30. Villa Savoy.
Source: Archdaily

Modern architecture aimed to create an architectural language that was not influenced by the past. It emerged at the end of the 19th century from revolutions in technology, engineering and building materials. Le Corbusier in this era is a key proponent of modern architecture with his infamous "Five points of new architecture" seen in his design of Villa Savoy in 1931 forming a basis of modern architecture and the ideal form. (Boesiger & Stonorov 1995) The key point in question for sun-shading is the ribbon windows that were characteristic of modern architecture.

It is during this period that Le Corbusier proposes the modern concept of sun shading popularly known as brise-soleil aimed at protecting the building from direct sun, which he describes as our friend in the winter and our enemy in the summer.

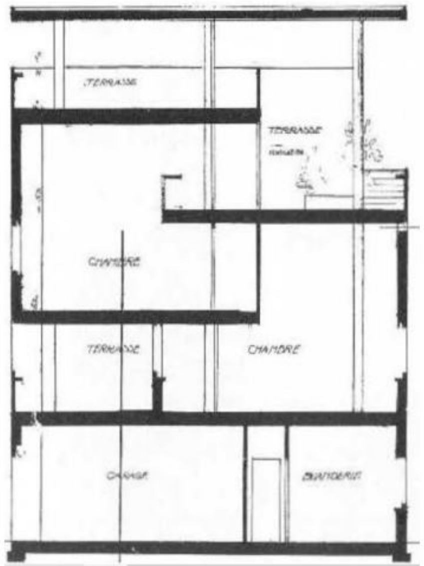

Fig 2.31. Section through LeCorbusier's design in Carthage, Tunis.
Source: Maina 2016

Before he discovered Brise-soleil, Le Corbusier's solution to heat was during the design of Cite de Refuge armed with two master concepts to environmental management: la respiration exacte and le mur neutralisant meaning controlled mechanical ventilation and neutralising wall which was double glazing with hot or cold air circulating within the space between the two skins. The system worked in the 1933 winter but in the summer, the glass wall made it an intolerable glasshouse. This failure led him to consider a different strategy which grew to the brise soleil.

According to Boesiger & Stonorov (1995), Le Corbusier's project in Carthage, Tunis was the starting point of his development of Brise-Soleil. While designing a house for his client, Lucien Baiseau, Le Corbusier proposed a modern building that did not respond to the North African Climate. The client rejected his proposal four times and suggested he instead introduce deep terraces on three facades of the building to shade the windows as shown in fig 2.31. The deep terraces ensured the sun did not directly reach the glass of the inner wall lined with ribbon windows. After this, Le Corbusier began to apply different variations of sun-shading elements to different projects. The brise soleil is viewed as an extension of the wall. According to Banham (1969), the invention of the brise-soleil is an example of the process by which the advantages of the traditional massive wall over the glazed curtain wall were argued back one at a time. The brise-solei were more than a technical device, it introduced a new architectural element in the form of a thick, permeable wall." (Colquhoun 1989)

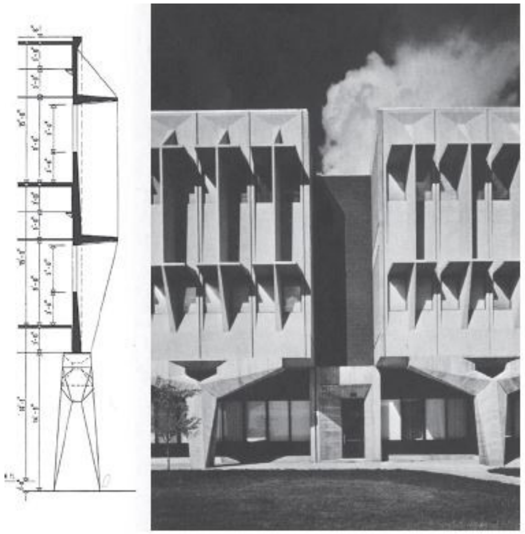

Fig 2.32. Section and image of brise soleil in design by Mark Bruere who was inspired by Le Corbusier Source: Yao (2021)

His work with Brise-soleil showcases not only the protection of glass from direct sunlight but also the importance of the aesthetic opportunities provided by these devices. Many of his buildings such as the L'Unité d'Habitation de Marseille, Mill Owners Association Building, Palace of Assembly, and Secretariat Building in Chandigarh all utilise sun-shading devices as strong visual elements.

Architect Clive Entwistle in 1946 refers to the brise-soleil as a gift to architecture (Boesiger & Stonorov 1995) and this 'gift' was readily adopted by several modernist architects and shared through the movements of the time such as CIAM and MARS group. Banham (1969) points out that from the 1930s to the 1950s, before the widespread use of mechanical HVAC systems, the brise-soleil operated as a techno-cultural object able to mediate a variety of climatic conditions. He states that it was essentially "one single building for all nations and climates."

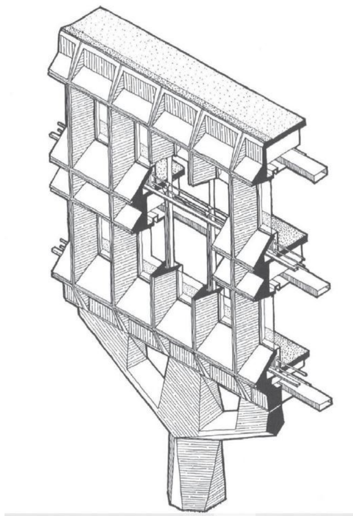

Fig 2.33. Mark Breuer's molded facade. Source: Yao (2021)

Architects re-interpreted the Brise soleil and improved on it to accommodate more features. For example, Michael Breuer in 1966, according to Yao (2021), announced his new, prefabricated thick concrete facade in an article "The faceted, Molded Facade: Depth, Sun and Shadow." in Architectural record. This comprised of thick concrete panels with deep windows and accommodation for modern mechanical systems like air conditioning as seen in fig 2.33. This system he designed for the IBM Research Center in La Gaude France from 1960- 1962 gives a structural solution that frees up the interior space as a principle of modern architecture while providing improved protection from the sun's radiation and integrating air conditioning within the beams of the pre cast facade. In this case, the sun shading device is no longer an added element attached to the facade afterwards, instead it merges into the envelope system.

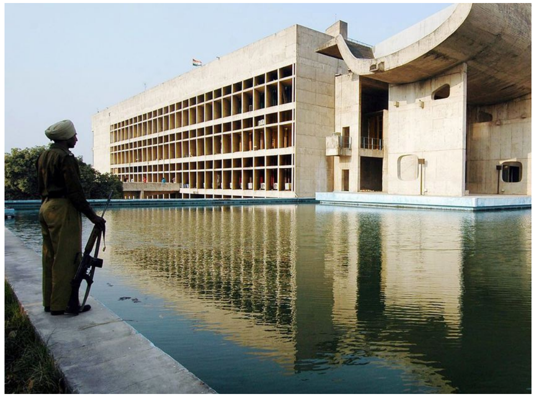

Fig2.34. Brise soleil in Chandigrah designed by LeCorbusier.
Source:the guardian

Aside from the Brise soleil, the Modern Architecture period also saw other types of sun-shading devices be utilised such as strip balconies on facades of apartment buildings beginning in the early 20s, canvas awnings, and projecting roller shutters. Awnings were considered a desirable aesthetic object in the first half of the twentieth century. When air-conditioning became available, richer people could afford to abandon the use of awnings, while the poor still used them. Consequently, awnings were associated with poor and run-down buildings.

2.2.5 TROPICAL MODERN ARCHITECTURE.

Tropical architecture is architecture adapted to tropical climate and it emerged shortly after the second world war when colonial architecture was redesigned to suit the local climatic conditions instead of replicating the European building designs in the colonies. According to Immerwahr (2007), 'tropical modernism' is an "architectural idiom" developed along inter-imperial, intra-colonial, and transnational networks. These included the exchange of knowledge from one colony to another—for example, ideas developed in India were disseminated in Africa. Inter-imperial flows of knowledge between imperial sites such as Paris and London meant that knowledge of architecture that developed in French colonies was also consumed in London.

Fig 2.35. Sun shading devices on the Ministry of Public Health Building in Rio.
Source: www.foundationlecorbusier.com

In 1928, alongside other architects, Le Corbusier founded Congres International d'Architecture Moderne (CIAM) also known as The International Congress of Modern Architecture. The members of this congress went ahead to propagate pillars of modern architecture one of which was the use of sun-shading devices. This was done through conferences, their work in various cities as well as their teaching in the AA School, Department

Fig 2.36. Mfantsipim School, Ghana designed by Maxwell Fry and Jane Drew .
Source: Transnational Architecture Group

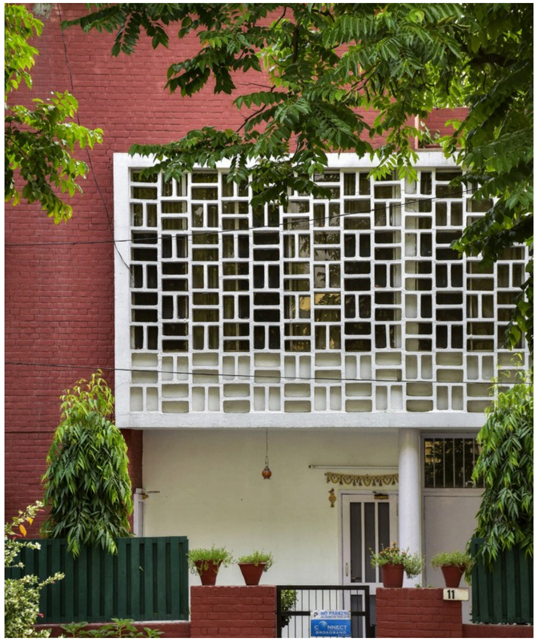

Fig 2.37. Building in Chandigarh's sector 22 designed by Maxwell Fry and Jane Drew showing interpretation of jaalis .
Source: The TribuneIndia

of Tropical Studies. Alumni of the AA school went on to practice in various British colonies and employed the lessons learnt. These include Dorothy Hughes and Richard Hughes who practiced in East Africa, Jane Drew, James Cubitt,John Godwin who practised in West Africa and Geoffrey Bawa and Raj Rewal who practised in India to name a few.

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This was also true of the AA School staff members such as Maxwell Fry who was a member of CIAM and Modern Architecture Research Group (MARS group). The world war caused major shifts in his architectural career that had a significant bearing on his position as a protagonist of Tropical Modern Architecture. He was given the post of Staff Captain in the Corps of Royal Engineers and insisted that Jane Drew be given a similar position. The outcome of their work in Africa and India is the buildings, books (Tropical Architecture in the Dry Humid Zones, 1964 and Village Housing in the Tropics, 1947), and teaching in the AA school Department of Tropical Studies which propagated Tropical Modern Architecture.

During the war, modernist architects found exile outside Europe during the Nazi period e.g., Ernst May who left during the war and moved to Uganda and later Kenya, Bruno Taut to Japan, and Otto Koenigsberger, who had worked in the office of Ernst May later emigrated from an imperial site (Berlin) to a colonial site (Mysore) and then back to another imperial site (London).

According to Baweja (2008), in the late nineteenth and early twentieth century, the concept of Tropical Architecture developed in the discipline of Hygiene and Tropical Medicine, which circulated through colonial hygiene manuals. An example is that when Otto Koenigsberger, a tropical modern architect, first started teaching in London, his first job was not at the Architectural Association School, but at the London School of Hygiene & Tropical Medicine (LSHTM). This is true for several other staff at the AA School.

After the Second World War, Tropical Architecture migrated from hygiene with the establishment of the Department of Tropical Architecture at the AA in 1954. The objective of Tropical Architecture shifted in the 1950s from disease prevention and focused more on comfort, which was defined comprehensively in terms of thermal, hygrometric, ergonomic, acoustic, and psychological well-being.

Fig 2.38. Architect Maxwell Fry and Le Corbusier at the opening of the Mars group exhibition in Burlington.
Source: Maina (2016)

In the 1950s, the mantra of Tropical Architects became "designing for the climate", which was defined as designing buildings without mechanical conditioning. It is this pillar that fostered the implementation of sun-shading devices in design for the tropics by the Tropical Modern Architects. Regionalism being a principle of the Tropical Modern movement was incorporated in the design of sun shading devices in the design of screens to mimic traditional motifs and jaalis as seen in fig 2.36 and fig 2.37 respectively.

The course on climatology at the Department of Tropical Architecture required students to acquire and interpret climatic data which would then be used to inform the design of architectural elements. A studio brief in 1962 required students to design sun-shading devices that cut off the sun's heat but allowed for daylight and views. (Baweja 2008) A Kenyan student named O. J. Pereira gave a solution that calculated the exact size of the building's sun-shading device. This was the beginning of the calculation of sun-shading device sizes for specific buildings.

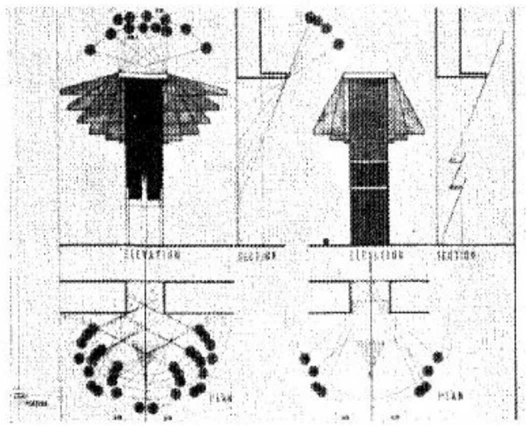

Fig 2.39. Pereira's sun shading solution as a student in AA school..
Source: Baweja Vandana (2015)

Sun shading devices during this period varied based on the type of building, materials, and region but the unifying factor was most buildings designed by Tropical Modern Architects had a sun-shading device as one of the principles on the prevention of heat gain.

2.2.6 INTERNATIONAL STYLE

Fig2.40. Margarethe Steiff factory building in Giengen Southern Germany
Source: Goethe Institut

The growing independence of the external skin from its structural function leads to complete separation from the load bearing structure in the 19th Century. The first curtain walls were realised in industrial buildings created without the participation of architects. An early example is the Margarethe Steiff factory building in Giengen Southern Germany shown in Fig 2.40 built in 1903. The next step was the use of iron and glass extensively on the facades of the new office buildings. Functional and commercial demands influenced the increased openness in facades viewed in urban areas.

The glass building known as International Style spread worldwide in the 1970s and the office building with the grid glass facade became its symbol. Facade design degenerated to monotonous surfaces and the climatic parameters such as passive cooling strategies like sun shading devices were ignored as the glass facade building was imitated in the tropics. It is in this architectural era that the sun-shading device lost its prevalence in the building's envelope. The architectural styles that followed such as post modernism, constructivism all had a common goal of giving the building skin a face since the curtain wall seemed to have reached its design limit.

Fig 2.41. Prism Tower Nairobi showing glass buildings in the tropics..
Source: Bizna Kenya

As designs of the International Style were adapted to the tropics from the colder western climates, there were huge energy costs incurred to maintain thermal comfort inside the buildings with large glass facades. Mechanical ventilation of buildings was the solution that most buildings employed. The advent of air conditioning saw the use of traditional natural cooling techniques dwindle.

For a period, they were almost completely ignored, until the energy crisis of the early 1970s prompted a revival that triggered a renewed interest in passive design strategies as well as pressing for advanced solutions. This revival has filtered through to commercial buildings only in the 1990s, however, and the use of sun shading devices is yet to regain its original standing.

2.2.7 SUSTAINABLE ARCHITECTURE

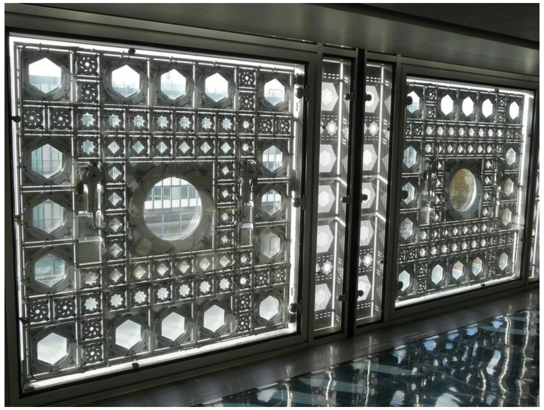

Fig 2.42. Robotic shading screen of Institut du Monde Arabe.
Source: Arch Daily

The World Commission on Environment and Development defines sustainability as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable architecture seeks to minimise the negative environmental impact of buildings and it has generated a renewed interest in sun shading devices in buildings following its decline in place of glass facades.

Energy efficiency is one of the principles of sustainable architecture and it can be achieved through the installation of sun shading devices. To match the architectural and aesthetic wants and needs of the 21st century, the design of sun shading devices has evolved from the static brise soleil. Pesenti et.al (2015) states that there is an increased interest in adaptive architecture that reconfigures itself to meet environmental mutations and user's needs thus driving the concept of a multifunctional, responsive and dynamic building skin. This has brought about the introduction of kinetic shading devices.

Fig 2.43. Penumbra kinetic shading system by Tyler Short
Source: Inhabitat

Sustainable architecture has as an example of self-adaptation and responsiveness adopted kinetic motion of responsive facades as key in the design of sun shading devices. Improvements in technology and the use of clever geometries and materials allow sun shading devices to meet changing needs with variable mobility, location, and geometry. In 1987, French Architect Jean Nouvel envisioned what has been deemed the first kinetic facade with the responsive robotic shading screen of the "Institut du Monde Arabe" in Paris France as shown in fig 2.42 Nouvel's proposal for this system was well received for its originality and its reinforcement of an archetypal element of Arabic architecture – the mashrabiyya.

Such innovation is the cornerstone of sun shading devices in this architectural era. With the inability of static architectural facade components to solve for both low evening and high afternoon sun conditions, buildings now are designed to offer a mechanical solution to the problem of the sun's shifting position. One such solution is Tyler Short's Penumbra shading system shown in fig 2.43.

2.3 FACTORS AFFECTING DESIGN OF SUN SHADING DEVICES

Determination of sun-shading devices is broken into two main categories: Environmental Factors and Architectural Design Factors. Under these we have several sub-groups as shown below:

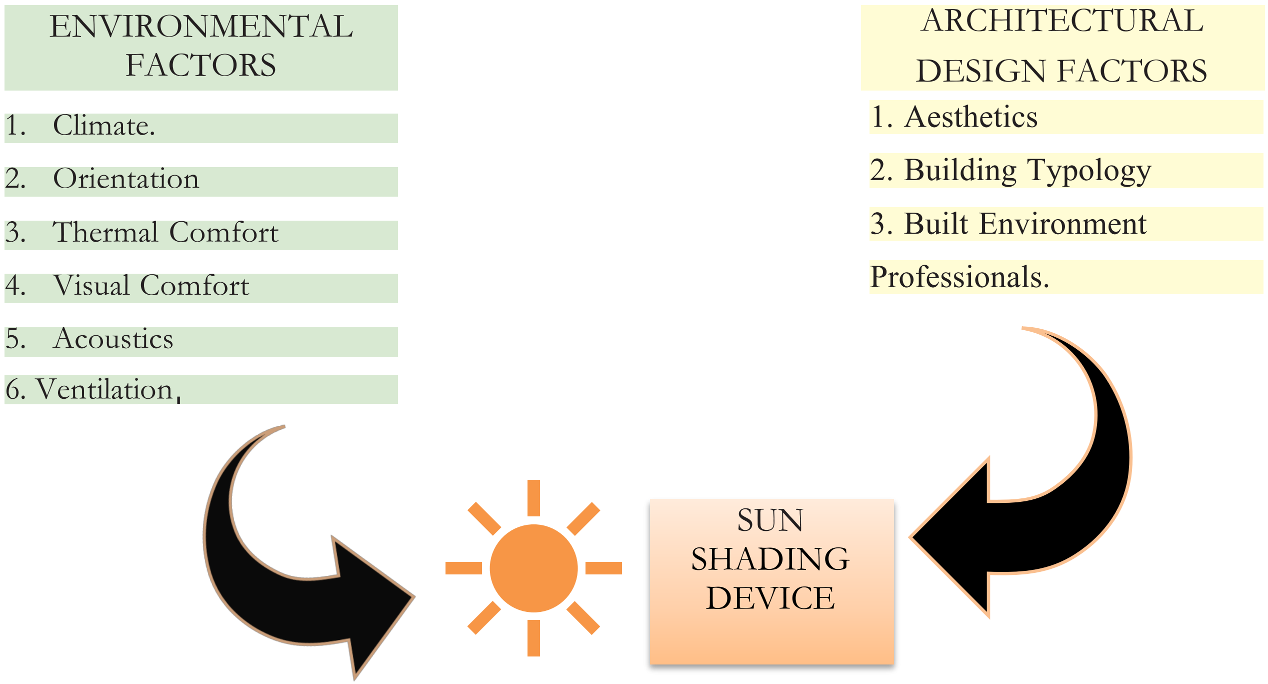

Table 2.2: Factors affecting design of sun shading devices.

2.3.1 ENVIRONMENTAL FACTORS

Sun-shading devices are primarily considered to be environmental design features. The presence or absence of sun-shading devices along a glazed facade plays a role in the perceived thermal comfort of the building. To design and implement an efficient sun-shading device, one must review all the environmental factors that have an outcome. These include the climate the building is located in, its orientation, and achieving thermal and visual comfort while still allowing for ventilation and acoustic consideration.

A. CLIMATE AND SOLAR RADIATION.

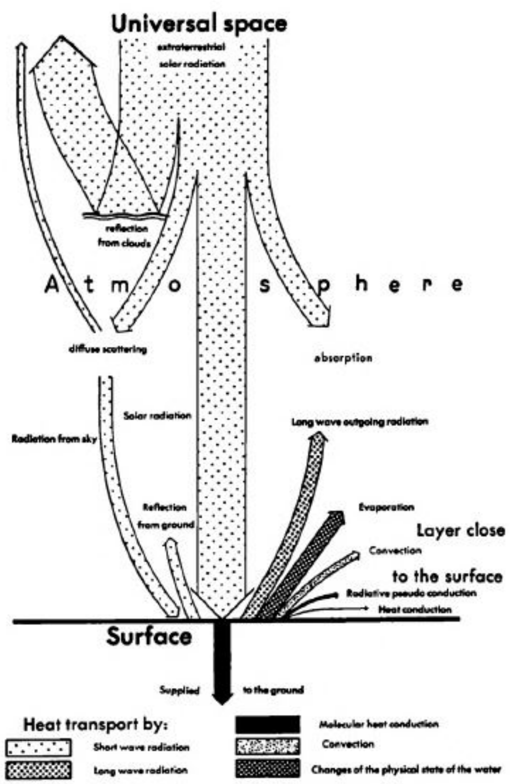

Fig2.44. Graphic representation of solar radiation being absorbed, reflected and diffuse with arrows corresponding to amount of heat transferred.
Source: Olgyay (1962)

Solar radiation is the electromagnetic energy emitted by the sun. When radiation penetrates the earth's atmosphere its intensity is decreased and the spectral distribution is altered by absorption, reflection, and scattering creating three types of radiation that affect the built environment namely: Direct solar radiation, diffuse solar radiation, and reflected solar radiation as shown in fig 2.44.

According to Givoni (1969), the climate of a region is determined by the pattern of variations of several elements and their combination. The principal climatic elements when considering human comfort and building design are solar radiation, long wave radiation to the sky, air temperature, humidity, wind and precipitation.

The different world climates have been classified in various methods such as Koppen climate classification, Koppen Geiger classification, and Thronthwaite to name a few. It is these climatic categories that are the beginning point for the design of external sun-shading devices. The intensity of solar radiation in a region is dictated by the climate. For example, Regions located near the equator such as Nairobi 1° 17' S, 36° 49' E receive far more solar radiation compared to those located farther from the equator such as London 51° 30' N, 0° 7' W.

Solar radiation penetration can be favourable or extremely unfavourable depending on the prevailing climatic conditions, season, time of day, the function of the building, and space use (occupant's activity) in the different climates, and as such sun shading devices aim to eliminate the penetration of solar radiation into buildings through glazed surfaces. External shading devices intercept unwanted solar rays and provide a cooling effect.

B. ORIENTATION

In hot climates, the devices should be carefully designed and oriented to maximise shading during overheated periods to reduce heat gain and maximise solar heat gain during cold periods. For tropical climates, the most appropriate building orientation to minimise solar heat gain is along the east-west axis with the long façades of the building facing north and south.

However, it should be noted that site constraints (such as topography, surrounding buildings, streets, etc.) and conflicting wind directions influence the efficiency of the location of sun-shading devices. For example: In an urban setting, with a grid pattern, the orientation of a building and its windows is more often than not dictated by the plot of land. Once again, in a street with high-rise buildings casting shadows on each other, the design of the sun-shading device should cater to this to still allow for enough solar radiation to reach the windows and achieve thermal and visual comfort.

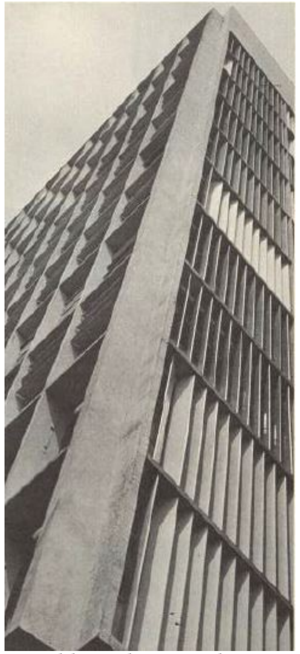

Fig2.45. Building showing different sun shading devices for different orientations.
Source: Olgyay & Olgyay (1957)

According to Olgyay & Olgyay (1957), differently oriented walls need different kinds of shading devices as seen in fig. 2.45. as compared to a building such as fig. 2.46 that doesn't consider orientation. The sun's path constantly changes and as such the devices should change types or dimensions depending on the orientation of each wall. They however warned that there is a sharp difference between playful variations of conviction and surface ornamentation.

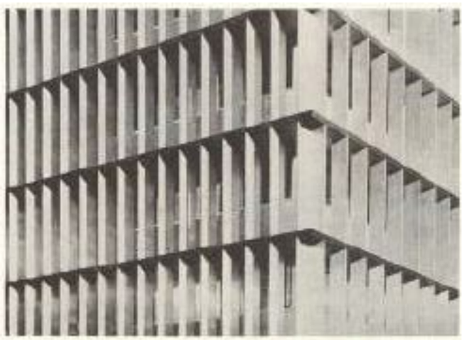

Fig 2.46. Building with similar sun shading for all orientations .
Source: Olgyay & Olgyay (1957)

C. THERMAL COMFORT

According to Givoni 1969, the maintenance of thermal equilibrium between the human body and its environment is one of the primary requirements for health, well-being, and comfort. The conditions under which such balance is achieved depends on the combined effect of many factors such as individual characteristics like acclimatization, clothing, etc., and environmental factors like air temperature, radiation, humidity, and air motion.

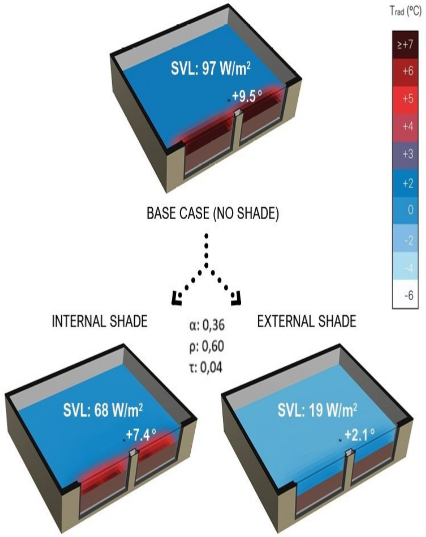

Fig2.47. Simulation of internal temperature calculations in a building when using internal and external shading devices.
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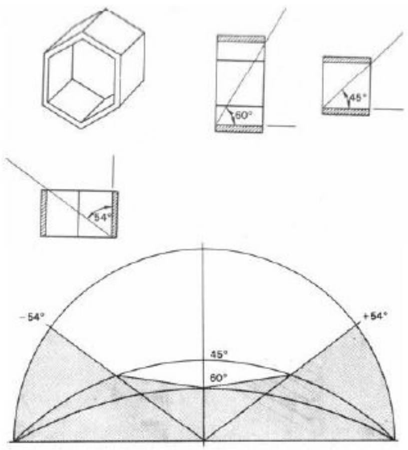

Fig 2.48. Image showing how to calculate a shading mask of egg crate device.
Source: Koeningsberger et al(1975)

The thermal performance of any building entails the interaction between the exterior environment and the building envelope. These external conditions are constantly changing hour by hour and season by season and the design of sun-shading devices should consider the hottest and coldest temperatures in the specific latitudes. Factors such as site location, building orientation, materials, and climatic conditions, if not appropriately considered in the building design, can result in thermal discomfort or high energy costs to achieve thermal comfort mechanically.

Thermal discomfort as a result of solar radiation through glazed openings is assessed by subjective evaluation of internal/indoor temperature. Thermal equilibrium is achieved when an occupant's internal heat production is the same as the heat loss. It can be influenced by levels of activity, clothing levels, and thermal environment. The Predicted Mean Vote (PMV) and Percentage People Dissatisfied (PPD) designed by Prof Ole Fanger is a method used to predict thermal comfort. PMV makes it possible to predict the thermal sensation of a population. Once done, the PPD establishes a quantitative prediction of the percentage of thermally dissatisfied occupants i.e. too cold or too hot. The main factors causing local discomfort are unwanted heating or cooling of an occupant's body. Sun shading devices deal aim to address unwanted heating of the body through direct radiation in a building from the glazed windows and openings.

D. VISUAL COMFORT

Sun-shading devices control the amount of daylight entering a building and can thus also determine visual comfort. Sun-shading devices are key in the prevention of glare. Depending on the type of sun shading device and the angle of the sun, a shading mask is created to prevent direct solar penetration and therefore prevent glare. The shading mask of each type of sun-shading device can be calculated and represented as shown in fig 2.48.

The shadows created by the sun-shading devices also reduce the daylight levels affecting the illuminance and daylight factor in a room and can increase artificial light needs and block the beneficial winter solar radiation This is dependent on the function of the room and there is a need to still compromise on user's visual wellbeing versus energy saving through the use of natural lighting. In cold climates, an increase in shading decreases the cooling requirements, but at the same time, they increase the heating demand given the reduction of solar gains. As shown in fig 2.49, a light shelf can act as both a sun shading device and reflect light to the interior of the room thus improving daylighting while preventing heat gain at the window glazing.

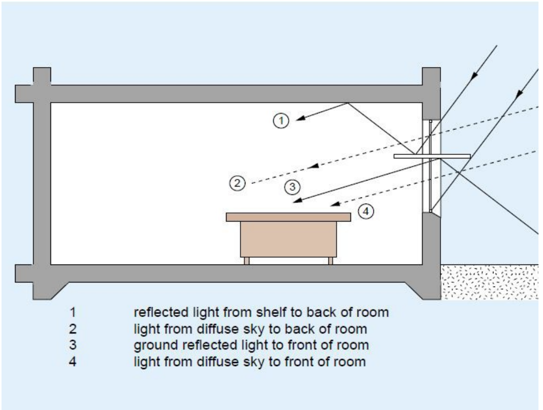

Fig2.49. Visual effect of a light shelf. Source: Stack. A et al.

Sun-shading devices also affect the view out. Depending on the type and materials used the device can completely obscure a view or frame a view thus creating either privacy or an obstruction. Fig 2.50 shows the design of a horizontal sun shading device with the eye level being considered not obstructing the view out. The views of the outdoors contribute to visual and psychological comforts, health, and productivity. Researchers have found that dissatisfaction with divided windows is very high as users felt the overall clear window was too small to view outside. The same is true for sun shading devices such as horizontal louvres or egg crate shading devices.

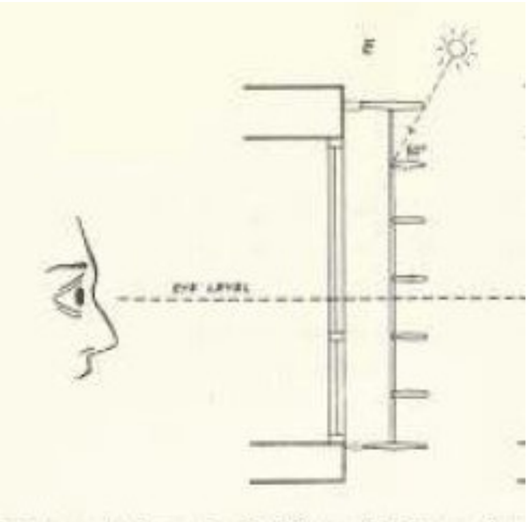

Fig2.50. Design of shading device with uninterrupted eye -level line of sight. Source:Olgyay & Olgyay (1957)

Sun-shading devices also provide privacy by preventing a view into the building. This can be seen in traditional mushraabiya and jaalis as well as with egg crate, louvred, and closely packed vertical sun shading devices. The traditional external shutter common to the Mediterranean is a very effective shading device and efficient light redirection system. The horizontal slats of the shutter reflect light to the ceiling resulting in increased light distribution in the space, improved visual comfort, and reduced heat gains.

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E. VENTILATION

Natural ventilation is a key factor in the achievement of sustainable design. Shading devices can change the external direction of the wind as well as the pattern of airflow inside a building by altering the direction and speed of the air.

The sun-shading device either encourages cross ventilation or impedes the movement of air. It can also increase the indoor temperature by causing a build-up of hot air between the window and sun shading device. As shown in fig 2.51, the sun-shading devices at Millowner's Association Building in Ahmedabad India are positioned away from the glass to allow air circulation to remove any heat captured.

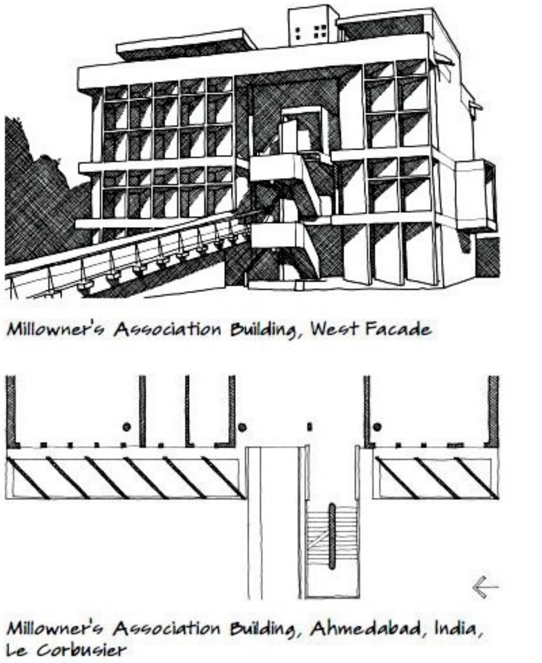


Fig 2.51 Millowners Association Building showing relationship of shading device to the wall to allow ventilation.
Source: DeKay & Brown(2014)

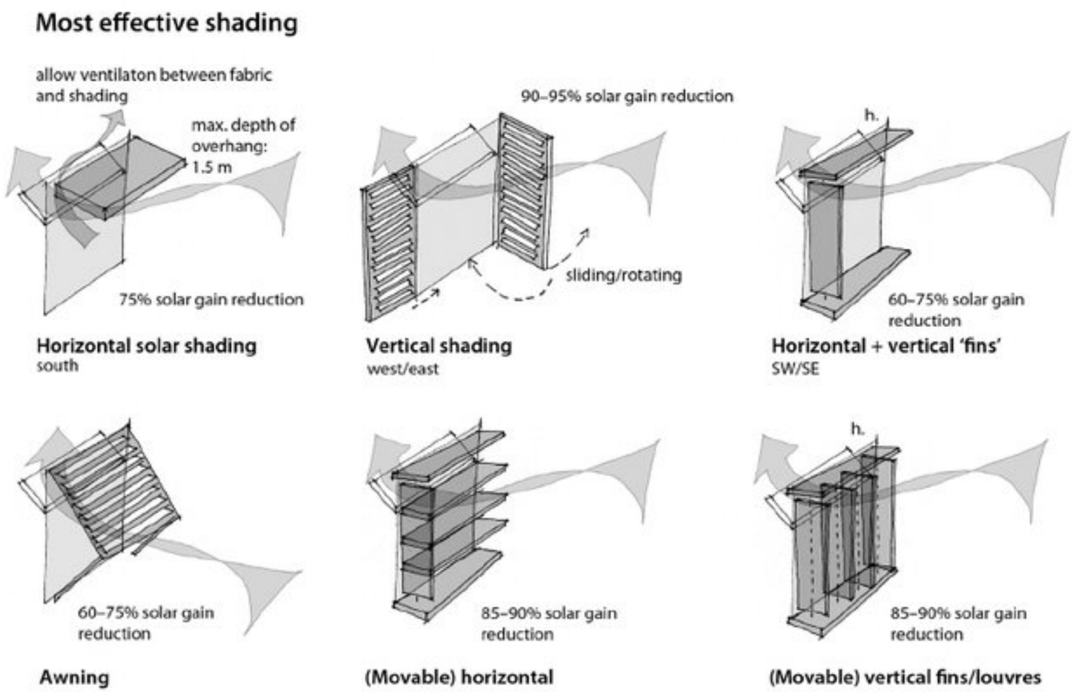


Fig 2.52 Different sun shading devices and air flow with a top hung window for ventilation. Source:Pelsmakers (2012)

F. MATERIALS

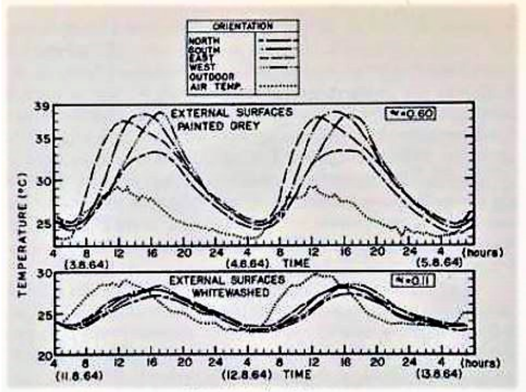


Fig2.53. Comparison of temperature of external surfaces between a light and dark coloured surface.
Source: Givoni(1969)

According to Givoni(1969), the external surface of any opaque material has three properties determining behaviour concerning radiant heat exchange namely its absorptivity, reflectivity, and emissivity.

Radiation on an opaque surface may be absorbed or reflected, being fully absorbed by a perfectly black surface and fully reflected by a perfect reflector. The absorptivity decreases and the reflectivity increases with the lightness of colour. Black surfaces become much more heated on exposure to the sun due to its darkness. This means a light-coloured shading device will reflect more light into the building through the window as compared to a dark-coloured device. This is expressed in the graphs shown in fig 2.53 showing different orientations of a building painted grey and whitewashed and the effective temperature when exposed to the sun's radiation. This affects the visual comfort within the building. A highly reflective light-coloured material will cause glare and thermal discomfort.

The choice of material on facades also dictates the transmission of heat. A material's time lag refers to the time taken for the conduction of heat through the material. Concrete has a higher thermal mass than glass and therefore a longer time lag than glass which has almost no time lag. The amount of solar radiation and visible light transmitted inside a building depends on the type of glazing used. For example, commonly used clear glass transmits more than 80% of incident solar radiation and more than 75% of visible light.

Fig 2.54. Scoring lines on concrete in Michael Breuer's molded facade.
Source: Yao(2021)

According to Yao (2021), sun shading devices are exposed to natural forces, dirt, dust, water, and other agents of the weathering processes which led Architect Breuer to claim that an advantage of glass sun shading devices is its ability to self-clean. Concrete is another material he utilised significantly in his practice and this was because he considered it to age well in nature. He began with pre-cast concrete leaving traces of the formwork on the concrete surface but later switched to sandblasted acid-washed concrete because the rough surface caused by exposed aggregates reduced reflection of light into the interior space.

Scoring lines in concrete was another design feature Breuer included in his design of sun shading devices. This was important in order to keep the concrete and the windows clean in his molded facade system. Having attempted it in three projects, the scoring line was eventually located next to the outer edge of the bottom side of the sun shading device as shown in fig 2.54.

G. ACOUSTICS

The acoustic effects of brise soleil or other external sun shading devices are not often considered yet they can be optimised to influence acoustic comfort on buildings even when windows are open. This is especially relevant when designing very close to noisy roads or railway tracks where they can act as sound barriers.

According to Fausti et.al (2019), external shading devices tend to increase the sound pressure level over the building facade therefore the introduction of the sound-absorbing material behind each louvre reduces this problem. Shading devices can cause noise by allowing reflection of sound into the building. Rough materials disperse sound whereas sound-absorbing materials reduce the risk of sound reflection.

When studying the Acoustic effects of sun shading devices such as louvres, it can be evaluated by looking into the following factors:

1. Insertion Loss (sound pressure level differences between situations without and with shading system)
2. effects of the size of shading device
3. spacing of louvres
4. the tilt angle of louvres
5. the height from the ground of the studied facade.

Shading device configuration also affects airflow patterns, air velocity, and the air temperature in an air cavity. The area of a double skin facade's vent opening could lead to an increase in noise transmission. Proper controls of shading devices inside a double skin facade's air cavity can contribute to thermal and acoustical comfort with avoiding overheating and noise transmission. This applies to the glass buildings common to International Style at the moment.

2.3.2 ARCHITECTURAL DESIGN FACTORS

John Ruskin differentiates between a building from architecture in the Seven Lamps of Architecture by stating that, “A building does not become architecture merely by the stability of what it erects. Architecture is the art which disposes and adorns the edifices raised by man for whatsoever uses, that the sight of them contributes to his mental health, power, and pleasure.” For sun shading devices, this statement means that the ornamentation, regionalism or localisation of design as well as the psychological effect on the users makes it more than just a building element but instead the sun shading device becomes an architectural element. Ruskin (1849) challenges young architects to rise to consider the effect of shading on a building through his statement:

> “And among the first habits that a young architect should learn, is that of thinking in shadow, not looking at a design in its miserable liny skeleton; but conceiving it as it will be when the dawn lights it, and dusk leaves it”

In this chapter we look at how design of sun shading devices as an architectural element is affected by aesthetics, building typology and the industry players.

A. AESTHETICS

The building’s facade can be described as ornamental packaging that defines the aesthetic and gives character to a building. According to Baird (2001), as the movement towards environmentally responsible buildings has continued, an awareness of the expressive possibilities of passive environmental controls seems to have led to more of them expressing the means of environmental control. The “place” of services, in the sense that Louis Kahn used the term, is, therefore, a matter of aesthetics rather than an overriding technical logic. When sun shading devices are designed with no consideration for appearance and the building’s form, the result is poor architecture.

Marcel Breuer in his book Sun and Shadow (1955) solidifies this notion by stating that “The sun control device has to be on the outside of the building, an element of the facade, an element of architecture. And because this device is so important a part of our open architecture, it may develop into as characteristic a form as the Doric column.” Going by this statement, the aesthetic value of sun shading devices is not secondary to the function of thermal performance but instead goes hand in hand as a factor to be considered during the design process.

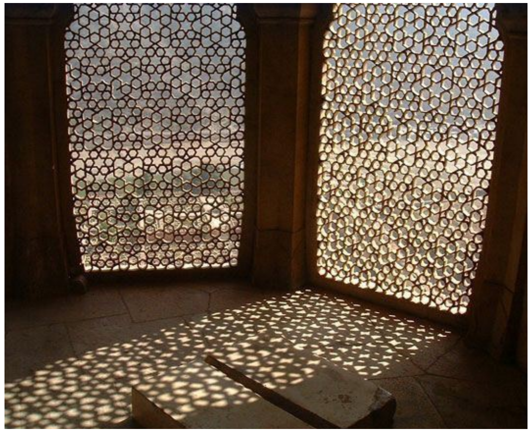


Fig2.55. Indian Jaali with geometric design in Mughal architecture.
Source: https://sites.psu.edu

Fig 2.56. Traditional Mashrabiya screen.
Source: Picfair

Exterior fixed sun shading elements are a medium of architectural expression and they can represent a dominant part of the facade. Progressive architects started using the possibility of shading devices a long time ago, not only to provide comfortable conditions on the premises but also to make the buildings more architecturally expressive beyond the technical and economical level.

“That designer who designs the shading devices all to be the same on every façade orientation or is more interested in creating a façade pattern as opposed to designing shading devices that perform is essentially creating false structure and deceiving designers and users as to what makes this building perform just as a false column would mislead a designer or user to understanding how a building is held up.” (Ruskin, 1849) this statement concludes that there is need for a balance of functional and aesthetic considerations when designing sun shading devices.

‘Shading devices are expressive because they ‘invite a rich play of light and shadow’, and to their ‘plastic appearance they add rhythm, light, colour, and texture’. ‘Patterns might be geometrical or use the fluid play of the claire-obscure of the light.’ Landis (2019) According to Ghosh (2016), culture generates desires and he questions how new buildings, new narratives, and new cultural practices can adjust such patterns and foster new desires. The highlighting of sun shading devices is visible amongst some cultures that have distinct sun- shade devices such as Mushrabiya and Jaalis shown in fig 2.55 and 2.56. These devices were dictated by a cultural desire to provide privacy for the women while still allowing them a view of the street for the Swahili people. The glazed towers of modern architecture that are reliant on mechanical air conditioning reflect how current cultural desire is interior spaces with adjustable temperature and humidity to suit the occupant’s needs. This has led to the decline in the use of sun- shading devices to provide thermal comfort in contemporary buildings.

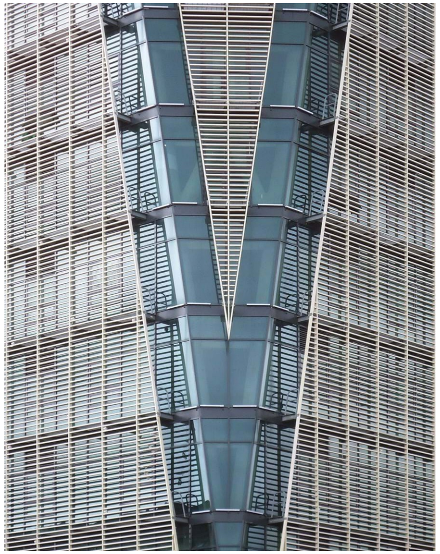


Fig2.57. Sun shading solution to the glass facade of Britam Tower, Nairobi.
Source: www.chapmanbdsp.com

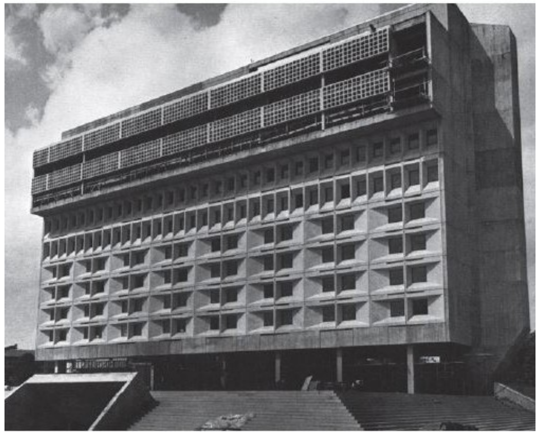


Fig 2.58 Campus Center in the University of Massachusetts showing different sun shading strategies based on internal functions of the building
Source: Yao(2021)

A. BUILDING FUNCTION

Internationalism which is currently in vogue is pushing for large glass facades in buildings however, with large glass facades comes overheating and the greenhouse effect which requires mechanical cooling or air conditioning. Office buildings as a building typology in contemporary architecture, with their transparent facades, tend to have a high window-to-wall ratio (WWR). While this is the current trend, most countries are faced with the need to reduce their national energy consumption while the use of air conditioning in buildings, computers and varying other electrical appliances is constantly increasing. The large glass facades create visual problems coupled with the increased glare caused by use of computers in offices therefore making sun shading devices a necessity in office buildings. Fig 2.57 is an example of sun shading of glass facade buildings of International Style.

Yao (2021) discusses how Michael Breuer designs sun shading devices that vary according to the internal function. For example, in design of office and factory buildings, the sun shading device pattern is usually identical and repetitive throughout the building but for multi-function spaces, the sun shading devices should have variations that directly correspond to the different internal functions of the building. As shown in fig 2.57, the south facade of the Campus Center at the University of Massachusetts was designed by Breuer with varying shading patterns for the hotel section, the office section, and the restaurant section.

B. KEY PLAYERS IN THE BUILT ENVIRONMENT

Architects naturally have spearheaded the discussion, research, development, and implementation of sun shading devices in buildings. Le Corbusier as discussed in 2.2.4 discovered Brise Soleil and this was implemented worldwide as a result of his influence in Architectural Conferences and CIAM. Architects Aladar Olgyay and twin brother of Victor Olgyay are both famed for pioneering the bioclimatic comfort charts and an early compendium of "solar control and shading devices," and the architectural spectrum of solar innovation via submissions for the 1957 "Living with the Sun" competition.

According to Landis (2018), in a 2012 survey of European architects, 82% stated that they believe designing for solar energy is 'Important' while at the same time a majority of respondents rated themselves as 'poor' or 'very poor' with solar design tools or advanced tools. This indicates designers have a strong desire to design shading devices that perform well, however, they may lack the ability to do so due to undisclosed deficiencies in the available tools.
Aside from architects, other specialised roles have emerged such as facade engineers and environmental design consultants to bridge the gap in the design of effective sun shading devices.

Architects Victor and Aladar Olgyay in their book Solar control and shading devices provide charts to highlight the economic feasibility of shading devices. Their study shows the thermal impact of each building element and the largest component is the solar gain through the window. Their study compares the cost of a curtain wall, vertical fin, fixed egg crate, horizontal, vertical movable, and movable egg crate and locates them at the most effective facade orientation. By calculating the installation cost of each device, adding a two-year operating cost, and comparing it to the cost of air conditioning, Olgyay & Olgyay(1957) concluded that it is evident that shading devices might not only pay their way but save in cost if properly designed. Several other sources have concluded the same economic value of sun shading devices, showing an almost a twenty percent reduction in cooling load requirement that results in a payback period that varies between three and a half to seven years, which is considered cost-effective.

Clients have the opportunity to ensure the use of sun shading devices as a means of passive cooling of the building is a key element through their choice of architect as well as through specifications in their brief. They have options such as architectural design competitions to decide on their preferred concept or designer. In other instances, they had approached a specific architect directly. Developers and clients are now beginning to show interest in having a low-energy building and are supportive of environmentally conscious design. Increasing acceptance by clients that it should not be necessary to operate mechanical ventilation systems all year round and instead seeing the benefits of environmentally responsible buildings through future-proofing, reduced operating costs, and comfort and health benefits is a step in the direction of revival of sun shading devices in building design.

Policymakers also play a role in encouraging the design of thermally comfortable buildings. For example, according to Komatina et al (2015), the European Union has gained significant experience in the valuation, design, application, testing, and calculations of various shading devices in construction. Currently, there are more than 50 European standards for shading devices whose requirements and use are available in both European directives and national documents on the design of various buildings. Other design guidelines of note that architects refer to, though not mandatory, are the green building rating tools also known as certification. The first was BREEAM which was introduced in 1990. They are used to assess and recognise buildings that meet certain green requirements or standards. Rating tools are voluntary and recognise and reward companies and organisations that build and operate greener buildings. This provides incentives to push the boundaries on sustainability which in turn sets industry standards that in the future become part of government building codes and regulations, workforce training, and corporate strategies. Fig 2.58 shows the various rating tools and their countries of origin. The most popular are Green Star, LEED, BREEAM, and EDGE.

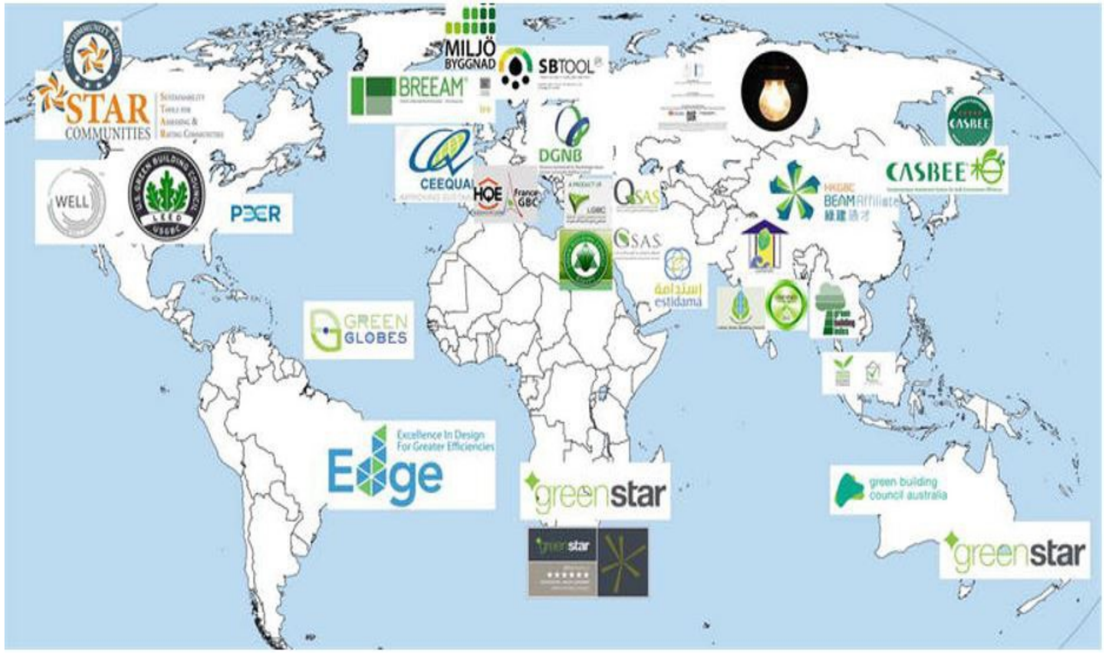


Fig 2.59. Common rating tools around the world
Source: Intechopen.com

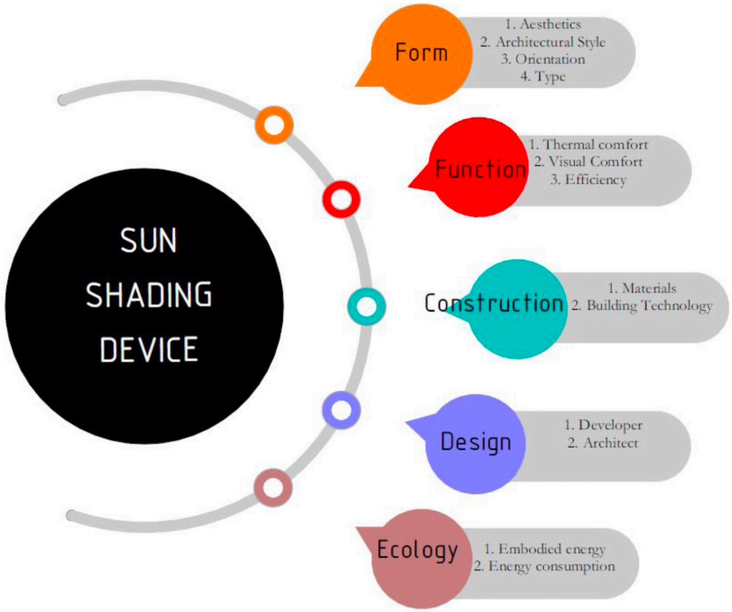


Fig 2.60 Conceptual framework
Source: Author

2.4 CONCEPTUAL FRAMEWORK

The literature reviewed brought out the types of sun shading devices and different aspects that determine the design and effectiveness of sun shading devices. A look at the evolution of architectural styles and the role of sun shading devices reveals the beginning of sun shading devices in vernacular architecture, the unconscious nature of sun shading devices during the classical era, and the role of glass and the industrial revolution in creating the need for sun shading device during the modern architecture period with Le Corbusier and the brise soleil being heralded as the turning point in modern architecture and introduction of sun shading devices globally and more so in the tropics creating the tropical modern architectural style. It further explains the decline in the use of sun shading devices with the introduction of International Style and the glass skyscraper. The sustainable architecture period that we are now in begins to rethink the sun shading device with a need to be environmentally conscious but still exploring the openness of the fully glazed facade akin to the office building in the 21st Century.

Aside from its role in achieving thermal comfort through the prevention of heat gain by direct radiation of glazing, the literature review discusses other roles that sun shading devices affect such as visual comfort, ventilation, acoustics, and the building's aesthetics. This is dictated by the architects who as discussed further deal with issues of calculation of sun shading devices, construction details, cost of construction, building policies, and developer satisfaction. Other professionals such as facade engineers and environmental consultants have recently emerged giving specialised input on the subject. All these factors affecting the design of sun shading devices can be categorised as expressed in fig 2.59

For this study on sun shading devices, the focus is on Form, Construction, Function and Design Professionals.

1. Function. Does the sun shading device meet the practical purpose of the device namely interception of direct solar radiation before it reaches a building's glazed windows or walls thus providing thermal and visual comfort? This requires a look at the climatic and environmental factors affecting design of the sun shading devices.
2. Form. What does the sun shading device look like? Is it influenced by the architectural style or movement of the day? Does the building function influence the type of sun shading device used?
3. Construction. What are the materials used in the construction of the sun shading devices and how are they assembled? What construction policies were considered? What cost factors were considered?
4. Design Professionals. What role does the architect play versus the developer? What methods are used in the calculation of the sun shading device? What are the policies considered if any? Are there any other professionals involved in the design aside from the architect?

CHAPTER 3: RESEARCH METHODS

3.0 Introduction

3.1 Research Strategy

3.2 Sampling Design.

3.3 Data Collection and Research Tools

3.4 Data Processing and Analysis

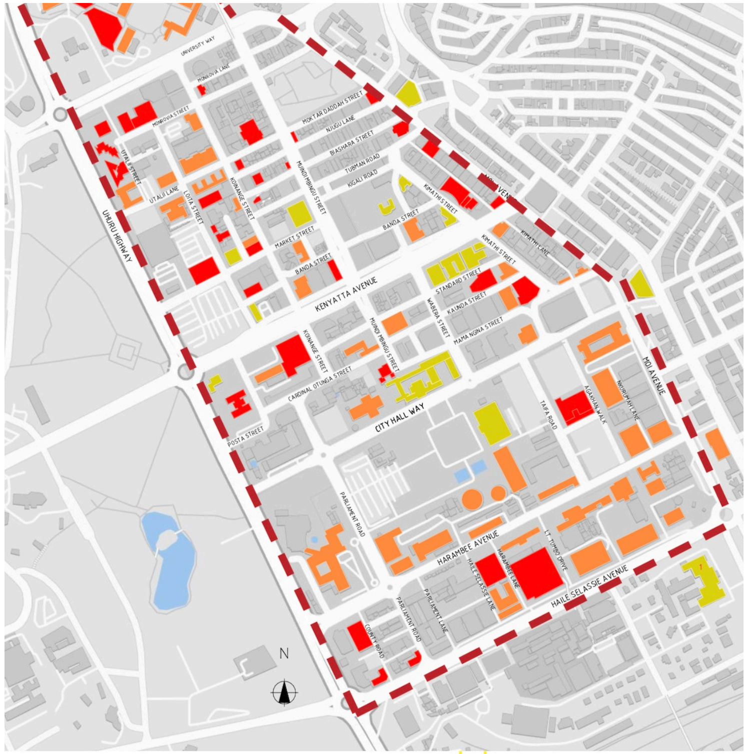


Fig 3.1. Scope of study. Buildings on either side of Haile Selassie Avenue to the South, Moi Avenue to the East, University of Nairobi, Main Campus to the North and Uhuru Highway to the West.
Source: Author.

3.0 INTRODUCTION

As defined in chapter one, the research focuses on external sun-shading devices in Nairobi with emphasis on Nairobi Central Business District. This chapter outlines the methodology used to meet the objectives listed in chapter one. These objectives are:

1. To identify factors affecting sun shading device design and implementation in Nairobi since its formation to 2020.
2. To analyse the historical trends of sun shading devices in Nairobi
3. To predict future trends of sun shading devices in Nairobi.

The research is qualitative research as it focuses on the 'why' of the subject matter rather than 'what' it is. An in-depth study of the sun-shading devices on buildings is done by use of case studies and historical inquiry. This will then be studied to generate a theory on the trends of sun shading devices in Nairobi

3.1 RESEARCH STRATEGY

The research strategy used is the case study method and trend analysis. This involves analysis of data collected through case studies to determine a trend and its development over time.

The purpose of trend analysis is to spot a prevalent trend within a user group and/ or to determine how a trend developed or would develop over time. This exercise helps identify new opportunities and ideas for concepts. It is, fundamentally, a method for understanding how and why things have changed – or will change – over time. (Rae A. 2014)

Fig 3.2. Nairobi in 1920s.
Source: http://www.sikh-heritage.co.uk

Fig 3.3. Nairobi in the 1950s.
Source: http://www.sikh-heritage.co.uk

Fig 3.4.Nairobi in the 1970s.
Source: http://www.sikh-heritage.co.uk

Temporal trend analysis is used to analyse the trend within or across user groups defined by specific time period(s) or change over time. As a methodology its core strength is it is helpful in figuring relationships between user groups from different generations and in predicting future events based on those of the past.

For purpose of this research the time periods have been divided into the following categories five based on the literature review.

a) Before 1898. The pre-colonial period looks at the traditional architecture of the communities living in the Nairobi area prior to the railway line reaching Nairobi on 30th May 1899.

b) 1898-1910. This period looks at the architecture during the foundation of Nairobi as a railway town to its growth to being the new capital city within the British protectorate.

c) 1910- 1940. This period is defined by the architecture of the British colonial administration and the influence of the First and Second World Wars.

d) 1940- 1980. The introduction of modern architecture to Nairobi defines this time period. According to Maina (2016), notable modern architects practicing in the tropics between this time period were responsible for the spread of tropical modern architecture alongside other styles of modern architecture, it focuses on the work of these tropical modern architects and their architectural input.

e) 1980-2020. Interpretation of International Style and Sustainable Architecture in Nairobi is the focus of this time period. The two styles run co-currently with sustainable architecture beginning around the year 2000 and being implemented in buildings that still feature aesthetic characteristics of International style.

The case study method is a reliable method and can be generalised to form a compelling theory. It captures information in a more explanatory way and answers the questions 'how', 'what' and 'why'. The case studies selected in the Nairobi CBD give insight into the variety of sun shading devices and the architectural period they belong to. It uses selected buildings relevant to the study to meet the research objectives by incorporating

incorporating multiple sources of evidence. These sources include examination of buildings from published and unpublished data available such as maps, images and drawings of the buildings, interviews with architects and other relevant people on the subject matter to give further insight as well as physical observation and examination of the sun shading devices on the selected buildings.

3.2 SAMPLING DESIGN

The number of buildings put up in Nairobi from 1898 to 2020 is extensive with some of the buildings having been demolished over the years. There is therefore a need to use sampling to select case studies that are according to the author relevant and responsive to save time.

The sampling frame is defined by the timeline of the study 1898-2020, the location of the case studies being Nairobi Central Business District, and the sun shading device type being external and fixed. All buildings within the CBD with sun shading devices will be documented. Stratified sampling is used to divide the buildings into subgroups based on the type of sun shading device (horizontal, vertical, or egg crate), and from each subgroup simple random sampling is used to select the case studies for each period. Some buildings selected may have two different types of sun shading devices.

All buildings within the respective period will be documented. A maximum of 14 buildings per period will be analysed as case studies of the period as a result of the stratified sample. One of the buildings from these case studies is selected for further analysis. This building is selected based on the availability of information, and accessibility as well as its being representative of the sun shading devices of the period it belongs to. Due to the lack of buildings from this period currently erect in the CBD, no building is selected for further study in the before 1898 and 1898-1910 categories.

Table 3.1 Case studies selected from the five architectural time periods for the study.

1. BEFORE 1898 - VERNACULAR ARCHITECTURE	**2. 1898 -1910 Buildings**
i) Maasai Manyatta ii) Kikuyu traditional hut.	i) Norfolk Hotel ii) Bank of India iii) Indian Bazaar Street iv) First DC's office and court house

3. 1910-1940 Buildings

1. Kipande House -1913
2. Old PC's House -1913
3. New Stanley Hotel (as built in 1913)
4. Khoja Mosque -1922
5. Pan Africa House - 1928
6. Westminster House -1928
7. Kenya Railways Headquarters- 1929
8. Law Courts - 1929
9. National Archives - 1931
10. McMillan Library - 1931
11. City Market - 1932
12. City Hall -1934
13. Kenwood House - 1937.
14. Stanbic (formerly Torr's Hotel)

Building selected for further analysis.

KIPANDE HOUSE

Representative of the classical and Neoclassical architectural style of the colonial administration in Nairobi.

4. 1940-1980 Buildings

1. Bhagwanji Building -1949
2. Parliament Building -1952 & 1963
3. Central Bank - 1962
4. Hyslop Building -1962
5. AG Chambers & Sheria House - 1962
6. IPS Building -1967
7. Education Building - 1968
8. Jogoo House B - 1968
9. Kenindia- 1970
10. Chai House - 1970
11. BIMA House - 1971
12. KCS House - 1975
13. Development House - 1977
14. National Bank Headquarters - 1978

Building selected for further analysis.

EDUCATION BUILDING

Representative of the Tropical Modern Architectural style in Nairobi.

5. 1980-2020 Buildings

1. ICEA Building - 1980
2. Re-insurance Plaza - 1982
3. Treasury Building - 1982
4. City Hall Annexe - 1982
5. Corner House - 1985
6. Barclays Plaza - 1988
7. Pension Towers - 1990
8. Nation Centre - 1997
9. Times Tower - 1998
10. GPO Telposta Towers -1999
11. I&M Building - 2001
12. Yala Towers - 2013
13. University of Nairobi Towers - 2016
14. CBK Pension Towers - 2020

Building selected for further analysis.

UNIVERSITY OF NAIROBI TOWERS

Representative of Sustainable Architecture and International style in Nairobi.

3.3 DATA COLLECTION AND TOOLS

Fig 3.5.Woolworths building on the then Delamere Avenue.
Source: http://www.sikh-heritage.co.uk

Structured observation is used to collect the required data to answer the research questions. In order to have a standardised criteria for observation, the author uses a format as described in Dekay and Brown's book Sun, Wind and Light (2014) The building is categorised based on a design characteristic of a design component. This then addresses a design issue for example it's impact on an energy issue.

Observation is used to collect the observable physical elements of the sun shading device. Using the five categories discussed in the conceptual framework and the categorisation in sun, wind and light (2014) the information is collected as follows. The design component is the sun shading device and the characteristics to be studied out of those highlighted in fig 3.6 are the size, shape, orientation, use, type, colour, texture and materials. These are broken down as follows:

1. Function. Use and efficiency of the device.
2. Form. Aesthetics, Size, Shape, Type and Orientation of the device.
3. Construction. Colour and texture of materials used.
4. Design Professionals. Architect and building developer.

For this study, the ecology category will not be studied.

DESIGN CHARACTERISTICS

- Size
- Shape
- Enclosure
- Orientation
- Increment
- Location
- Edges
- Use/Occupancy
- Linkages
- Layers
- Type
- Color
- Texture
- Material
- Switching
- Cycles
- Configuration
- Organizations, Open
- Organizations, Modular
- Organizations, Stacked
- Organizations, Staggered
- Organizations, Radial
- Organizations, Gridded
- Organizations, Combined
- Organizations, Sectional
- Organizations, Differential
- Organizations, Thin
- Organizations, Thick
- Organizations, Zoned
- Organizations, Elongated
- Organizations, Networked
- Organizations, Nodal
- Organizations, Compact
- Organizations, Clustered
- Organizations, Dispersed
- Organizations, Hierarchical
- Organizations, Interwoven

Fig 3.6. Design characteristics when studying a design component.
Source: DeKay & Brown. (2014)

Interviews are conducted using open ended interviews to acquire data on the building's architects, their building design strategies and years of construction.

The observed data is recorded using the data collection tools below:

1. Photographs
2. Sketches and analytical notes.
3. Measured drawings.

3.4 DATA PROCESSING AND ANALYSIS

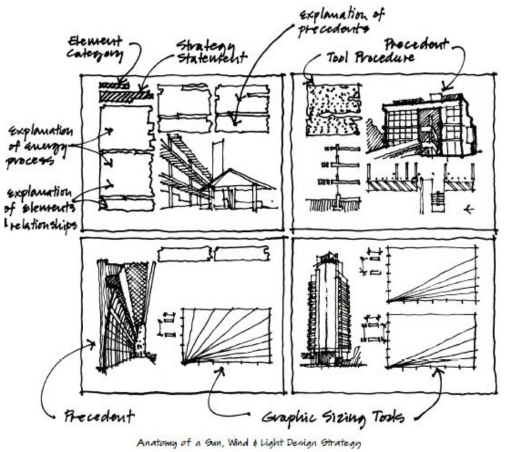


Fig 3.7. Format of presentation of information of a case study.
Source: DeKay & Brown (2014)

Each building is studied based on the four categories of element analysis in the conceptual framework namely form, function, construction and design professionals. The descriptions follow a consistent, transparent pattern. The intent is to enable ready comparison of the sun shading devices to these issues. The pattern is as follows:

1. The history of the architectural era and it's corresponding architectural style.
2. The building, its location and its designers.
3. The form of the sun shading device. Type, orientation, size and shape of the sun shading devices.
4. Construction materials used, the colour and texture.
5. Performance of the device

Aside from the documentation of the information in the five points above, the presentation of time-trend data will include graphical plots displaying the observed data over time and a descriptive interpretation of the trends seen.

CHAPTER 4: SUN-SHADING DEVICES IN NAIROBI

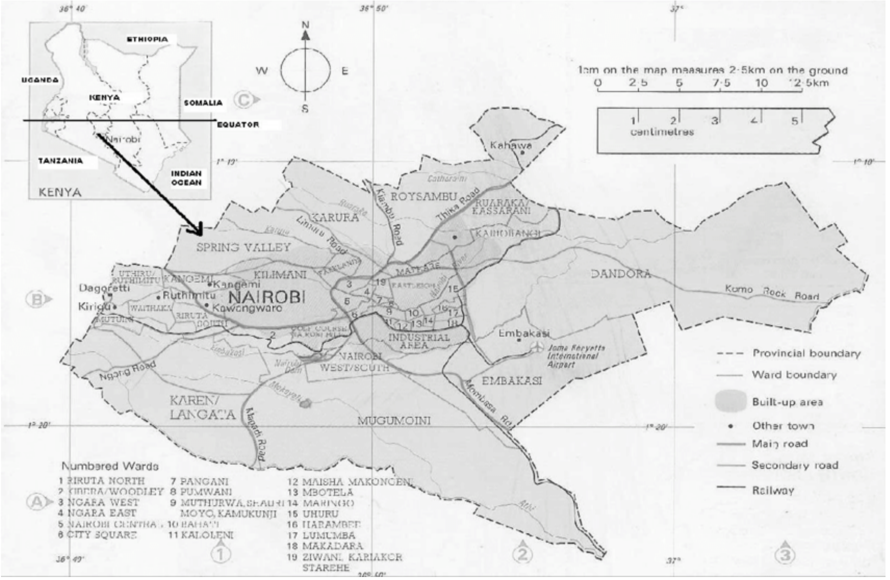


Fig 4.1. Old Map of Nairobi showing administrative divisions and estates .
Source: Afullo Otieno (2016)

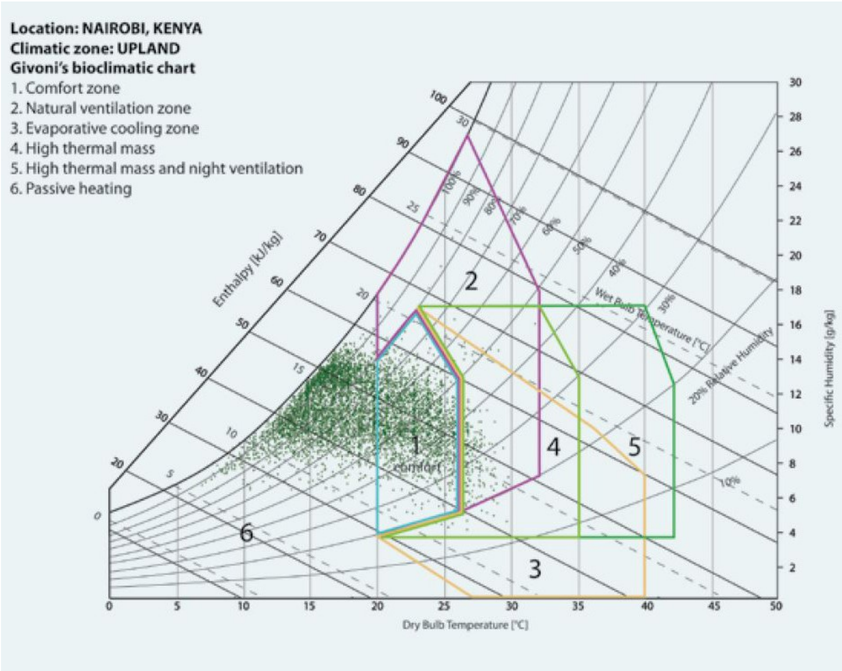
Fig 4.2. Aerial Image Nairobi Central Business District.
Source: Getyourguide.com

4.1 SUN-SHADING AND THE NAIROBI CLIMATE

Nairobi is the administrative capital city of Kenya and is referred to the city in the sun despite its origin being the Maasai phrase Enkare Nyrobi which means place of cool waters.

Its geographical co-ordinates are Latitude: 01_0 17'S and Longitude: 360 49' E and at an altitude of 1,661 metres above sea level. The city falls within Tropical Uplands Climate according to Koeningsberger (1975) who describes the characteristics of this climate as follows:

1. Mountainous regions and plateaux more than 900 to 1 200 m above sea-level between the two 20°C isotherms.
2. Seasonal variations are small in upland climates near the Equator
3. Air temperature, i.e., the DBT, in the shade decreases with altitude. At an altitude of 1 800 m the day-time mean maxima may range from 24 to 30°C and the night time mean minima are around 10 to 13°C.
4. The diurnal range is great. The annual range depends on latitude: at the Equator it is slight; but at the tropics of Cancer and Capricorn it may be 11^0C to 20^0C
5. Sky conditions are normally clear or partly cloudy, to the extent of about 40%. During the rains the sky is overcast – and the clouds are heavy and low.
6. Solar radiation is strong and direct during the clear periods. Ultra-violet radiation especially is strong and becomes more diffuse as cloud cover increases. Strong radiation loss at night during the dry season
7. Winds are variable, predominantly north-east and south-easterlies, but may be drastically deflected by local topography. Wind velocity rarely exceeds 15 m/s.



							Protection of openings
					0–2	8	Exclude direct sunlight
		2–12				9	Provide protection from rain

Fig4.3. Psychometric Chart and Mahoney table recommendations for Nairobi.

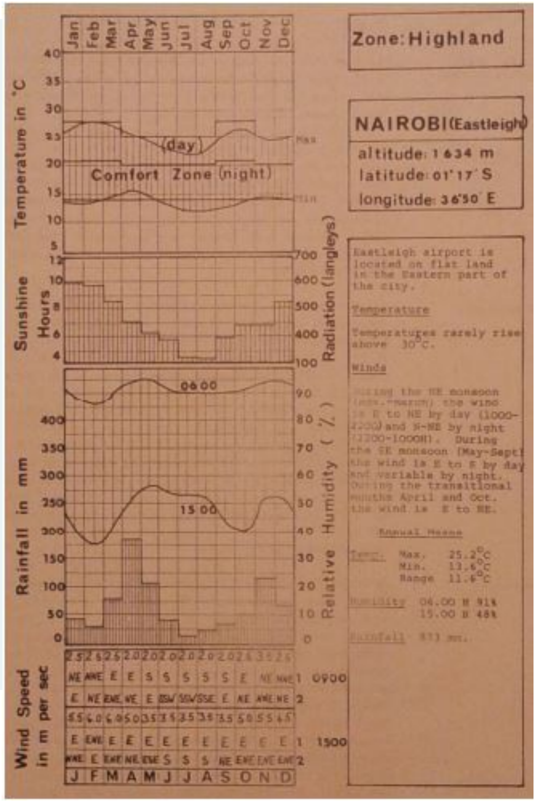


Fig4.4. Climatic data for Nairobi
Source: Hooper(1975)

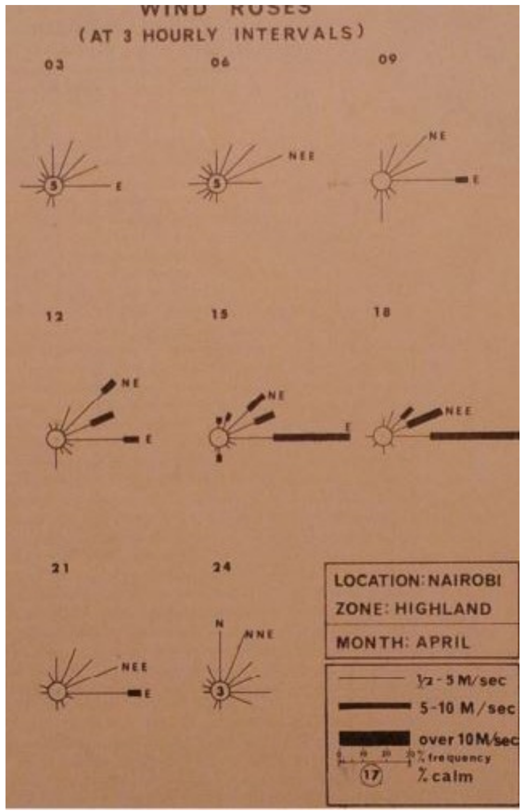


Fig4.5. Nairobi wind rose
Source: Hooper(1975)

Effective - HSD				Effective - VSD			
N	E	S	W	N	E	S	W
166	173	173	300	173	1046	173	1141

Fig 4.6. Effective HSD and VSD calculated for 300mm width and 300mm height window in Nairobi using a 0^0 solar chart.
Source: Munyao (2017)

The climatic data above points towards a need for sun shading devices in Nairobi. the wind rose showing an increase in wind velocity from the East and North East that requires to be factored into the design of the shading devices.

The chart alongside is a quick guide that can be used to calculate the effective depths of horizontal and vertical shading devices for all orientations using a factor of 300mm.

4.2 GROWTH OF NAIROBI CITY

Nairobi today contains buildings with elements from both colonial and post-colonial eras and for this reason gives a good overview of the development of sun-shading devices throughout its existence. The built form shows a clear inheritance of the colonial European built form, the Asian influence, representation of contemporary vernacular architecture and later global contemporary design worldwide.

In order to chronologically analyse the development of the sun-shading devices from the begging of Nairobi to 2020, the time period has been categorized into five (5) distinct categories based on defining political and architectural events. These are:

a) Before 1898. Pre-colonial traditional architecture.

b) 1898-1910. Foundations of Nairobi

c) 1910- 1940. Colonial Administration.

d) 1940- 1980. Tropical Modern Architecture.

e) 1980-2020. Modern and Sustainable Architecture

Fig 4.7. Nairobi in 1911
Source: http://www.sikh-heritage.co.uk

Fig 4.8 Nairobi in 1920s.
Source: http://www.sikh-heritage.co.uk

Fig 4.9 Image of Government Road in 1957.
Source: AGSC Digital Photo Archive University of Wisconsin Milwaukee

Fig 4.10.Nairobi in the 1970s.
Source: http://www.sikh-heritage.co.uk

Fig 4.11. Nairobi in the 1950s.
Source: http://www.sikh-heritage.co.uk

4.2.1 BEFORE 1880: PRE-COLONIAL TRADITIONAL ARCHITECTURE

Fig 4.12.Maasai Manyatta
Source:Wander traveller

Nairobi city is named from a Maasai word, 'Enkare', meaning a place of cold waters and true to its name, it was used by the Kikuyu and Maasai people came to Nairobi to water and graze their livestock. There were no permanent settlements in Nairobi apart from Maasai manyatta who by nature of being a nomadic community set up their homesteads from time to time.

Design and location of the buildings and homesteads was based on the individuals who built the structures using locally available materials such as twigs, mud, cow dung and grass thatch. The buildings were built by the users for residential and storage purposes.

A. ARCHITECTURE AND SUN-SHADING.

African traditional homestead also had dark interior but this was socio-economic, all functions during the day happened at the courtyard or outside so no need for large windows. Vernacular Maasai architecture was a homestead with the individual unit known as a manyatta as shown in fig 4.12. The Maasai manyatta lacked windows therefore had no external sun-shading devices. Traditional Kikuyu architecture comprised of a hut as shown in fig 4.13. The walls and openings were shaded from sunshine and rainfall by an extended grass thatch roof eave creating a verandah. Labour was sourced from neighbours and relatives hence a community affair for both tribes.

Overall, this time period saw no use of distinct external shading devices attached to the wall but achieved sun-shading through extended eaves amongst the Kikuyu and by lack of openings amongst the Maasai community.

Fig 4.13 Sketch of Kikuyu Hut
Source: Anyamba & Adebayo(1993)

A. SUN SHADING DEVICE ANALYSIS BEFORE 1898.

	MAASAI	KIKUYU
ARCHITECTURAL	**Vernacular architecture**	**Vernacular architecture**
DESIGN: Architect	**Individuals**	**Individuals**
SHADING DEVICE		
FORM: Type	**No shading device**	**Horizontal.** Extended roof eaves.
FORM: Aesthetics		**Secondary** feature. Primarily acts as roof.
FORM: Orientation		All facades based on the building's round shape.
CONSTRUCTION: Material, Colour		**Grass thatch roof**
FUNCTION: 1. Visual comfort		Unobstructed view out..

Characteristics Of Sun Shading Devices Before 1898

FORM:

1. Only type of shading was the verandah created by the extended roof eave.
2. Sun shading was secondary function of extended roof eave for the Kikuyu.
3. Sun shading devices were on all facades based on the round hut design

CONSTRUCTION:

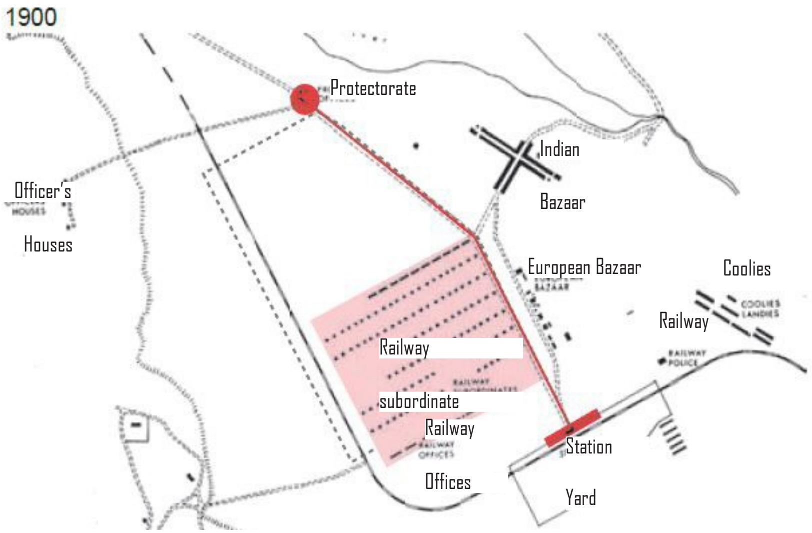
1. Use of locally available materials namely grass thatch.
2. Thatch was dark coloured and rough therefore absorbing direct light.

DESIGN

1. Construction was based on individual families and was replicated by all individuals in the community.

FUNCTION

1. View out is not impaired by sun shading device.



Source: ETH Nairobi Legacy. Author modified.

Fig 4.15 Nairobi in 1899.
Source: https://twitter.com/kresearcher/status/776153406369067008

4.2.2 1898 -1910: FOUNDATION OF NAIROBI

The initial growth of Nairobi is attributed to the following:

1. Birth and growth of the Kenya- Uganda Railway.
2. The transfer of the provincial offices from Machakos to Nairobi
3. Move of the protectorate headquarters from Mombasa to Nairobi in 1907 when it became the capital.

According to Muhoro, Munala & Mugwima (2016), Nairobi's location was selected as a shunting yard, stores depot and camping ground for the Indian labourers working on the railway line which reached Nairobi on 30th May 1899.

Arthur Church, in 1898, prepared a town layout for the railway depot that had two main streets namely; Victoria Street (Tom Mboya) and Station street as shown in Fig 4.14. (Muhoro, Munala & Mugwima. 2016). By 1909, the CBD was already established with the boundaries being defined by the Railway, Nairobi river and the Nairobi trachyte bluff(hill). These also dictated the street pattern. (Owuor & Mbatia 2008)

With these key functional roles, Nairobi changed from a railway town to an administrative and commercial centre within the British protectorate. In these early years, construction was led by the British protectorate to serve their administrative and residential needs.

A. ARCHITECTURE AND SUN-SHADING.

Fig 4.16. First DC Office and Court House.
Source: Buildesign.co.ke

The architectural style of this era gave Nairobi the description of the 'Tin town.' The buildings were characterized by the corrugated iron sheets used for walling and roofing and an extended roof eave that acted as sun-shading to the doors and window openings. An example being the First DC office and Court House 1900 shown in Fig 4.16 Other similar buildings can be seen in Fig 4.19 showing Biashara (Bazaar) Street in 1910. This style of construction was seen to mimic the vernacular architecture of the Swahili, Kamba and Kikuyu who all had the extended eaves for protection from the elements.

Awnings made of corrugated iron sheets were another sun shading device used as seen in fig 4.17 of Bank of India in 1904. Due to the nature of corrugated iron sheets as a construction material, these buildings were temporary and are no-longer in existence. The first stone building was National Bank of India built in 1906 as shown in fig 4.18.

In conclusion, the key type of sun-shading device was horizontal sun shading devices in the form of extended roof eaves forming verandahs and awnings.

Fig 4.17. Bank of India in 1904 on Government Road .
Source: Buildesign.co.ke

Fig4.18. Bank of lndia in 1906.
Source: Buildesign.co.ke

Fig 4.19. Nairobi's Indian Bazaar Street in 1910.
Source: http://www.sikh-heritage.co.uk

B. SUN SHADING DEVICE ANALYSIS BETWEEN 1898 AND 1910.

	FIRST DC's OFFICE -1900	NORFOLK HOTEL -1909
ARCHITECTURAL DESIGN: Architect	**Mimics vernacular** Built by the British administration as it set up in	**Mimics vernacular** Built by and for the British settlers living in Nairobi.
SHADING DEVICE		
FORM: Type	**Horizontal.** Extended roof eaves.	**Horizontal.** Extended roof eaves.
FORM: Aesthetics	**Secondary feature.** Roof is the primary function.	**Secondary feature.** Roof is the primary function
FORM: Orientation	**Two parallel** facades.	Two parallel facades.
CONSTRUCTION: Material, Colour	Iron sheets.	Iron sheets
FUNCTION: 1. Visual comfort	View out unobstructed.	View out unobstructed

Characteristics Of Sun Shading Devices Between 1898 And 1910.

FORM:

1. The main type of shading was the verandah created by the extended roof eave thus horizontal shading device. Introduction of the first stone building, Bank of India, in 1906 introduced colonnaded walkways and verandah.
2. Sun shading was secondary function of extended roof eave and therefore, did not stand out as an element.
3. Sun shading devices were on two parallel facades based on the rectangular building design with a gable roof.

CONSTRUCTION:

1. Corrugated iron roofing sheets was the material used. This was smooth and highly reflective.

DESIGN

1. Construction was based on needs of the British administrators, settlers and Indian workers.

FUNCTION

1. View out is not impaired by sun shading device.

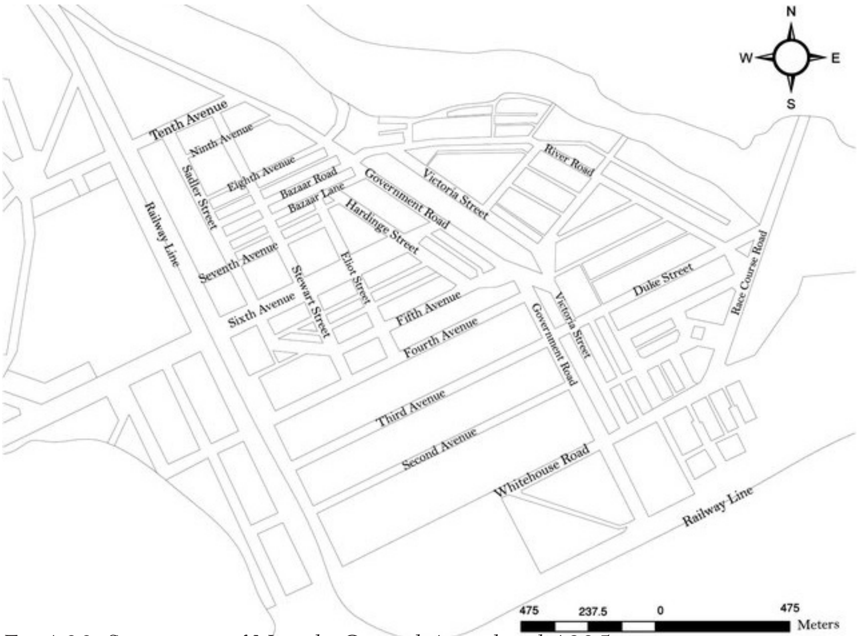


Fig 4.20. Street map of Nairobi Central Area dated 1925.
Source: Wanjiru et.al

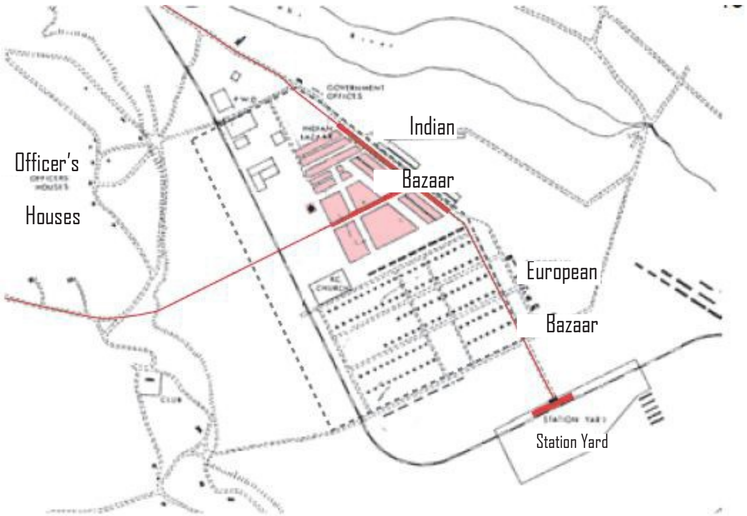


Fig 4.21. Map of Nairobi in 1920 .
Source: ETH Nairobi Legacy. Author modified.

4.2.3 1910-1940: COLONIAL ADMINISTRATION

Once Nairobi became the capital, the Colonial Administration began to set up permanent administrative structures based on the grid set out in the master plan. After world war 1, the population in Nairobi increased with white settlers to the west of the CBD and their African workers to the right of the CBD and the railway subordinate quarters were relocated outside the CBD.

Prior to 1926, there were no planning and building by-laws. According to Chana (1980), much of the early legislation related to buildings and planning were carried out by surveyors who were often ex-military men working for the Railways. The Town Planning Act was introduced in 1931.

As highlighted in red in Fig 4.21 Moi Avenue formerly known as Government road and Haile Selassie Avenue formerly Whitehouse Road formed the town's economic centre. The rest of the streets had either numerical or British names as shown in the 1925 map in fig 4.20. Gradually, the numerical names were later replaced with British and Indian street names.

A. ARCHITECTURE AND SUN-SHADING.

The architectural style of construction during this period was the classical buildings brought on by European influence of the British. The architects were primarily British architects such as Architect Herbert Baker who was invited to Kenya by the then Governor of Kenya Sir Edward Grigg in 1925. He designed Nairobi Primary School formerly Nairobi European School, the Law Courts, East African Railways Headquarters and State House.

Fig 4.22. State House in 1934 designed by Sir Herbert Baker.
Source: Arch. Kimeu's library

Fig4.23. New Stanley Hotel built in 1913 and reconstructed in 1932.
Source: Arch. Kimeu's library

Fig 4.24. Nairobi's Government road in 1927 showing Khoja mosque, the tin buildings of the previous era and newer storied masonry buildings.
Source: Arch. Kimeu's library

As the British began to construct permanent structures, they began with structures similar to their own construction and using locally available masonry stone (Nairobi Blue Stone), bricks, terra cotta and wood.

The buildings in this period had distinct features of European influence in the colonial-imported architecture that used colonnades as well as windows recessed in thick walls as shallow horizontal shading devices. Modern architecture also begins to be visible in this period with the introduction of Neo-Classical architecture and Art Deco. The buildings that showcased the architectural styles of the period are:

1. Classical Revival style whose basis is ancient Greek and Roman architecture. This was used to express imperial authority in public buildings such as City Hall, Railway Headquarters, Sate House formerly known as Government House, Law Courts, Macmillan Library and Khoja mosque (Darkhana Jamatkhana).

2. Renaissance Revival Style reminiscent of the palaces in Italy with features such as quoining, triangular and round-arched pediments, cornices and lintels. Examples are Panafric House, New Stanley Hotel, Standard Chartered Building and Westminister Building along Kenyatta Avenue.

3. Georgian Architectural Style which employed Ancient Greek and Roman decorative vocabulary seen in the classical orders These buildings such as Kipande House and the Old Pc's House had ornamental columns, symmetry and used stone to name a few characteristics.

Fig4.25 Nairobi's showing City Market and Jamia mosque.
Source: http://www.sikh-heritage.co.uk

4. Art Deco which started in France and flourished worldwide between the inter war years of 1918-1945 and common characteristics included rounded edges and bold geometric shapes with rich colours. This style was mainly embraced along the Indian Bazaar street and there are several small two or three storey buildings in existence that reflect this period. Examples include Kenwood House and City Market whose design was a replica of the award-winning Lawrence Hall Royal Horticultural Market in Westminster.

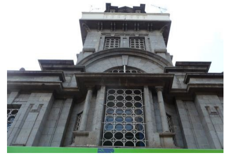
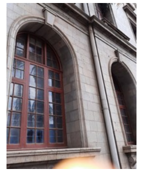
Fig4.26 Delamere Avenue showing Stanchart, Panafric House and Westminster House from right to left. These three buildings still stand today as a reflection of the construction in the 1930s.
Source: https://twitter.com/kresearcher/status/1318997379257749504

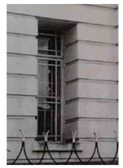
B. MAP OF SUN SHADING VARIETIES BETWEEN 1910-1940.

LIST OF BUILDINGS

1. Kipande House
2. Old PC's House
3. New Stanley Hotel
4. Khoja Mosque
5. Pan Africa House
6. Kenya Railways Headquarters
7. Law Courts
8. National Archives
9. McMillan Library
10. City Hall
11. City Market
12. Kenwood House
13. Barclays
14. Standard Bank
15. Stanbic

C. SUN SHADING VARIETIES BETWEEN 1910-1940.

Building and Description of Shading Device		Horizontal	Vertical	Egg crate
	**KIPANDE HOUSE** - 1913- Gurdit Singh Nayer (assisted by Architect David Fialt) Recessed window in thick masonry wall.			
	**OLD PC'S HOUSE** - 1913 Recessed window in thick masonry wall. Colonnaded Portico			
	**NEW STANLEY HOTEL** - 1913 Colonnaded Portico and verandah			
	**KHOJA MOSQUE** (Jamatkhana)- 1922 - Architect Virji Nanji Recessed window in thick masonry wall.			
	**PAN AFRICA HOUSE** - 1928 Projected pediments. Colonnaded Portico			
	**WESTMINISTER HOUSE** - 1928 Recessed window in thick masonry wall.			
	**KENYA RAILWAYS HEADQUARTERS**- 1929 - Architect Sir Herbert Baker. Balconies, walkways and			

Building and Description of Shading Device		Horizontal	Vertical	Egg crate
	**LAW COURTS** - 1929- Architect Sir Herbert Baker Colonnaded Portico and roof eave overhang.			
	**NATIONAL ARCHIVES** - 1931 Colonnaded Portico, Balcony and cornice above second floor windows.			
	**MC MILLAN LIBRARY** - 1931 Colonnaded Portico and cornice above windows.			
	**CITY MARKET**- 1932 - Architect Easton and Robertson Horizontal projected overhang			
	**CITY HALL** - 1934 Recessed window in thick masonry wall.			
	**KENWOOD HOUSE** - 1937 - Architect Ernst May Horizontal projected overhang			
	**STANBIC HOUSE (formerly Torr's Hotel)** Recessed circular windows in thick brick wall.			

D. CASE STUDY 1:

RAILWAYS HEADQUARTERS

CONSTRUCTION YEAR: 1924-1929

ARCHITECT: Sir Herbert Baker

ARCHITECTURAL STYLE:

Neo-Classical.

FUNCTION: Institutional Building

LOCATION: Southern part of CBD

Haile Selassie Avenue

Fig4.27 Railways headquarters front facade

Source: Buildesign

Fig4.28 Aeriel view of Railways Headquaters

Source: Buildesign

SITE PLAN.

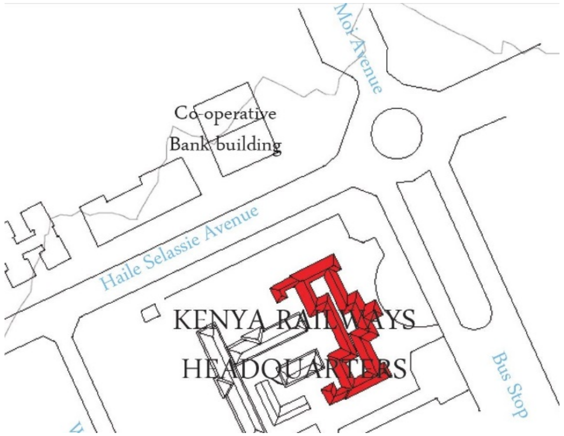


Fig4.29 Site plan

Source: Buildesign

BUILDING PLAN.

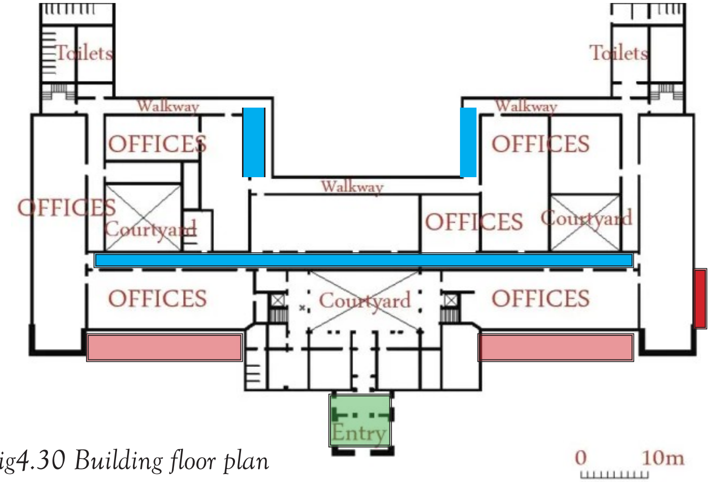


Fig4.30 Building floor plan

Source: Buildesign. Author modified

1. The building's orientation, like all buildings in Nairobi, is dictated by the street grid with the main entrance generally facing East but the building is rotated 26^0 counter clockwise so faces NEE.
2. The building has opening on all facades.

1. Horizontal Shading - BALCONIES

These are located on the first and second floor of the East facing facade and provide shade to the windows below.

The balcony is approximately 1000mm deep and sufficiently shades the windows below it from direct glazing as the morning sun gets hotter while allowing the low angle early morning sun to penetrate the building and heat the offices.

Fig4.31North facade

Source: https://commons.wikimedia.org/

Fig4.31 Balcony detail

Source: Buildesign

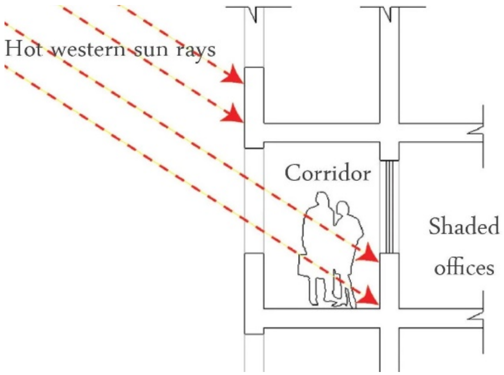


Fig4.32 Sketch of walkway as a sun shading device
Source: Buildesign

MATERIALS

The main material used for all these shading devices is concrete for the balcony and walkway slabs with masonry stone smoothly dressed.

1. Smooth dark coloured Nairobi blue stone.
2. Light coloured smooth plaster painted concrete for reflection of light at internal walkways.
3. Terracotta roof.

AESTHETICS

Sun shading device is a secondary ,maybe unconscious, function of other architectural elements and functions of the building therefore do not stand out as sun shading devices on the facade.

2. Horizontal Shading - WALKWAYS

These are located on the first and second floor facing the west facing facade of the courtyard and building and provide shade to the windows below. The walkway on the ground floor is supported by arched columns.

The walkway is approximately 1200mm deep and sufficiently shades the windows below it and those along the corridor from direct sunlight.

Fig4.33 Internal walkway
Source: Buildesign

3. NO SHADING to North and South facing windows.

These windows receive minimal direct sunlight and are therefore not shaded.

4. Horizontal Shading - ROOF EAVES

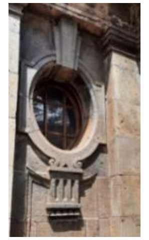
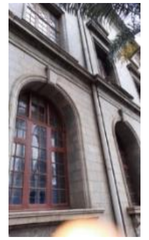
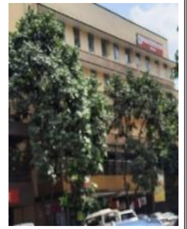
The roof eaves provide minimal shading to the second floor windows facing east and west. The eaves are approximately 600mm deep.

5. Horizontal Shading - COLONNADED PORTICO

This is located at the entrance facing the east. The double volume verandah on the first floor is covered by the roof and is approximately 3500mm deep and 6000mm high sufficiently providing shade for the windows on the first and second floor below. Unobstructed view out.

Fig4.34 Front facade
Source: http://artmatters.info/

E. SUN SHADING DEVICE ANALYSIS BETWEEN 1910 AND 1940.

	OLD PC'S HOUSE -1913	KHOJA MOSQUE-1922	KIPANDE HOUSE -1913	RAILWAYS -1929	CITY MARKET - 1932	KENWOOD HOUSE -1937
ARCHITECTURA	Classical revival	Neo-Classical	Classical revival	Neo-Classical	**Modern:** Art-Deco	**Modern:** Art-Deco
DESIGN: Architect	**British** Architect	**Indian** Architect Virji Nanji	**Indian** Gurdit Singh Nayer assisted by **British** Architect David Fialt	**British** Architect Sir Herbert Baker invited by Governor.	**British** Architects Easton and Robertson. Replica of Lawrence Hall Royal Horticultural Market.	**German** Architects Ernst May exiled from Germany during the soviet government rule
SHADING DEVICE	 	 	 			 
FORM: Type	1. **Egg crate.** Circular recessed windows 2. **Horizontal.** Colonnaded	**Egg crate.** Recessed windows.	**Egg crate.** Recessed windows	**Horizontal.** Colonnaded portico, Balconies, Walkways and extended roof eaves.	**Horizontal.** Projected overhang	**Horizontal.** Projected overhang
FORM: Aesthetics	**Secondary** feature. Does not	**Secondary** feature. Does not	**Secondary** feature. Does not	**Secondary** feature. Does not	**Facade feature.** Distinct fixed shading device. Linear	**Facade feature.** Distinct fixed shading device. Curved and
FORM:Orientation	1.**West-** Recessed windows 2. **North** - Portico 3. **East & South** -No shading.	**All** facades- Recessed windows	1.**West, East and South-** Recessed windows 2. North - No shading.	1.**West-** Walkways 2. North & South - No shading 3. **East -**Balcony & portico	1.West- No shading 2. **North & South** - Projected overhang 3. East -No shading	1.**West-** Projected overhang 2. **North -** Projected overhang 3. **East -**Projected overhang 4. **South -**No shading
CONSTRUCTION: Material, Colour	1. Smooth, dark coloured (Grey) Nairobi Blue **Stone**.	1. Smooth, dark coloured (Grey) Nairobi Blue **Stone**.	1. Smooth, dark coloured (Grey) Nairobi Blue **Stone**.	1. Smooth, dark coloured (Grey) Nairobi Blue **Stone** 2. Smooth, light coloured	Smooth, light coloured plaster & painted **concrete**	Smooth, light coloured plaster & painted **concrete.**
FUNCTION: 1.Thermal comfort 2. Visual comfort	1.Depth cuts out all direct glazing	1.Depth cuts out all direct glazing	1.Depth cuts out all direct glazing	1.Depth cuts out all direct glazing	1.Depth cuts out most direct glazing	1.Depth cuts out most direct glazing

Characteristics of Sun Shading Devices Between 1910 and 1940

FORM:
1. Common types of sun shading were windows recessed in wall creating an egg crate device and colonnaded portico, pediments and cornices that created horizontal shading devices.
2. Sun shading was secondary function of classical elements that had other primary functions thus does not stand out as sun shading device at first glance.
3. Emergence of the modern movement towards the end of the era with Art Deco buildings introduces horizontal shading devices identifiable with the linear appearance of the architectural style.
4. Neo classical buildings were symmetrical and generally had sun shading devices on all facades.
5. Location of openings and consequently the sun shading devices is dictated by the street orientation. The buildings in this era were the first stone buildings therefore have the advantage of corners that allow for more than one facade facing the street.

CONSTRUCTION:
1. Use of locally available materials mainly Nairobi Blue Stone for construction of the building elements. Concrete was also used.
2. Stone was rough and dark coloured which reduced reflectivity whereas concrete had a smooth finish and was lightly coloured once plastered and painted which increased reflectivity of light into the building.

DESIGN
1. Design was initiated by the British Colonial Administration, the European settlers and Indian workers who settled in Nairobi thus architects were mainly of British or Indian descent invited to the country or working in the military.

FUNCTION
_View out for all buildings of this era was unobstructed by sun shading devices.

4.2.4 1940-1980 –TROPICAL MODERN ARCHITECTURE

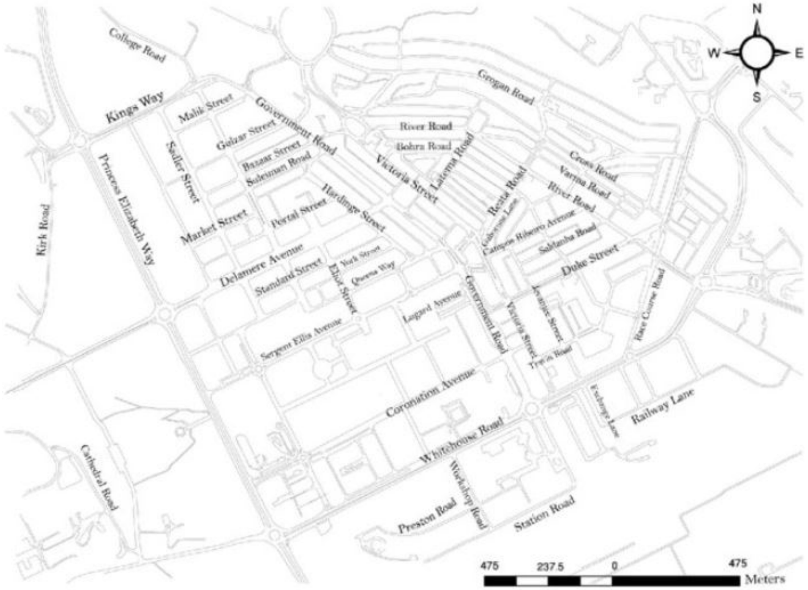


Fig 4.35. Street map of Nairobi Central Area dated 1960
Source: Wanjiru et.al

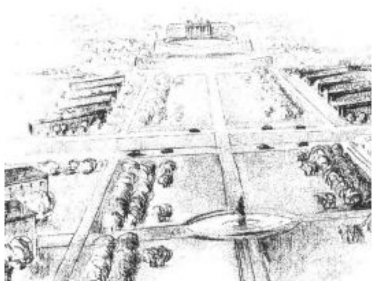


Fig 4.36. The proposed 1948 Nairobi Centre Plan and perspective representation.
Source: White, Solberman and Anderson. (1948)

This time period showcases architecture of both pre-and post-colonial Nairobi. Nairobi City Council introduced its own Building By-laws in 1948. The By-laws consisted of guidelines for future development, allocated land use and proposed road network expansions. This was later followed by Local Government (Adoptive By-Laws) introduction in 1968 commonly known as the Building Code. (Chana 1980)

Figure 4.27. shows a map of Nairobi in 1960 with the street names being mostly British such as Duke Street, Princess Elizabeth Way and Sadler Street. These were named after commissioners in the British East Africa Protectorate or British Royalty. Some streets also bore Indian names but none were African. The street names were replaced by mainly African names post-independence.

The key drivers of construction was government; both colonial and post-colonial administrations. The colonial government created an early political center with the Law Courts, Parliament and City Hall with Harambee Avenue later becoming the political center with several government buildings including Office of the President and KICC being constructed. The economic center also densified during this period with high rise building being constructed for commercial purposes.

A. ARCHITECTURE AND SUN-SHADING.

Colonial cities were convenient sites for experimentation with modern forms, ideologies and technology in the 1940s and 1950s. Architects experienced a freedom of design in the tropics as compared to Europe at the time. (Maina 2015) Due to the war, there was reduced construction due to rationing of resources.

European settlers required the services of professional architects and so did the Royal British service that posted British architects to different areas as the army required. These architects pioneered Tropical Modern Architecture in Nairobi. These architects either studied at AA school or had intellectual interactions with modernist architects and their work prior to their move to Kenya. These architects include:

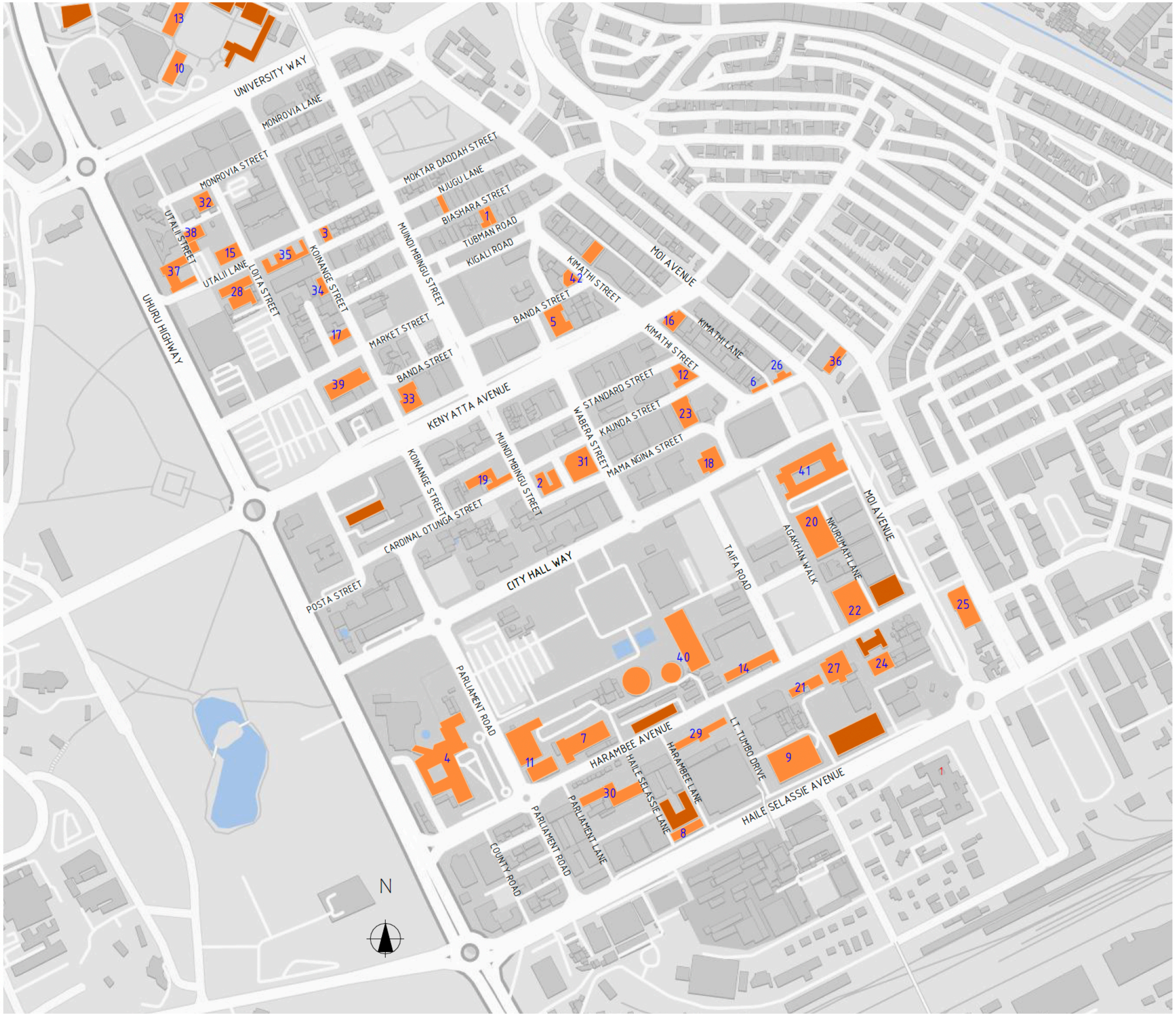
1. Ernst May who was exiled from Germany during the second world war and practiced in Tanzania before moving to Kenya in 1937.
2. Amyas Douglas Connell who founded TRIAD architects in 1963 He moved to Kenya from Tanzania by invitation of then Chief architect, Thornley Dyer.
3. Richard Hughes studied in AA School bettween 1947-1953. Corporal in the Kenya Regiment attached to the Royal Engineers.
4. Dorothy Hughes who's practice Hughes and Polkinghorne was founded in 1933.
5. Graham McCullough was a TRIAD architect founder member.
6. Karl Henrick Nostvicwho worked unde the Ministry of Public Works from 1966 and later his own practice.
7. David Mutiso who was the first Kenyan Architect and founded Mutiso Menezes International in 1974.
8. Robert Marshall of Dagliesh Marshall Johnson Architects founded in 1965.

These architects designed majority of the buildings of note in the Nairobi Central Business District and run the most influential architectural practices in the 1960s and 1970s. Kenya attained independence in 1963 and as in other the newly independent African countries, modern architecture that was without elements of colonial classical architecture was embraced as it was seen to portray progress and development. Governments and investors wanted to portray an image of progress and increase investment. (Maina 2015) Towards the end of the era and the advent of International Style worlwide, architects begin to experiment with more materials such as Richard Hughes using glass as a sun-shading device in the National Bank Building to match global architectural trends.

B. SUN SHADING VARIETIES BETWEEN 1940-1980.

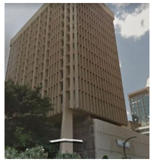
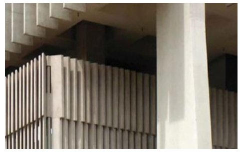
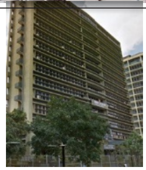
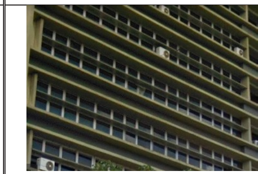
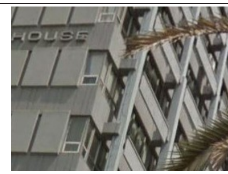
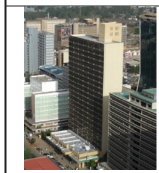
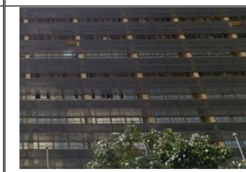
LIST OF BUILDINGS

1. Bhagwanji Building
2. UTC Parking
3. Rattansi Educational Trust Building.
4. Kenya National Assembley(Parliament)
5. Bank of India
6. Norwich Union
7. Harambee House
8. Agip Building
9. Central Bank
10. Hyslop Building
11. Attorney General's chambers/ Sheria House
12. IPS Building
13. Education Building
14. Jogoo House B
15. Kenindia
16. Kimathi House.
17. Chai House
18. International Life House
19. Bruce House
20. Uchumi House
21. BIMA House
22. Electricity House
23. KCS House
24. NHC House
25. Development House
26. Union Towers
27. National Bank Headquarters
28. Nyati House
29. Vigilante House
30. Shell and BP House
31. Diamond Jubilee House
32. Maendeleo House
33. Rehani House
34. Cianda House
35. Consolidated Bank House
36. Commonwealth House.
37. Utalii House
38. French Cultural Centre.
39. Chester House
40. KICC
41. Kencom
42. Nanak House
43. Commonwealth House



C. SUN SHADING VARIETIES BETWEEN 1940-1980.

Building and Description of Shading Device		Horizontal	Vertical	Egg crate
	**BHAGWANJI BUILDING** - 1949 Balcony and projected horizontal overhang			
	**NATIONAL ASSEMBLEY** - 1952 & 1963 - Architect Amyas Connel 1.Angled vertical fins. 2.Egg crate patterned screen & Grid frame egg-crate.			
	**CENTRAL BANK** - 1962 - Architect Chris Archer Vertical fins			
	**HYSLOP BUILDING** - 1962- Architect Graham McCollough (TRIAD)			
	**ATTORNEY GENERAL'S CHAMBERS** - 1962 Patterned egg crate screen			
	**IPS BUILDING** - 1967 Grid frame egg crate.			
	**EDUCATION BUILDING** - 1968 - Architect Graham McCollough (TRIAD) Egg crate with louvred slats, vertical fins and horizontal			

Building and Description of Shading Device		Horizontal	Vertical	Egg crate
	**JOGOO HOUSE B**- 1968 - DMJ. Dagliesh Marshall Johnson Architects 1.Vertical fins			
	**KENINDIA** - 1970- DMJ. Dagliesh Marshall Johnson Architects 1.Grid frame louvred egg crate. 2. Vertical fins.			
	**CHAI HOUSE** - 1970 Egg crate square grid.			
	**BIMA HOUSE** - 1973 Projected horizontal overhang.			
	**KCS HOUSE** - 1975 Suspended horizontal panels.			
	**DEVELOPMENT HOUSE** - 1977 Egg crate grid with suspended horizontal panels.			
	**NATIONAL BANK HEADQUARTERS**- 1973 - Architect Richard Hughes Suspended horizontal glass panels.			

D. CASE STUDY 2

EDUCATION BUILIDNG

CONSTRUCTION YEAR: 1969

ARCHITECT: Graham McCollough

ARCHITECTURAL STYLE:

Tropical Modern

FUNCTION: Institutional Building

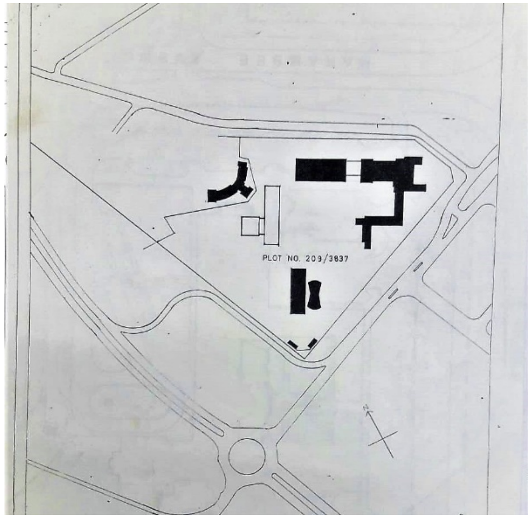
LOCATION: University of Nairobi

Eastern and southern facade.

Western facade.

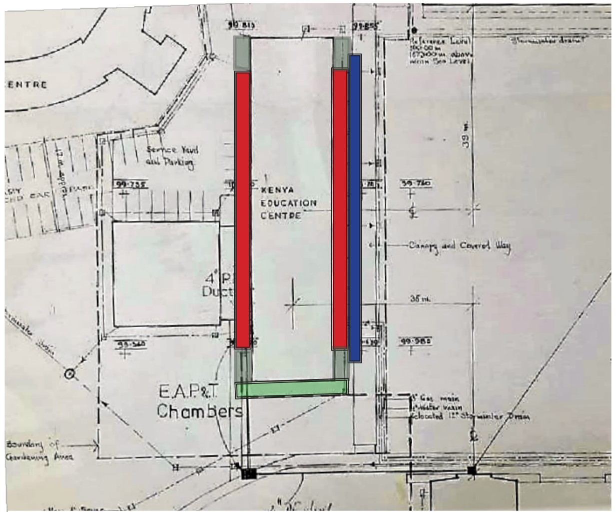
SITE PLAN.

Building orientation is dictated by Great



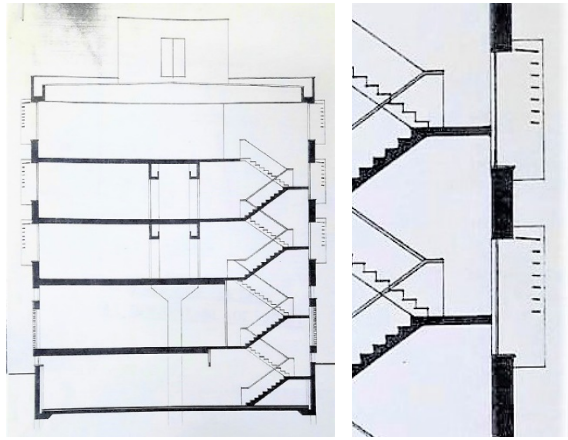
BUILDING PLAN.

The building ground floor plan showing the location

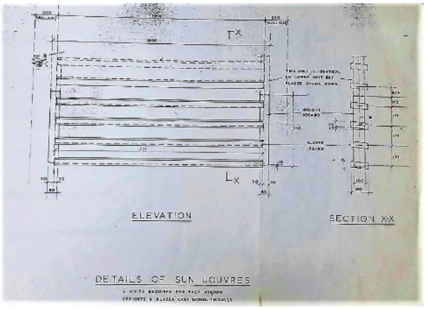


Egg crate device.

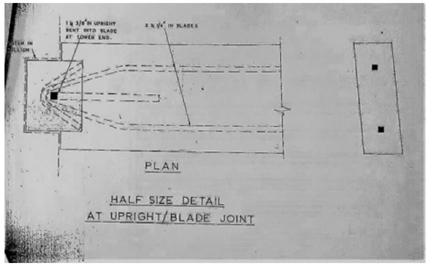
Comprises of 50mm thick, 150mm deep and 1800mm wide concrete louvres and 80mm wide, 9000mm deep and 3000mm high vertical concrete fins cast monolithically to create an egg crate device. The louvres are spaced 175mm apart. The top louvre is a projection from the wall.



Section through building showing the horizontal louvres on the 1st, 2nd and 3rd floor of the East and West Facade. A blow up detail of the section shows the horizontal overhang that is projected at the top of the shading system.

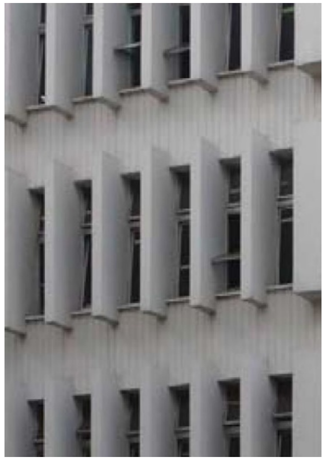


Detail of concrete louvres. The louvres are cast in two parts to complete a single sun shading. device



Detail of louvre blade joint.

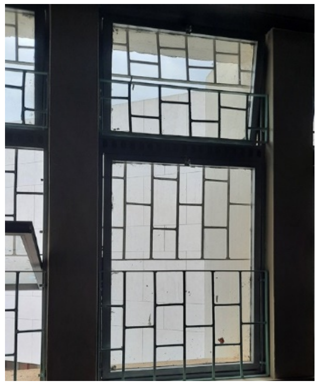
The louvres of the western facade have been removed and show the concrete notch that supported the concrete louvres when cast.



Vertical device.
80mm wide, 9000mm deep and 3000mm high vertical concrete fins.
The fins are spaced 750mm apart.
Located on southern facadeand create the illusion of deeply recessed windows.

Horizontal device.
Concrete beams running along the front of the building and anchored onto the wall and concrete slab above the walkway.
Provides shading to the ground floor windows.

The single window on each floor of the northern facade was not sun shaded and has now been blocked by the UoN tower. The windows at the end of the walkway on ground floor are also not shaded. This is an aesthetic decision.



The images show the interior spaces at 4:00 pm.
The southern room with the vertical fins is darkest due to the 750mm spacing vs the 900mm depth of the shading device.
The louvres obscure the view out in image one and image 2 is obstructed by the narrow spacing but image 3 alongside only has the vertical fins along the corridor and thus have a clear view out.

E. SUN SHADING DEVICE ANALYSIS BETWEEN 1940 AND 1980.

	BHAGWANJI -1949	DEVELOPMENT HOUSE 1977	JOGOO B - 1968	EDUCATION - 1968	KENINDIA - 1970	HYSLOP - 1962
ARCHITECTURAL	**Art Deco**	**Tropical modern architecture**	**Tropical modern architecture**	**Tropical modern architecture**	**Tropical modern architecture**	**Tropical modern architecture**
DESIGN: Architect		**British** Architect Richard Hughes. Tropical modern architecture pioneer.	**British** Architects. DMJ Dagliesh Marshall Johnson. Tropical modern architects.	**British** Architect Graham McCollough. TRIAD. Tropical modern architecture pioneer.	**British** Architects. DMJ Dagliesh Marshall Johnson. Tropical modern architects.	British Architect Graham McCollough. TRIAD. Tropical modern architecture pioneer.
SHADING DEVICE	 				 	 
FORM: Type	**Horizontal.** Balcony and projected horizontal overhang at top floor.	**Egg crate.** Suspended horizontal shading device supported by vertical columns.	1. **Egg crate.** Patterned screen 2. **Vertical** fins.	1.**Horizontal** louvres on ground. 2. **Vertical** fins.	1. **Egg crate.** Louvred horizontal slats. 2. **Vertical** fins.	1. **Horizontal.** Projected overhang above ground floor. 2. **Egg crate.** Circular
FORM: Aesthetics	**Secondary** shading feature but stands out as aesthetic feature	**Facade feature.**Suspended panels create distinctive	**Facade feature.** Vertical fins	**Facade feature.** Fins and louvres create distinctive	**Facade feature.** Vertical fins create distinctive building	**Facade feature.** Creates distinctive building facade.
FORM: Orientation	1.West, East & South -No shading. Determined by street and plot orientation.	1.West- No shading 2. **North** - Egg crate 3. East -No shading 4. **South** - Egg crate	1.West- No shading 2. **North** - Vertical fins 3. East -No shading 4. **South** - Vertical fins	1.**West**- Egg crate 2. North - No shading 3. **East** -Egg crate 4. South - Vertical fins	**All** facades have sun shading devices.	1.**West**- Egg crate 2. North - No windows 3. **East** -Egg crate 4. South - No windows
CONSTRUCTION: Material, Colour	1. Smooth, light coloured plastered and painted	Smooth, light coloured plaster & painted **concrete**	Smooth, light coloured plaster & painted **concrete**	Smooth, light coloured plaster & painted **concrete**	1. Smooth, light coloured plaster & painted **concrete**	Smooth, light coloured, circular painted **concrete**
FUNCTION: 1.Visual comfort	1. Clear view out.	1. Clear view out. Egg crate located above the window.	1.View out is framed by vertical fins therefore obstructed. 2. Egg crate creates privacy for	1.unobstructed view out with vertical fins. 2. Egg crate device has clear view at eye level but	View out obstructed by vertical fins in podium. Narrow spacing gives privacy to cars	View out obstructed by screen

FORM:

1. Most common types of sun shading devices were egg crate and horizontal with few having vertical sun shading.
2. Sun shading devices are a distinct architectural feature of the building with the facade design being composed of sun shading devices even on facades without windows for aesthetic continuity such as Bruce House and Sheria House.
3. Following the horizontal shading devices of the early 1940s and Art Deco movement on Bazaar street, Tropical modern architecture introduced more varieties of sun shading devices based on the interpretation of the brise soleil in egg crate sun shades as well as cultural motifs in patterned egg crate devices.
4.Location of sun shading devices was determined by street orientation and aesthetic of the building. Some buildings such as Development house adjusted the towers of their buildings to ensure north and south facing windows on streets running north south.
6. Building like Education Building that varied the sun shading device according to orientation are few yet this is the best method to achieve efficiency in thermal performance.

CONSTRUCTION:

1. Main sun shading material is concrete. Steel is introduced as a material for louvres and later at the end of the era glass is introduced as international architectural style begins in Kenya with National Bank Headquarters. Concrete mostly was plastered and painted a light colour which increased reflectivity of light into the building.

DESIGN

1. Design was dictated by the architects of the day. The new Kenyan government hired several British architects to design the new official buildings. The client was also the architect giving the architects free reign on budget and design and thus could ensure the principles of Tropical Modern Architecture were implemented. This was also applied in privately owned commercial buildings by the same pioneer architects of TMA.

FUNCTION

1. View out is impaired by the patterned egg crate sun shading devices with the suspended horizontal louvres or panels located above eye level allowing visual comfort.
2. Narrow spacing between vertical fins and patterned egg crate devices provides privacy for internal users.

4.2.5 1980-2020 – GLASS BUILDINGS ERA.

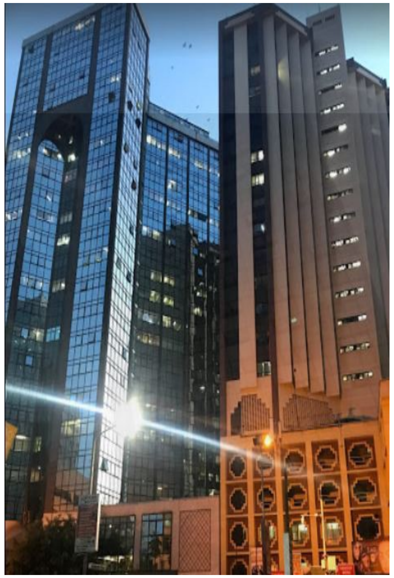


Fig 4.37. Image of New glass buildings in Nairobi..
Source:

This era can be named the glass building era as the buildings constructed in the Nairobi Central Business district are all fully glazed commercial buildings with a high window to wall ratio. To further push the glass building agenda, existing buildings such as Family Bank Towers, Jamahiriya House and Alibhai Shariff house were renovated to include a fully glazed facade.

The driver of this architectural language is the western architectural language seen in Contemporary Architecture or International Style. The world is now considered a "Global village" as a result of ease of knowledge transfer through the internet and travel. As such the buildings designed could be located in any location globally. The idea of regionalism and climatic response is lost in favour of the contemporary aesthetic.

A. ARCHITECTURE AND SUN-SHADING.

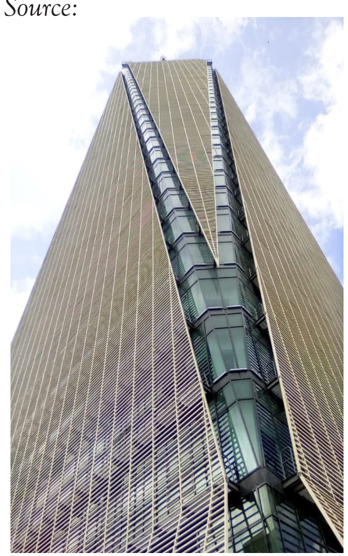


Fig 4.38. Britam Towers
Source: Buildesign

The architectural style of the era in Nairobi takes three distinct forms. Ending of Tropical Modern Architecture, International Style and Sustainable design. Alongside the architects, the developers and clients are the key drivers of construction. Few architects borrowed lessons from pioneer architects on tropical modern climate responsive design and instead adopted International style in the 1980s with no attempt to transform it to make it suitable for the tropics. In the 2000s a new shift is seen with the beginning of sustainable design and re-introduction of climate responsive architecture.

Design of sun shading devices on buildings in this era are affected by the following:

1. Economic Value. Sun shading devices that are not integrated into the structure of the building are seen as an unnecessary additional cost and may be removed at either the scheme design or construction stage.
2. Materials. Technology has brought about improvements in material performance such as the heat absorbing glass and construction technology such as double glazing whose thermal performance is designed to provide thermal comfort in lieu of sun shading devices.

Fig 4.39. Image of international style in Nairobi. Source: Googleearth

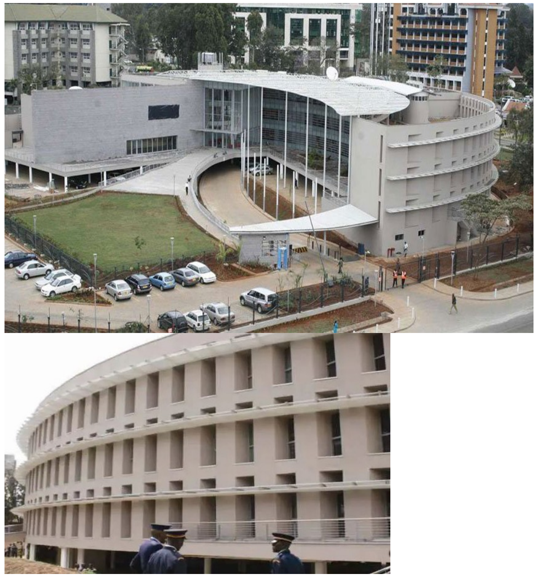


Fig 4.40 Cocacola Headquarters, Upperhill Nairobi.
Source: Buildesign

3. Aesthetic Value. Current culture views the clarity of glass buildings as more appealing than those of the 1960s-1980s that had the sun shading elements as the prominent visual of the building's facade. Fully glazed buildings are seen to be more modern and as such attract more tenants for commercial buildings and improve the corporate image of institutions and companies. Some buildings such as I&M building with its vertical fins have incorporated sun shading devices for purely aesthetics and they provide little to no shade to the windows. Fig 4.39 shows such buildings along University way.

4. Sustainable Architecture. The local and international architectural community is awarding buildings that are considered to be green buildings. This distinction is an incentive to developers and architects to incorporate sun shading devices in their buildings alongside other strategies in order to improve their corporate image and increase their international reach through this publicity. Examples are the Coca-Cola Headquarters in Upperhill, Nairobi shown in fig 4.40

5. Technology. Improvements in calculation of sun-shading devices to allow for computer simulations have made calculation and analysis of sun-shading device design prior to construction much easier. It has also created a niche profession for facade engineers and sustainable design architects with this expertise. Technological advancement has meant there are several new materials available for use as sun-shading devices. In this era, the materials used for sun-shading increase to include metals such as steel, aluminium such as Kenya Re and City hall Annexe, Glass as used in ABSA building and Terra Cotta Briquettes in Britam Towers. The Nairobi CBD has grown to informally include the UpperHill region. It is in this area that the post year 2000 sustainable architecture style is becoming more visible in buildings such as Britam Towers and the Coca Cola Headquarters in fig 4.38 and 4.40. Sun shading devices are now being re- introduced amongst the glass facades.

C. SUN SHADING VARIETIES BETWEEN 1980-2020.

LIST OF BUILDINGS

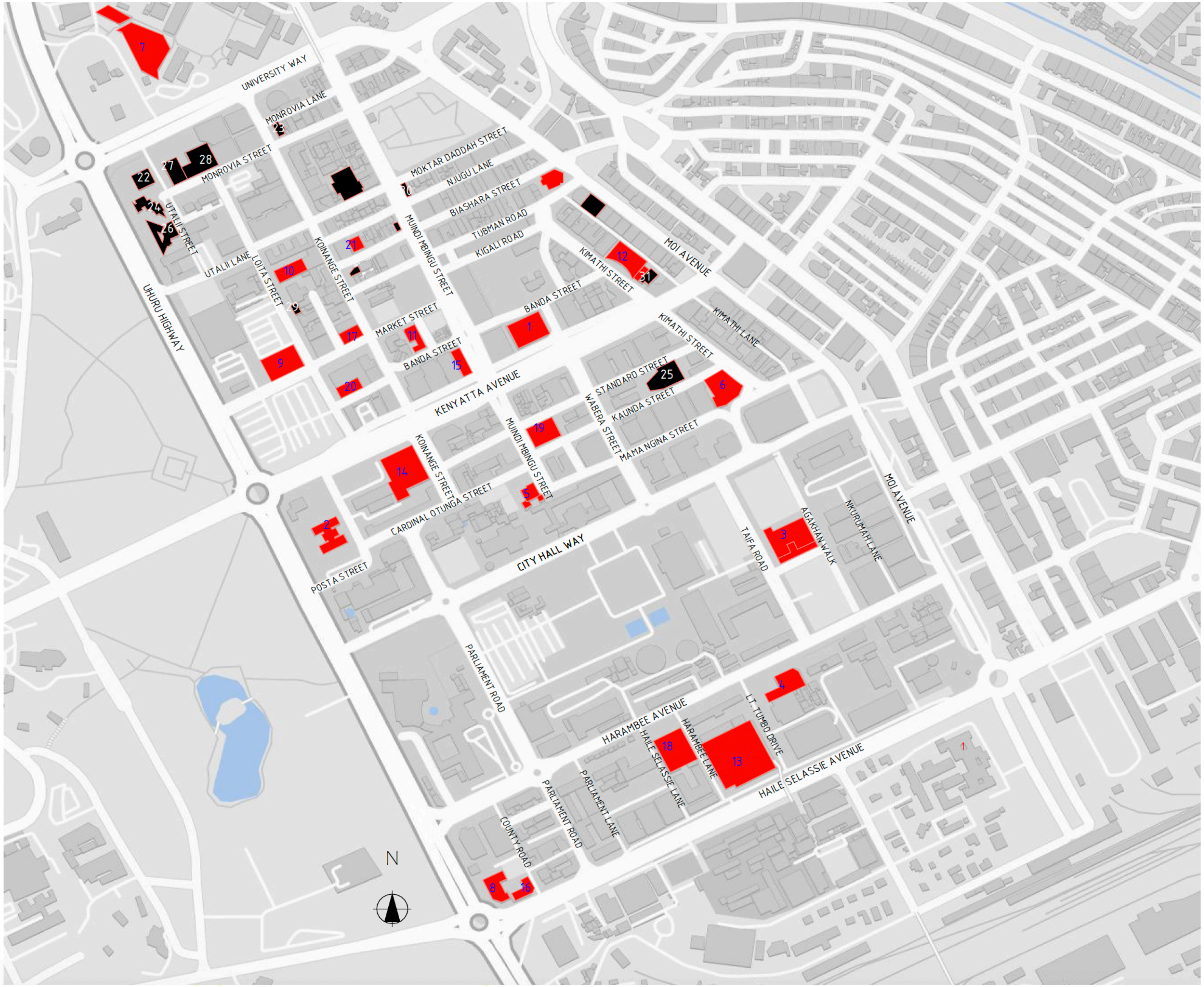
1. ICEA Building (JKUAT Towers)
2. Nyayo House
3. Kenya Re-insurance Plaza
4. Treasury Building
5. City Hall Annexxe
6. Corner House
7. JKML
8. Harambee Co-op Plaza
9. Barclays Plaza(ABSA)
10. Loita House (Pension Towers)
11. Postbank House
12. Nation Centre
13. Times Tower
14. GPO (Telposta Towers)
15. I&M
16. Ukulima Co-op.
18. CBK Pension Towers
19. Eco-Bank Towers
20. Finance House
21. Yala Towers

CURTAIN WALL BUILDINGS

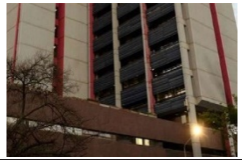
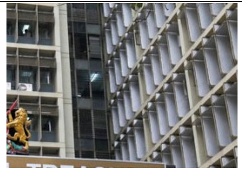
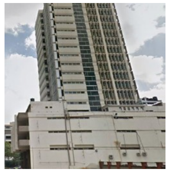
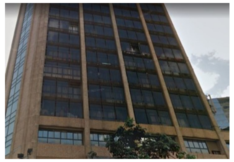
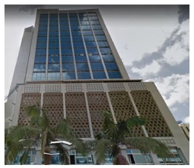
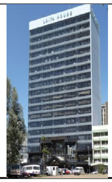
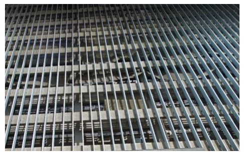
22. KEMU Towers
23. KEMU Hub
24. Hazina Towers
25. Lonrho House
26. View Park Towers
27. AM Bank House
28. Anniversary Towers

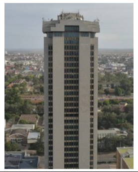
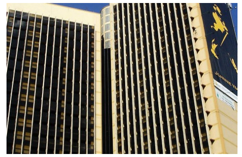
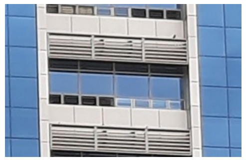
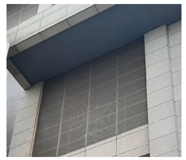
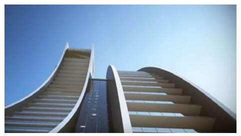
RETROFITTED TO CURTAIN WALLS

29. Jamarhinya
30. Family Bank Towers
31. Alibhai Shariff



C. SUN SHADING VARIETIES BETWEEN 1980-2020.

Building And Description Of Shading Device		Horizontal	Vertical	Egg crate
	**ICEA BUILDING (JKUAT Towers)**- 1980- Architect Richard Hughes Shallow horizontal projected overhang.			
	**REINSURANCE PLAZA** - 1982- MMI Mutiso Menezes International Architects Grid frame egg crate with moveable horizontal louvres.			
	**TREASURY BUILDING** - 1982 -MMI Mutiso Menezes International Architects Grid frame egg crate with vertical fins and horizontal			
	**CITY HALL ANNEXE** - 1982 - Architect Kimura Grid frame egg crate with horizontal louvres.			
	**CORNER HOUSE** - 1985 TRIAD Architects Grid frame egg crate with suspended horizontal glass panel with suspended			
	**BARCLAYS PLAZA** - 1988 - TRIAD Architects Grid frame egg crate with suspended horizontal glass panel			
	**PENSION TOWERS**- 1990 - TRIAD Architects 1.Vertical fins. 2.Horizontal louvres			

Building and Description of Shading Device		Horizontal	Vertical	Egg crate
	**NATION CENTRE -** 1997 - Plnning Systems and Henning Larsen Tegnestue. Horizontal louvres			
	**TIMES TOWER**- 1998 - TRIAD Architects Horizontal overhang			
	**TELEPOSTA TOWERS (GPO)**- 1999 Grid frame egg crate with suspended horizontal glass panel			
	**I&M BUILDING** - 2001- Planning Systems Vertical fins. Purely aesthetic.			
	**YALA TOWERS** - 2013 1. Suspended horizontal glass panel. 2. Horizontal louvres			
	**UNIVERSITY OF NAIROBI TOWERS** - 2016 - Waweru and Associates. 1. Egg crate perforated screen.			
	**CBK PENSION TOWERS**- 2020 Horizontal overhang. Balconies			

D. CASE STUDY 3

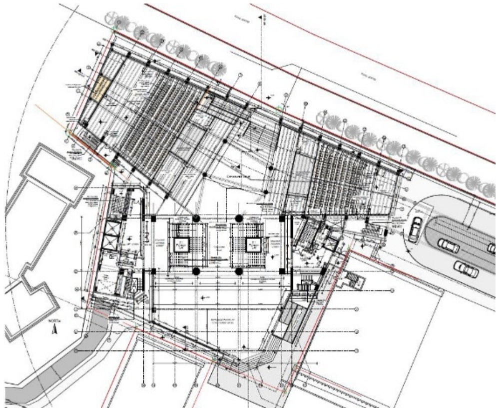
UNIVERSITY OF NAIROBI TOWERS

CONSTRUCTION YEAR: 2015

ARCHITECT: Waweru and Associates.

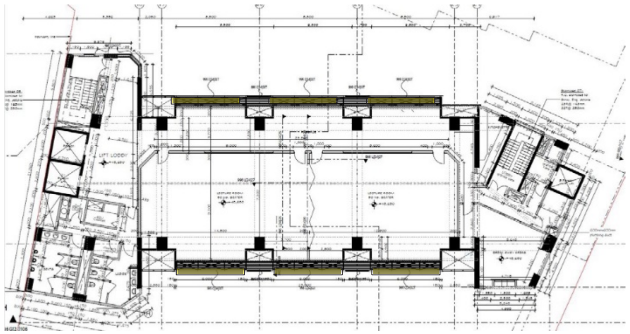
ARCHITECTURAL STYLE:

Sustainable architecture



SITE PLAN.

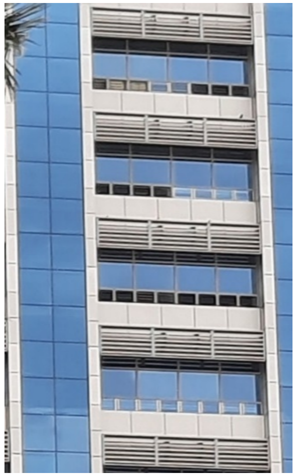
Building orientation is dictated by Great Court. The tower is oriented east west with windows on the northern and southern façade.

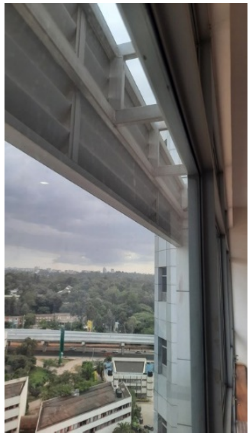


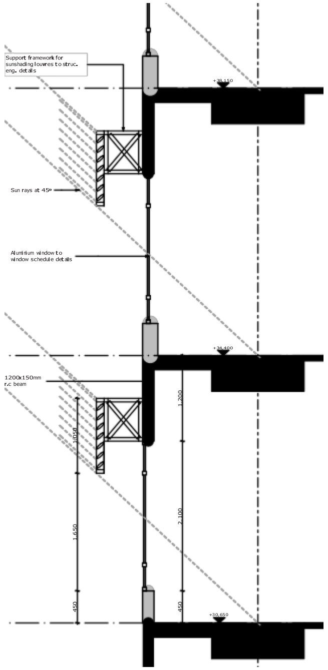
TOWER PLAN

Horizontal device.

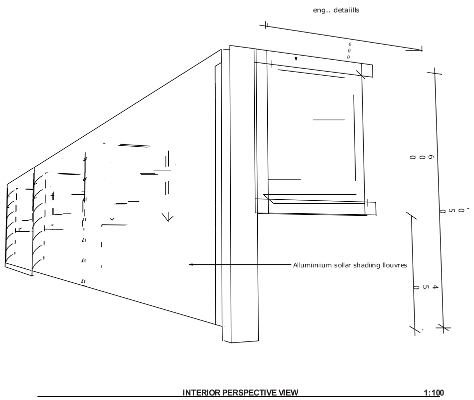
1050mm high Aluminium louvres suspended on steel brackets to shade the glazed windows on the tower.



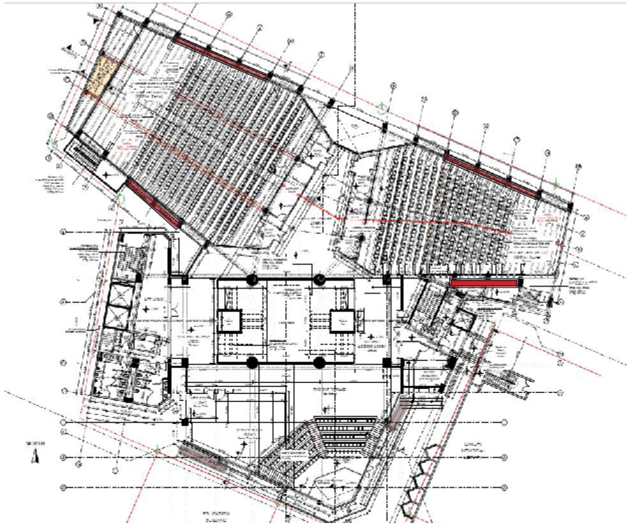




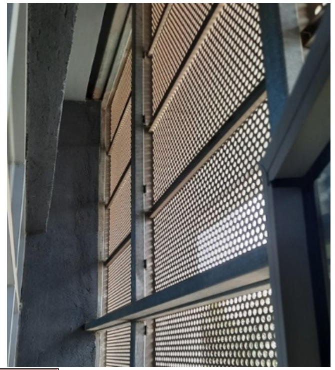
Section through sun shading device showing RHS bracket support



Louvres are supported by a 600 X 600mm RHS bracket. The louvres are 2100mm above the finished floor level. They are 600mm away from the widow allowing for air movement.



PODIUM PLAN



Egg crate device.
Composed of perforated steel sheets anchored to the wall. The perforated steel screen allows for ventilation while giving privacy to the users in the lecture halls. The perforated steel sheets are anchored onto an RHS grid frame support.

Visual comfort

Egg-crate device provides privacy from the outside but allows for view out from inside the lecture hall while preventing glare. The obscured view out is beneficial to the learning environment.

The view out at the tower level is unobstructed at eye level allowing unobstructed views of the Great court and Nairobi city.

E. SUN SHADING DEVICE ANALYSIS BETWEEN 1980 AND 2020.

	1CEA BUILDING - 1980	UON TOWERS - 2013	PENSION TOWERS -1990	I&M BUILDING - 2001	BARCLAYS PLAZA - 1988	NATION BUILDING - 1997
ARCHITECTURAL	**Tropical modern architecture**	**International Style &**	**International Style**	**International Style**	**International Style**	**International Style &**
DESIGN: Architect	**British** Architect Richard Hughes. Tropical modern architecture pioneer.	**Kenyan** Architect Waweru and Associates.	TRIAD Architects. Founded by tropical modern architecture pioneer but designed by Kenyan.	**British** Architects in Kenyan Firm. Planning Systems.	TRIAD Architects. Founded by tropical modern architecture pioneer but designed by Kenyan.	Planning Systems alongside international architects
SHADING DEVICE		 				
FORM: Type	**Horizontal.** projected horizontal overhang.	**1. Egg crate.** Patterned screen **2. Horizontal** suspended louvres.	**1. Egg crate.** Patterned screen **2. Vertical** fins.	**1.Vertical** fins.	**1. Egg crate.**Patterned screen **2. Horizontal.** Suspended horizontal panels.	**1. Horizontal.** Louvres
FORM: Aesthetics	**Primary** shading feature but does not stand out as aesthetic	**Primary** shading feature but does not stand out as aesthetic	**Facade feature.** Vertical fins	**Facade feature.** Does not stand out as distinct feature of	**Facade feature.** Glass shading emphasizes the glass facade of	**Facade feature.** Creates distinctive building facade.
FORM: Orientation	1.West, East -No shading. 2. **North & South-** Horizontal overhang.	1.West- No shading 2. **North** - Louvres 3. East -No shading 4. **South** - Louvres	1.North- No shading 2. **East-** Vertical fins 3. South -No shading 4. **West** - Vertical fins	**All** facades have sun shading devices.	**All** facades have sun shading devices.	1.**West-** Horizontal louvres. 2. North - No shading 3. **East** -Horizontal louvres. 4. South - No shading
CONSTRUCTION: Material, Colour	1. Smooth, dark coloured plastered and painted	Aluminium louvres and perforated steel sheet.	Steel vertical fins. Concrete horizontal louvres.	**Aluminium** fins.	1. Blue tinted **glass** panels 2. **Precast concrete**	Smooth, light coloured plaster & painted **concrete**
FUNCTION: 1.Visual comfort	1. Clear view out.	1. Clear view out. 2. Egg crate screen obstructs view out while providing privacy	1.View out is obstructed by the vertical fins. 2. Vertical fins do not provide adequate sun shading.	1.unobstructed view out. 2. Fins not adequate for thermal comfort, purely aesthetic.	View out is unobstructed. Egg crate shading	View out obstructed by louvres. Frames a small square portion of the window.

FORM:

1. Most common types of sun shading devices were egg crate and horizontal with few having vertical sun shading.
2. Sun shading devices are not a distinct architectural feature of the building for buildings of International Style. With the advent of sustainable design, sun shading devices begin to appear as part of the facade composition but not the entire design of the facade as was the case in Tropical modern architecture. It is limited to the windows or mimics the glass of the building's skin.
3. Following the brise soleil expression of the Tropical modern architecture, sun shading devices play a less obvious role in facade design of International Style.
4.Location of sun shading devices was determined by street orientation and aesthetic of the building.

CONSTRUCTION:

1. Main sun shading material is glass. Steel, aluminium and concrete are still in use especially with the sustainable architecture buildings.

DESIGN

1. Design was dictated by the clients. Buildings such as UoN Towers were designed following a competition whose brief was a sustainable building. More local architects are involved as more architects have been trained locally since the start of the architectural department at the University of Nairobi.

FUNCTION

1. View out is mostly not impared by the glass sun shading devices. The louvred devices such as in Nation Centre are few.

4.3 ANALYSIS OF SUN SHADING DEVICES IN NAIROBI

Having documented the buildings in Nairobi Central Business District, trends begin to emerge based on the four criteria of function, form, construction and design. In order to address these trends, the following factors affecting sun shading devices will be analysed:

i. Global architectural styles
ii. Key players in the built environment
iii. Types of sun shading devices
iv. Construction materials
v. Aesthetics
vi. Orientation

4.3.1 GLOBAL ARCHITECTURAL STYLES

Based on the five categories of architectural periods discussed in 4.2 above it is clear that each period was defined by a distinct architectural style. Figure 4.41 shows a comparison of significant architectural periods and their counterparts in Nairobi highlighting how fast global architectural styles are adopted locally.

From the onset of Modern architecture such as Art Deco it seems to take an average of 10-20 years for a building in the new architectural style to be built in Nairobi. With the first kinetic shading device having been built in 1987 and design of such buildings becoming more popular in the early 2000s, future designs of sun shading devices in Nairobi, with improvement in material and building technology, are likely to feature moveable active sun shading devices as is the current trend worldwide.

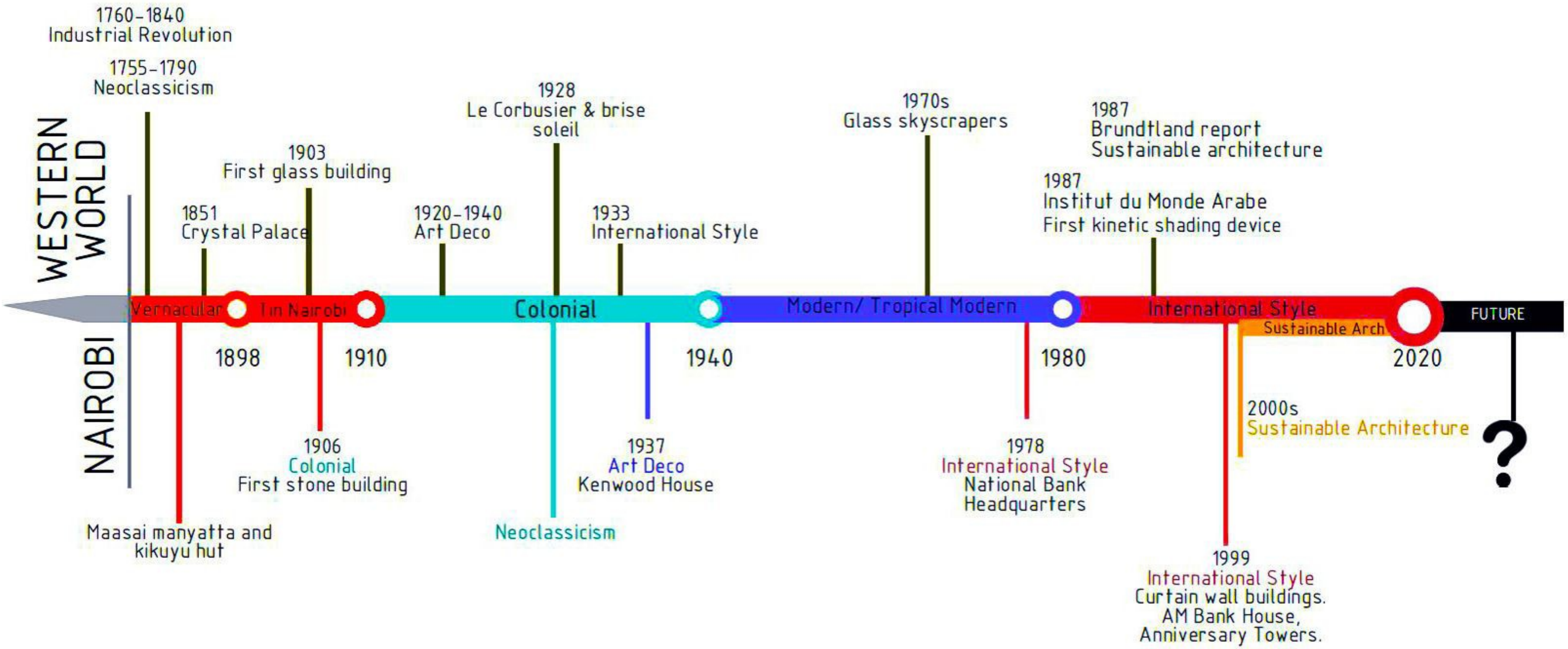
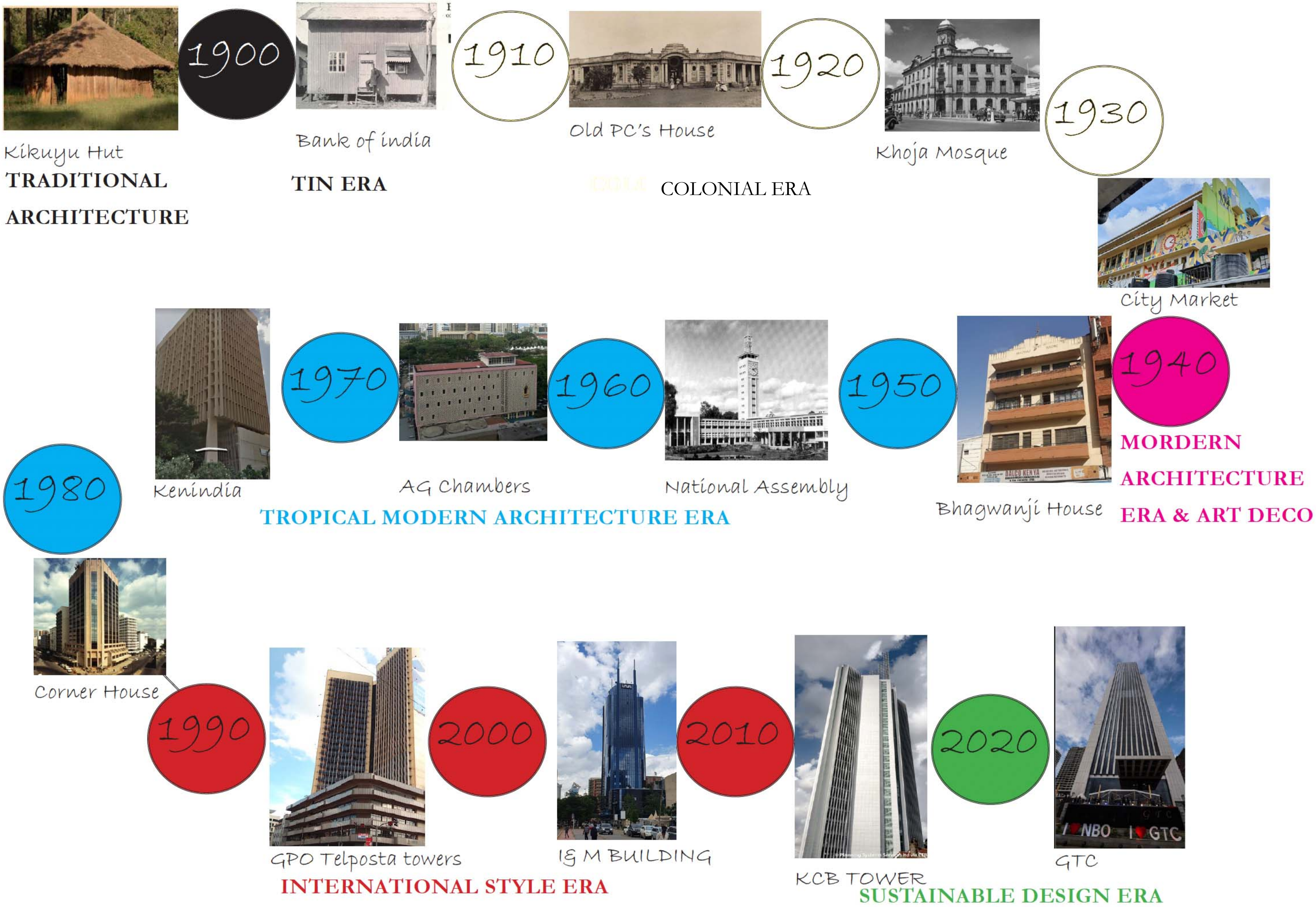


Fig 4.41 Timeline of architectural styles globally versus locally
Source: Author

4.3.2 NAIROBI'S SUN SHADING DEVICE TIMELINE

Using a single building as representative of sun shading device type of a specific decade, the table below showcases the evolution and transformation of sun shading devices in Nairobi since pre-colonial era to 2020. The decades are colour coded to highlight the eras as per the research and years with similar sun shading device types.


Kikuyu Hut
TRADITIONAL
ARCHITECTURE
1900
Bank of india
TIN ERA
1910
Old PC's House
COLONIAL ERA
1920
Khoja Mosque
1930
City Market
1940
MORDERN
ARCHITECTURE
ERA & ART DECO
Bhagwanji House
1950
National Assembly
1960
AG Chambers
1970
Kenindia
TROPICAL MODERN ARCHITECTURE ERA
1980
Corner House
1990
GPO Telposta towers
INTERNATIONAL STYLE ERA
2000
I& M BUILDING
2010
KCB TOWER
2020
GTC
SUSTAINABLE DESIGN ERA

4.3.3 KEY PLAYERS IN THE BUILT ENVIRONMENT

The research highlights that the background **of the architects of the buildings in the Nairobi Central Business District played a major role in the design of sun shading devices.** Their background refers to their country of origin, their architectural training, how they arrived in Kenya and the predominant architectural style at the time of their practiced. Categories of architects who designed sun shading devices studied can be categorised into the following:

a. European Architects- colonial administration and Tropical Modern Architecture

Majority of the architects from 1898 -1980 time period were British architects. Some were invited by the Colonial Administration to design their administrative buildings e.g. Herbert Baker and Amyas Connel who was hired by the Chief Architect at the time, Thornley Dyer to work in Nairobi from Tanganyika. Others were Corporals in the British Military such as Architect Richard Hughes who was a corporal in the Kenya Regiment. Hitler's Nazi regime in Germany forced some architects into exile such as Architect Ernst May who was moved to Tanganyika in 1933 and later on to Kenya in 1937 after a failed project in USSR. He designed some of the first modern buildings in Nairobi such as Kenwood House.

Some architects went on to become pioneers of tropical modern architecture in Kenya and introduced brise soleil to Kenya. Architect Richard Hughes who studied in the AA school is one of them. Other architects of note are Graham McCollough and Amyas Connell who founded TRIAD who have a large percentage of buildings in the Nairobi Central Business District.

b. Indian Architects - Colonial Architecture

The Indian community that settled in Nairobi also had their own architects who designed their buildings such as Nayer building and Khoja Mosque. Kipande house was designed as a warehouse by its owner Mr. Gurdit Singh Nayer who was assisted by **British** Architect David Fialt.

c. Kenyan Architects and International Style

The first Kenyan architect Mutiso founded the architectural firm Mutiso Menezes International (MMI) and their work is visible in several buildings within the Nairobi CBD. Prior to this, he worked in the Ministry of works and was part of the team that designed KICC as the chief architect in the Ministry of Works. As more and more local architects began to practice, they failed to continue with the principles of Tropical Modern Architecture which was practised from 1940-1985 and instead opted for the glass facade buildings in line with the International Style seen in Nairobi from 1980.

d. International architects' collaborations and Sustainable Architecture

Sustainable architecture as well as global collaboration and local policies on construction has seen international firms partner with local firms to deliver buildings in Nairobi. Examples include Britam Towers and Coca Cola Headquarters. This has brought about knowledge exchange on the design of sun shading devices as the world moves towards kinetic sun shading devices.

Fig 4.42 Buildings along Harambee Avenue
Source: www.Pbase.com

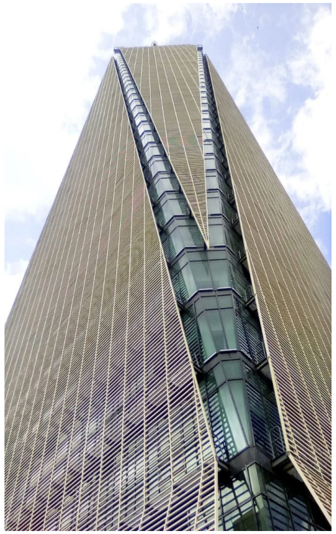


Fig 4.43. Britam Tower veil sunshading device.
Source: Buildesign

The research also finds that the **architect is influenced by the client or developer of the building.** During the colonial period the client was the colonial government and their buildings needed to reflect authority which had specific classical elements that defined the type of architecture seen in buildings such as the Law courts, City Hall etc. But with the advent of the modern movement, the architects were free to explore their creativity during the Tropical Modern period especially with all the government buildings on Harambee Avenue. The government, post-independence, hired several architects making the client also the architect. The buildings were designed to show a shift from the colonial administration and associate with the global standards of architecture to attract investors to the new country.

During the glass building era, the primary construction driver shifted to corporate entities who envisioned their corporate image in the buildings in order to attract clients. Government as the developer gave architects free reign and they designed with sun shading devices as key facade elements whereas the corporate developers of 1980s to 2020 advocate for clarity and crisp designs of the glass facade to show their modernity.

Towards the 2000s, some clients are beginning to appreciate the need for sustainable architecture and in their brief alongside the architects have managed to construct award winning buildings such as the Britam Tower which is EDGE certified, has won an award by the Council on Tall Buildings and Urban Habitat.
The building though not within Nairobi CBD, is located in Upper Hill which is considered an extension to the current CBD and features suspended horizontal louvred terracotta briquettes as sun shading devices to the glass building skin.

As a trend, environmentally conscious developers will continue to push architects to come up with innovative sun shading devices.

4.3.4 TYPES OF SUN SHADING DEVICES

Popularity of a type of shading device over time.
Most popular device in the CBD is the horizontal shading device followed by the eggcrate sun shading device.
Vertical shading devices are fewest.

Evolution of each type of shading device

Horizontal devices

a. Colonial- Porticos, verandah, balconies
b. TMA-projected overhang, suspended louvres and panels.
c. Glass era- suspended louvres and panels.

Vertical Devices

a. Colonial- none
b. TMA- vertical fins
c. Glass era - aesthetic vertical fins

Egg crate devices

a. Colonial- recessed windows.
b. TMA-grid frame and patterned screens
c. Glass era - suspended louvres

Future trend will be to maintain the status quo.
Horizontal and egg crate types are versatile in design flexibility and are best for thermal performance in Nairobi.

4.3.5 SUN SHADING DEVICE MATERIALS

Popularity of a shading device material over time.

The most popular material in the CBD is the concrete sun shading device.

The least popular material is glass due to its cost and poor performance as a sun shading device.

Evolution of each type of material.

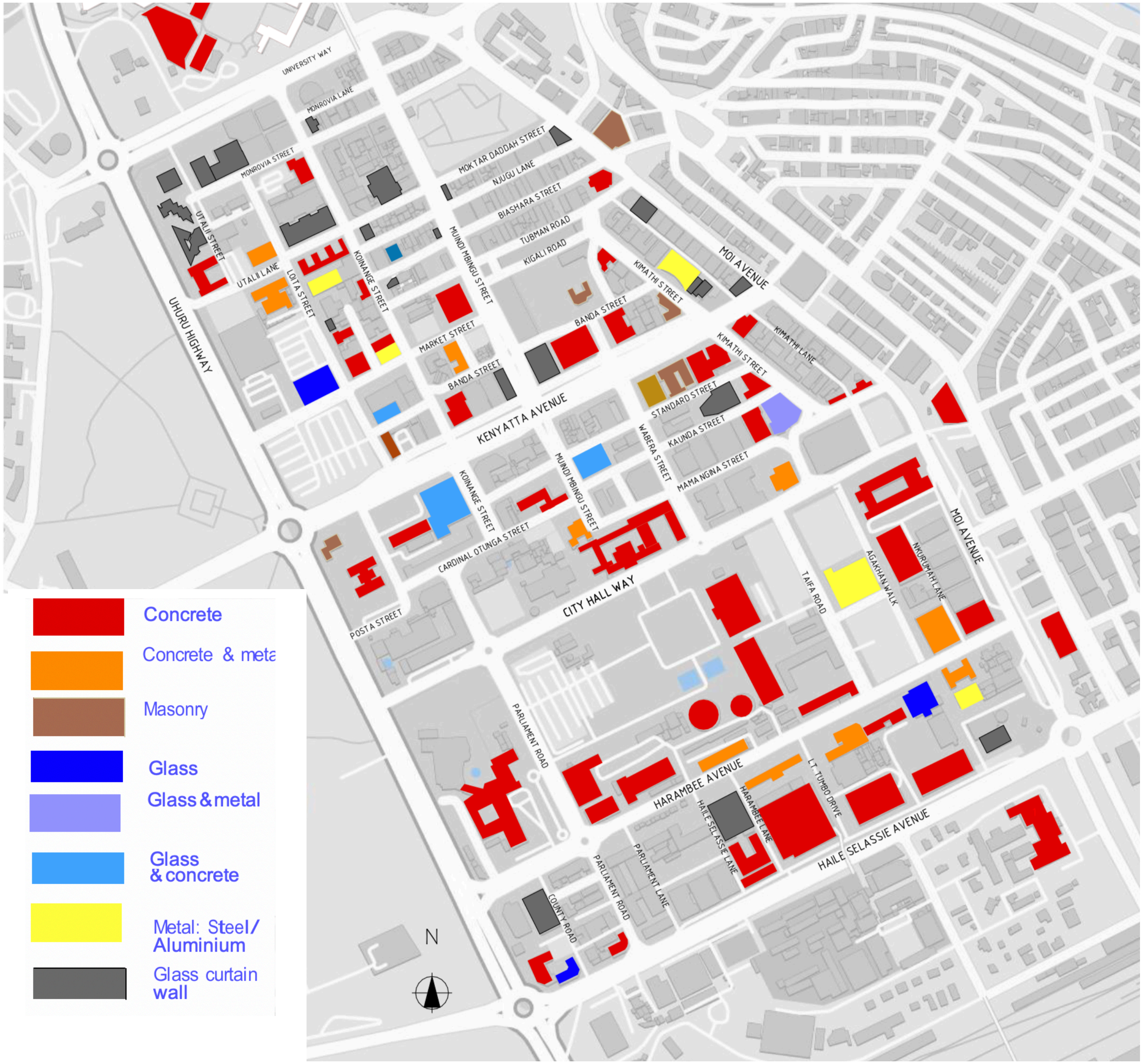
a. Colonial- Masonry stone & concrete
b. TMA- Concrete and steel
c. Glass era -Glass, Concrete, aluminium and steel

TRENDS:

Future trend will be development of new materials with improved technology.
Existing materials will be re-engineered to come up with new shading possibilities.

Use of lightweight materials will also be popular in order to achieve mobility of devices.

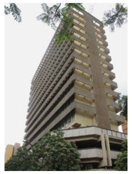
Smooth and light-coloured materials will continue to be a trend to increase reflected light into the building and improve the daylighting factor.



4.3.6 AESTHETICS OF SUN SHADING DEVICES

The sun shading devices of the Tropical Modern Era create the most distinct architectural features of the five time periods analysed. The first three eras have sun shading devices as secondary features and therefore did not stand out whereas the glass era generally focuses on glass as a sun shading device and therefore leaves aesthetic design to the form of the building. Though most fixed tropical modern buildings have sun shading devices form the building's facade, the following two features have been found to highlight the sun shading device as an aesthetic feature:

1. Wraps around the building in areas without windows for example Bruce house and Sheria House.

Bruce House

Sheria House

2. Patterned egg crate sun shading devices. These patterns are sometimes random such as Hyslop Building and UTC Parking while others such as Sheria House have a cultural background. Other such shading devices are found in the National Assembly, City Hall, ABSA plaza, Harambee House and Jogoo House B.

Hyslop Building

Chai House

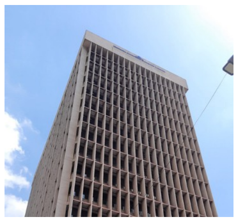
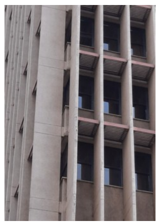
3. Highlight a sun shading device through use of colour for example KCS House and International life house with their blue sun shading device.

KCS House

International Life House

4. Proportions of the distance between vertical and horizontal panels also creates visually appealing and distinct patterns. This is seen in vertical sun shading devices such as Jogoo House B, Central Bank and Kenindia whereas grid type egg crate shading devices such as IPS Building and Kenindia also have the same distinct feature.

IPS Building

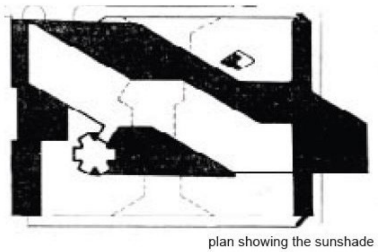



Kenindia

4.3.7 ANALYSIS OF SUN SHADING DEVICE ORIENTATION

Orientation of buildings in Nairobi is dictated by the street grid which runs North South with a 23^{o} tilt. Some architects have managed to change the natural building orientation based on the street to reduce solar heat gain and therefore sun shading devices are on the North and South facing windows as it should be. Examples are the buildings designed by Architect Richard Hughes. Development bank whose natural alignment along Moi Avenue should have East and West facing windows on its longest side and ICEA Building which is designed to ensure it faces exactly north not north

east as dictated by the street.



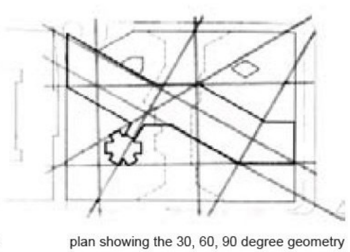


Fig 4.44 ICEA Building plan showing orientation
Source: ETH Basel

Buildings such as the National Assembly and Education have employed the use of different sun shading devices depending on the building's orientation to achieve high thermal performance.

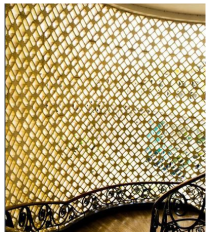


Fig 4.45National Assembly
Source: Nation, Buildesign, UN Habitat

Design of towers in the greater Nairobi today is not confined to the square or rectangle as seen in the design of One Africa Building in Westlands with its elliptical design and the pyramidal form of BRITAM Towers means that future building orientation and that of sun shading devices will not be dictated by the street but rather by the form as designed.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.0 INTRODUCTION

Fig5.1. Horizontal shading devices on Uchumi House
Source: Author

Fig5.2. Horizontal shading devices on Jubilee house.
Source: Author

The research carried out documentation of the sun shading devices in Nairobi in order to analyse the trends. This is achieved through the literature review as well as the data collected in the field. Conclusions were made based on the following research objectives:

1. To identify factors affecting sun-shading device design and implementation in Nairobi since its formation to 2020.
2. To analyse the historical trends of sun shading devices in Nairobi.
3. To predict future trends of sun shading devices in Nairobi.

From the research objectives set out, three main conclusions were made. These are:

a. The key factors affecting design and implementation of sun shading devices in Nairobi is the architectural style and the architects of the day. There is a direct co-relation between the architectural style and the type of sun shading device built. From the arrival of the British settlers to 2020, the architects practicing in Nairobi are seen to follow the trends of the west.

b. The overarching historical trend of sun shading devices in Nairobi is that they are influenced by the global architectural designs. The transfer of knowledge and architectural trends takes, on average, 10-20 years from previous historical statistics although this is dependent on several other factors such as economy and unexpected world events such as war and a global pandemic. These trends are visible in the types of shading devices, the construction materials and aesthetics of the sun shading devices.

c. The future of sun shading devices in Nairobi is the use of kinetic shading devices as seen in the Western world and Asia.

5.1 CONCLUSIONS

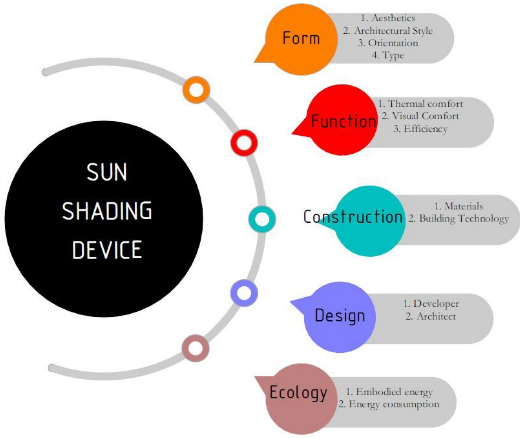


Fig5.3. Conceptual framework
Source: Author

Fig5.4. Recessed windows of Kencom building facade act as secondary sun shading feature.
Source: Author

A. From the literature review, the lessons learnt are that the architectural style of the day is the primary element to consider when designing a sun shading device. This is then followed by insight into architectural design factors as well as environmental design factors. These factors include thermal and visual comfort, ventilation, acoustics and materials. The architectural features deal with the key players in the built environment namely the architect, the developer and policy makers. These factors when grouped created four categories namely: function, form, construction and design.

With the information from chapter two as a conceptual framework to guide the research and analysis of chapter four the first research question can be concluded as follows. The factors affecting the design and implementation of sun shading devices in Nairobi are as follows:

1. Architects and Architectural style.

The architect's background determines their architectural style and therefore the type of sun shading device used. Distinct characteristics of an architectural style determine the type of sun shading device or lack of sun shading device. Tropical Modern Architecture had brise soleil as a cornerstone of their architecture and therefore sun shading devices are most prevalent during this architectural period as opposed to International Style that brought about the decline of sun shading device use in favour of the clean glass facade.

2. Developer

This determines the freedom an architect has in design of sun shading devices in relation to aesthetics and cost. The main developer was the government during the Tropical Modern Architecture era and the architect had a freedom to fully implement their architectural vision to meet the client's brief of showing Kenya as a new independent country able to meet the International Standards and attract investors. Later on, during the Glass Era, the developers were private investors keen on upholding corporate image and economic viability of the buildings and thus would leave out the additional cost of sun shading devices.

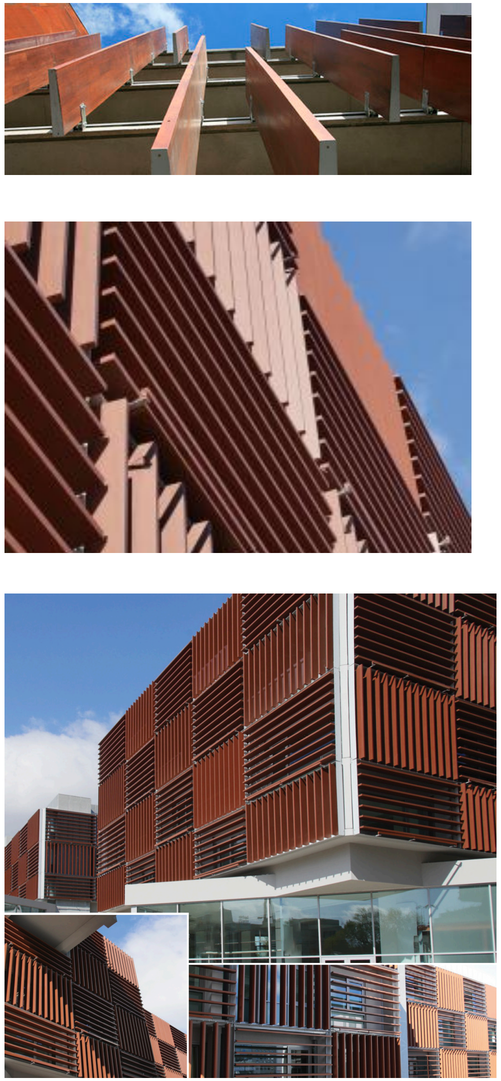


Fig5.5. Variations of timber brise soleil on a building showing use of different materials and kinetic sun shading devices in use in the Western world.
Source: Glasscon

3. Aesthetics

Sun shading devices give building facades their character whether intentional or as a secondary feature. This is most visible during the tropical modern architecture era whereas during the glass era use of glass sun shading devices mimicked the bland glass facade.

4. Materials

Improvement in technology and availability of materials determines the type of sun sharing device. The introduction of new materials such as steel, aluminium and glass brought about more variations in the types of sun shading devices as compared to purely concrete and masonry stone.

5. Street orientation

Nairobi street grid and plot sizes determine the direction of most of the building facades. This causes some windows to be oriented East and West instead of the desirable North South orientation.

6. Thermal and Visual comfort

Though not analysed in this research, the sun shading devices provide varying degrees of thermal and visual comfort to the users of the buildings.

B. The second research question is answered in section 4.3. The key trend in sun shading devices in Nairobi is the adoption of **the architectural style trending in the Western world** 10-20 years after it begins. Fig 5.5 showcases the types of kinetic sun shading devices that are currently being designed and are likely to be found in Nairobi in the years to come as we embrace this new architectural style.

Another trend in the sun shading devices in Nairobi is the adoption of new materials and construction technology from the western world and Asia.

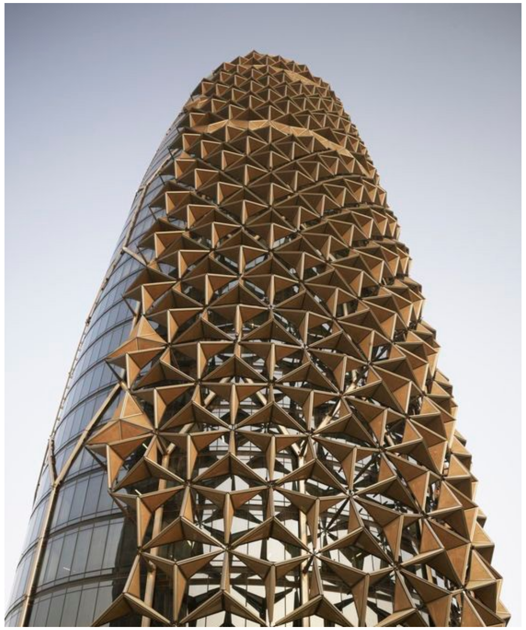


Fig5.6. Al Bahar Towers, Abu Dhabi with autpmatic shading facade that opens and closes in response to the sun's movements.
Source: Pinterest

C. Based on the findings in chapter 4, **the varieties of sun shading devices in Nairobi CBD are egg crate, horizontal and vertical**. There are no dynamic moveable shading devices in the CBD. The only moveable devices are manually operated such as the moveable louvres in Reinsurance Plaza. The world of sustainable architecture is now focusing on energy efficiency and the moveable kinetic sun shading devices such as the Al Bahr Tower in Abu Dhabi are becoming popular. These are yet to be implemented in a local building but it seems likely that the future of skyscrapers in Nairobi in the near future will be such moveable shading devices that adapt and respond to the varying daily sun conditions.

With the current trend of new buildings in the Nairobi CBD tending to eliminate the podium and tower building style, the new building towers are not being dictated by street orientations. This is likely to shift new sun shading devices from the traditional vertical and horizontal shading devices to more complex sun shading devices such as the moveable or kinetic shading devices.

With the improvement in material and construction technology the future of sun shading devices in Nairobi will include n**ew materials or re-engineering of current materials**. This can be seen in the use of Terracotta briquettes as a sun shading device in the Britam Towers building whereas Terra cotta is traditionally known locally as a roofing material. Concrete as the primary sun shading device material will begin to lose its prominence in lieu of **lightweight materials** which will be used to allow for ease in the movement of the kinetic sun shading devices of the future.

5.2 RECOMMENDATIONS

Fig 5.7.Creative Climate responsive facade of SDU- Kolding University of Southern Denmark. Source: Archdog

Fig 5.8.Representation of the mushrabiya screen in the robotic shading screen of Institut du Monde Arabe. Source:Quora

Sun shading devices today act as a secondary skin and need to find the balance between functionality, aesthetics and sustainability. Multi-layered facade systems that incorporate sun shading devices allows for a future with improved performance compared to the sun shading devices designed by our predecessors. Based on the predicted future trend being the implementation of kinetic sun shading devices in Nairobi, architects and developers need to be ready for the arrival of kinetic devices.

Due to higher complexity of kinetic sun shading devices, such as fig 5.6, than traditional design there is need for expansion of stakeholder's knowledge on new technologies, their risks, their opportunities and the role of the users and executing companies in the initial design phase. New technology should include holistic performance evaluation models that consider thermal comfort levels, operational strategies, energy efficiency and environmental impact. The kinetic sun shading devices may also require adequate and consistent electrical power supply depending on the type of smart materials used. This would require developers to ensure back up energy supply of the national grid. Renewable sources of power such as solar power for the development would be a requirement to ensure optimal functionality of the sun shading devices.

Another recommendation is the creation of a local **design aesthetic** for buildings in Nairobi through use of sun shading devices as both an environmental feature and an aesthetic feature of a building's facade. Just as modern architecture was re-interpreted as Tropical Modern Architecture to suit the local climate and culture for the specific region, future design of sun shading devices should be interpreted locally rather than directly mimicking those of the western world. Fig 5.8 is a good representative of interpretation that suits the cultural aspects of the region.

Areas for further research

This study focused on the analysis of existing sun shading devices to determine future trends in specific areas. Proposed areas of further research are:

1. Calculating the cost benefit of buildings using sun shading devices. This can be compared to a building of similar nature in the Central Business District for comparison.
2. Thermal performance comparison of the different types of shading devices designed during the different architectural eras in the Nairobi Central Business District to determine which device type functions best.
3. Development of a manual sizing sun shading devices in different orientations for Nairobi. This can be used to further size the sun shading devices for Nairobi.
4. Creation of a local sun shading devices. This features cultural elements of significance and gives the sun shading device a two-fold function of thermal performance while being aesthetically pleasing and reflective of Kenya and Nairobi.

REFERENCES

1. Aldakheel, J.A & Aoul, T K.. (2017). *Building Applications, Opportunities and Challenges of Active Shading Systems: A State-of-the-Art Review*. *Energies*.10. 1672. 10.3390/en10101672.
2. Baird. G. (2001) *The Architectural Expression of Environmental Control Systems*. Spon Press. London.
3. Banham. R. (1969)*The Architecture of the Well-Tempered Environment*. The Architectural Press, London.
4. Barber. D. (2012) *Le Corbusier, The Brise-Soleil and the Socio-Climatic Project of Modern Architecture, 1929-1963*. Thresholds 2012; (40): 21–32. doi:
5. Barber D. (2019) *Climate-Sensitive Architecture as a Blueprint: Habits, Shades and the Irresistable Staircase*. RCC Perspectives: Transformations in Environment and Society 2019, no. 2,77-85. Doi.org/10.5282/rcc/8743
6. Barber. D. (2020) *Modern Architecture and Climate. Design Before Air Conditioning*. Princeton University Press. Oxfordshire.
7. Baweja. V. (2008) *A Pre-History of Green Architecture: Otto Koenigsberger and Tropical Architecture, from Princely Mysore to Post colonial*

London. University of Michigan.

8. Baweja V (2015) *Messy Modernisms: Otto Koenigsberger's Early Work in Princely Mysore, 1939–41* South Asian Studies. 31. 1-26. 10.1080/02666030.2015.1008806.
9. Bruer. M. (1955) *Sun and Shadow. The Philosophy of an Architect*. Longmans, Green and Co. Toronto.
10. Boesiger. W & Stonorov.O (1995) *Le Corbusier: Complete Works*. Birkhauser Architecture. Basel
11. Chana T (1980) *Urban Legislation relating to zoning. A historical review in Kenya*. Housing research and development unit. University of Nairobi, Kenya.
12. Colquhoun, A. 1989. *Modernity and the Classical Tradition: Architectural Essays, 1980-1987*. MIT Press, Cambridge.
13. DeKay M & Brown G.Z. (2014) *Sun, wind and light. Architectural design strategies*. John Wiley and sons, New Jersey.
14. Fausti, P., Secchi, S., & Zuccherini Martello, N. (2019). *The use of façade sun shading systems for the reduction of indoor and outdoor sound pressure levels*. Building Acoustics, 26(3), 181–206
15. Ghosh. A. (2016) *The Great Derangement: Climate Change and the Unthinkable*. University of Chicago Press, Chicago.
16. Givoni. B. (1969) *Man, Climate and Architecture*. Elsevier Publishing Company Limite, London.
17. Immerwahr D (2007) *The politics of architecture and urbanism in postcolonial Lagos, 1960– 1986* Journal of African Cultural Studies, 19(2), 165–186.

18. Kirimtat, Ayca & Koyunbaba, Basak & Chatzikonstantinou, Ioannis & Sariyildiz, Sevil. (2016). *Review of simulation modeling for shading devices in buildings*. Renewable and Sustainable Energy Reviews. 53. 23-49. 10.1016/j.rser.2015.08.020.
19. Koeningsberger O.H, Ingersoll T. G, Mayhew A & Szokolay S.V (1973) *Manual of Tropical Housing. Climatic Design*. Longman, London.
20. Komatina. D, Žarić. S, Alihodzic. E, Sokolovskiy, N & Riabuhina, S. (2015). *Static shading devices in the architecture of buildings*. Construction of Unique Buildings and Structures. 4. 122-134.
21. Landis. M (2019) *Development of a Parametric Data-Driven Fixed Shading Device Design Workflow*. (Unpublished master's thesis) University of Cincinnati.
22. Maina M (2016) *Tropical modern architecture. Climate responsive modern architecture in East Africa between 1940 and 1980*. (Unpublished master's thesis) University of Nairobi.
23. Muhoro T, Munala G & Mugwima N.(2016) *Reflections on architectural morphology in Nairobi, Kenya: implications for conservation of the built heritage*. UCL Press, London.
24. Munyao V (2017) *Guidelines for design of sun shading devices for buildings in the tropics*. (Unpublished master's thesis) University of Nairobi.
25. Olgyay V (1963) *Design with Climate: Bioclimatic Approach to Architectural Regionalism*. Princeton University Press, Princeton, New Jersey.
26. Olgyay & Olgyay (1957) *Solar control and shading devices*. Princeton University Press, New Jersey.
27. Owuor. S & Mbatia T. (2008) *Post Independence Development of Nairobi City, Kenya*. (Paper presention) Workshop on African capital Cities.
28. Pesenti.M, Masera G, Fiorito F & Sauchelli M. (2015) *Kinetic solar skin: a responsive folding technique*. Energy Procedia. 70. 661–672. 10.1016/j.egypro.2015.02.174.
29. Rae A. (2014) 'Trend Analysis. In: Michalos A.C. (eds) *Encyclopedia of Quality of Life and Well-Being Research*. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-0753-5_3062
30. Rappaport. A. (1969) *House, Form and Culture*. Prentice-Hall Inc. Englewood Cliffs New Jersey.
31. Ruskin J.(1849) *The seven lamps of architecture.'v*Smith, Elder & Co. Scotland
32. Sener D. (2006), *Understanding facade between design and manufacturing: A case study on High -rise office buildings in Istanbul*. (Unpublished master's thesis) Middle East Technical University.
33. Stack A.,Goulding J & Lewis O. *'Solar shading for the European Climates*. Energy Research Group, University College Dublin, Ireland.
34. Szokolay S. (2004) *Introduction to Architectural Science. The basis of sustainable design*. Architectural Press. Oxford.

35. Voigt, Michael & Roth, Daniel & Binz, Hansgeorg. (2021, October). *Challenges with adaptive facades - a life cycle perspective*. (Paper presentation) Advanced Building Skins, Bern
36. Yao Y. (2021) *From segregated to integrated: The evolution of shading designs in Marcel Breuer's Works*. (Unpublished master's thesis) Southeast University.