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Solar-shading systems designed to increase user satisfaction in public buildings, a case study of Britam Towers in Nairobi, Kenya

Evans Kimani Njunge, Çilen Erçin *

Department of Architecture, Faculty of Architecture, Near East University, Nicosia, Cyprus

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ABSTRACT

Solar-shading systems play various roles to the users of public buildings and may vary from user to user but some of the common user's needs for these systems include; thermal comfort, energy-saving, daylight, and glare reduction. Understanding these needs can help Designers and Architects select from a wide array of Solar-Shading types and see which of them serves the needs of the users better. The Types of Solar-Shading Systems include either internal systems which are placed inside the building or can include external systems which are placed to the outside of buildings. To clearly understand the role Solar Shading Systems, play to satisfy Users' needs, a case study of a Public Building in Nairobi, Kenya; Britam Towers, was selected. The case study found out that architects, designers, and developers play a preeminent role in coming up with projects that can better serve the User's needs by creating designs that better suit the needs of the users have for using such Solar-Shading Systems. These designs may vary from building to building, region to region but the main withstanding factor to be noted is the functionality issue, as the Solar-Shading Systems should be able to meet the needs of users effectively and in turn, increase the user's satisfaction.

1. Introduction

Solar-shading systems have been used for centuries now, with their effects being much desired by building occupants. Solar-shading systems are generally elements attached to the interior or exterior of building spaces and whose primal purpose is to bring a comfortable thermal environment for the users/occupants of the public buildings. They work by shading the interior spaces from unwanted solar radiation while still allowing the requisite daylighting to pass through, hence the need for these devices cannot be understated. The User's satisfaction derived from the use of these systems varies from different occupants bearing the fact that different occupants of these public buildings have different requirements they expect from the use of these different solar shade systems. With the need for habitable and thermally comfortable building spaces, the occupants are faced with a wide selection of different solar-shading systems. This study, therefore, comes in handy to try and make us understand the role different designs of solar-shading systems placed in public buildings play in the overall satisfaction of users and how the different solar-shading systems can be generally designed to increase the satisfaction of the users of these public buildings.

1.1. Aims and objectives

This study purposes to make us appreciate the different solar-shading designs in public buildings and how they in turn help to increase the overall user satisfaction of the building occupants, this will be done by the analysis of various solar-shading system designs in buildings and how they altogether play a role to help increase the user satisfaction of the occupants by critically analyzing a case study of the Britam Towers in Nairobi, Kenya. The study will also aim to evaluate the various factors that influence the user's selection of the various solar-shading systems. To further understand the relationship between the solar-shading system designs in public buildings and the user satisfaction of the occupants, the study will endeavor to seek answers to the following question: "What are the different solar-shading system designs in public buildings, and what role do they play in increasing the overall user satisfaction of the occupants?"

* Corresponding Author.
Email Address: cilen.ercin@neu.edu.tr (Ç. Erçin)
https://doi.org/10.21833/ijaas.2021.04.012
Corresponding author's ORCID profile:
https://orcid.org/0000-0002-9799-1810

1.2. Study area

Kenya is a country in East Africa; bordering the Indian Ocean with a population of 48 million people. Its capital city is Nairobi City County which is the only Capital City in the world with a national park inside. The city normally experiences a Tropical upland type of climate characterized by strong solar radiation, often with moderate to cool air temperatures. Even during the hot season, air temperatures rarely rise above 30°C. However, due to Nairobi's location near the Equator and the high number of sunshine hours experienced, overheating is mainly caused by direct solar radiation. Humidity levels are moderate and there is an almost constant air movement, which is never too strong.

1.3. Methodology

A literature review has been carried out on Solar-Shading Systems designed to Increase User Satisfaction in Public Buildings. Reviewed literature is shown in Table 1.

Table 1: Relevant literature

Author and Topic	Publication Date	Country
Sustainable Design Assessment in Planning Process; SDAPP	2015	Australia
Typology of building shading elements on Jalan Sudirman corridor in Pekanbaru; Faisal and Aldy	2016	Indonesia
Brazilian solar Architecture Analysis; Tavares and Silva	2008	Brazil
Evaluation of Overheating Protection with Sun-shading systems; Kuhn et al.	2001	Germany
Solar Shading in Low Energy Office Buildings; Grynning et al.	2017	Norway
Shading Device as Thermal Comfort Strategy; Zulkifli	2011	Malaysia
The Sky Scrapper Centre; CTBUH	2018	USA
Solar Shading Louvre Systems; Fayek	2017	USA
User Satisfaction in Sustainable Office Buildings; Wilkinson et al.	2011	Australia

2. Historical background of solar-shading dating back to the 20th-century architecture

The growth in architecture raised questions regarding sustainability; conventional architecture focused primarily on traditional and vernacular practices and was being rapidly replaced by passive design and environmental techniques, such as solar-shading ventilation to ensure thermal comfort and satisfaction to the occupants in the building spaces (Requena, 2012). The rise of passive design and environmental approaches came about great minds Architects like *Le Corbusier* who was one of the architects who idealized Solar-shading systems. Solar-shading systems design according to *Le Corbusier* composed of one or more slats which were placed to the external of buildings. He recommended the usage of traditional Venetian-blinds for internal solar-shading designs, then for External solar-shading designs he advocated for the use of either vertical or horizontal solar-shading systems to counter solar radiation before the sun rays get to the indoors of buildings. The vertical or horizontal solar-shading systems which were placed on the outside façade of buildings were a great change to what had traditionally been known and people accustomed to (Olgoy and Olgoy, 1957).

Brazilians took on the designs of the solar-shading systems, which became one of the characteristics of their buildings. In the 1930s-1960s, the so-called Modern Brazilian Architecture had created significant, distinctive, and appealing esthetic gestures in the built environment around the world. That was accomplished through the control of unnecessary solar radiation which altogether rendered the interior warmer, more comfortable, and more habitable for the users (Requena, 2012). These initiatives led to efficiency in energy consumption and to more satisfied building users. The introduction of solar shading systems was not only for thermal efficiency, but they also played a significant role in enhancing the building's aesthetics as the improvements in the exterior appearance gave the facade a more majestic impression. The design parameters for buildings primarily in tropical areas have been widely used as a critical preference for designing solar-shading systems (SDAPP, 2015).

2.1. Solar-shading systems description

They are any mechanical or textile equipment that can be used either internally or externally or between internal and external building spaces to give the interior of buildings a shading and cooling effect (Corona and Lemos, 1987). These devices help bring a shadowing cool effect to the indoors of buildings, for they prevent the number of sun rays from getting inside the building without compromising on lighting and natural air ventilation lowering energy costs (Fayek, 2017). An effective solar-shading system should be able to effectively influence the thermal comfort of the users inside the building. The main aim of solar shades is to create a pleasant indoor atmosphere, i.e. cool in summer and warm enough in winter. This is done by controlling the amount of solar radiation and sunlight penetrating through while allowing the requisite daylighting and natural air ventilation inside the building.

Solar-shading systems mainly compose of the technology placed on building spaces either to the interior or exterior to bring a shadowing and cooling effect to the interior of the buildings (Faisal and Aldy, 2016). The primary reason for using solar-shading systems is to enhance a thermally comfortable environment to the interior building spaces. Other vital roles Solar-Shading Systems play in buildings is to help improve daylighting, preventing glare that is got from the solar reflection of light rays, provide privacy to the interior side of buildings, improve and enhance the overall aesthetics of the buildings and noise reduction where the window shades help to limit the sound coming from the outside while also harboring the sound coming from the inside from interference (Grynning et al., 2017). Different designs of the shades can therefore help bring out unique outlooks which go a long way in meeting the user's desired tastes.

2.2. Types of solar-shading systems

2.2.1. Internal solar-shading systems

On the Interior side of building spaces, this technology can range from fabric roller shades, wooden woven shades, cellular honey-combed shaped shades, or tint shades. The shades can be placed in a permanent or temporary setting where the users can set them up according to their desired needs. These designs can be placed directly on the windows or on different railings on the windows according to the desired needs the users deem fit.

- **Curtains:** They comprise of textile or linen material hand on the inner side of windows. It is the most commonly used internal solar-shading system and is often placed on residential buildings. It is often cheaper when compared to other devices due to its simplicity of use and ease of access. Its primary function, while also serving more of an aesthetic purpose, is limiting the amount of solar radiation coming through the windows hence keeping the indoors spaces more habitable. It serves more as an aesthetic role, which according to the different occupant's needs and tastes can be placed and adjusted into their living spaces to make them more appealing.
- **Venetian blind and vertical louver blinds:** Venetian blinds, made of aluminum, plastic, wood, or bamboo, are plain slatted blinds running horizontally across the walls. All slats can be rotated vertically or horizontally almost 180 degrees in compliance with the needs of different users and types of blind selected, with slats ranging in width between 16 and 50mm, with a width of 25mm being the most common. Its primary function is limiting the amount of solar radiation coming through the windows while also serving more of an aesthetic purpose. Suitable for many applications where the controlling of heat, light, and glare in commercial and public buildings is of concern. It can also be found in wider windows and doors. Fig. 1 shows Venetian blinds and Venetian Louvre blinds.

Fig. 1: Venetian blinds and Venetian Louvre blinds (Fayek, 2017)

- **Roller blinds and blackout blinds:** Roller and blackout blinds consist mainly of stiffened polyester, placed on a metal pole or aluminum tube and operated with a side chain or spring mechanism. The blind works on a method in which the user rolls the blind out to the place they deem suitable for their needs as can be seen in Fig. 2. One can opt for the translucent blind or for places that need total darkness to go for the blackout ones while also offering privacy as it limits out the unwanted solar radiation from penetrating inside the building spaces.

Fig. 2: Roller and blackout blinds (Nagy et al., 2016)

2.2.2. External solar-shading systems

For the exterior side of buildings, this technology normally can range from simple or patterned designs of concrete structures/sustainable wood, aluminum, or stainless steel placed to the external side of windows or the overall façade of the building. These designs often described as *brise-soliel* can extend horizontally/vertically or at different angles over the external building so as to get perfect shade conditions. This in turn lowers the amount of solar radiation entering the building hence reducing overheating caused by the reflecting light. The technology is mainly placed on the outside façade of buildings, the façade being the point where the indoors and the outdoors of buildings generally meet.

They perform better than internal solar-shading systems for they limit the unwanted solar radiation to reach the indoor living spaces, unlike the internal solar-shading systems which can enable leaks of unwanted solar radiation making the users have uncomfortable living spaces, hence external solar-shading systems are most preferred.

Horizontal devices

These are devices placed to the exterior of building spaces and often run horizontally. They offer not only shade to the interior building spaces during hot summer months, but also they permit enough solar radiation to pass through to the interior in the winter, to help warm a building. They are preferred when dealing with North facing buildings. With reference to Fig. 3, it can be seen that the devices can be either permanent or temporary based on the structure of the buildings and also the different user's needs of the occupants of the building spaces. They can be made of different materials depending on the user and specifications.

Fig. 3: Horizontal solar-shading systems (Nagy et al., 2016)

Vertical devices

They compose of vertical devices placed to the external side of building spaces running vertically (as shown in Fig. 4). The devices can be either permanent or temporary based on the structure of the buildings and also in accordance with the various user's needs of different occupants of the building spaces. Primarily useful for east and west-facing buildings for they to improve the thermal insulation by ensuring that there are a slow heat loss and fast heat gain in the winter months by providing a barrier in between the indoor spaces and the exterior of the building.

Fig. 4: Vertical solar-shading systems (Fayek, 2017)

Egg-crate devices

These devices consist of a mixture of vertical and horizontal shading elements. The use of the egg-crate devices increases annual performance, improves the amount of natural lighting, reduces window solar incident radiation, and reduces the consumption of artificial lighting. However, its efficiency is heavily affected by user behaviors in relation to ambient systems, as users specifically control the level of blind angles and the activation of the lighting system. Fig. 5 shows egg-crate solar-shading systems.

Fig. 5: Egg-crate solar-shading systems (Nagy et al., 2016)

3. Solar-Shading system designs and user satisfaction in public buildings

3.1. Relationship between solar-shading systems and user satisfaction

Users in public buildings get Satisfaction from the use of Solar-Shading Systems if the said systems have met their set out requirements. These requirements can be classified as the users' need for the different Solar-Shading Systems. In relation to the study, the various user needs that the occupants of these public buildings have when using the Solar-Shading Systems include: having thermally habitable and comfortable working spaces; Daylight penetration and glare reduction; having a more appealing and aesthetic surrounding; having privacy. Kuhn et al. (2001) and Wilkinson et al. (2011) both supported the fact that different Solar-Shading Systems may meet the different requirements of various users. Therefore, for a user to be satisfied by the use of the different Solar-Shading Systems, it is a requirement that his/her needs be met fully and to his/her contentment. Table 2 shows a summary of different user needs for Solar-Shading Systems by Users in Public Buildings.

Table 2: Summary of the user's needs for solar-shading systems by users in public buildings

User's Need	Explanation
Thermally Comfortable and Habitable spaces	Having Cool enough Spaces having room temperature in the Summer and Warm enough Spaces in the Winter Months.
Energy Saving	Cooling and Heating the Indoor spaces without the need for Auxiliary Power Hungry Sources.
Daylight Penetration	Having enough Sunlight Penetrating for Illumination.
Reduced Glare from windows	Reduced Difficulty in Seeing Due to the Reflection or Direct Sun-rays.

3.2. Solar-shading designs principle in public buildings

Different buildings can employ the use of different Solar-Shading designs. The Solar-Shading designs in public buildings are not typical in the sense that they do not have to follow any requirements strictly for they are dependent on the design team and the architects who come up with Solar-Shading designs that will greatly impact and satisfy the users by meeting their needs. There are certain aspects that influence the selection of various designs all with the aim of meeting the user's needs for the different Solar-Shading Systems. The principles that influence the Solar-Shading Systems design selection include; the position the Solar-Shading is placed, the type of Solar-Shading selected, the position of the building in relation to the sun, the provision of adjustability, and the material used for Solar Shading.

3.2.1. Position placed

A Solar-Shading design can be intensively being influenced by the position where the Solar-Shading System is being placed. There are External Solar-Shading Systems that are placed on the exterior of the buildings and also Internal Solar-Shading Systems which are placed in the interior of buildings. A Designer can select which design to opt for, either a system that will be put externally or internally all with the common purpose of meeting the different needs and requirements of the users. External Solar-Shading Systems are at times mostly preferred due to the fact that they have better functionality compared to internal Solar-Shading Systems

3.2.2. Type of solar-shading selected

The kind of Solar-Shading selected from the array of the different internal and external Solar-Shading Systems also helps constitute the overall design of the Solar-Shading placed. This is dependent on the different user needs, for different Solar-Shading types serve different functions. For that reason, designers understanding the different needs of the users can help them select the best Solar-Shading type that would constitute the overall Solar-Shading design to be placed and also one which would considerably serve to satisfy the user's needs in a more excellent manner. The type of Solar-Shading selected will inherently form part of the Solar-Shading design.

3.2.3. Position of the building in relation to the sun

When the building is facing north, the most effective Solar-Shading Systems are the ones that are external, fixed, and horizontal Solar-shades and this is because of the sun's high position. The solar shades are fixed at an angle of 45° from the window sill to the underside of the Sun-Shading system. The space in between gives a good balance between solar gains in the winter and Solar-shading in the winter. When the building is facing East or West, it may experience low solar radiation exposure because the sun angles are below 60°. Because of the low sun angles, fixed and horizontal Solar-shades are ineffective, the adjustable Solar-Shading Systems are highly recommended either vertical or horizontal. This setting allows the users of the buildings to adjust themselves to the various settings that they would prefer. When the building is facing south, there is no need for Solar-Shading Systems for the buildings are usually hit by low sunlight which normally happens in the mornings and evenings. But in case of overheating a flexible adjustable Solar-shade may be placed to provide for extra Solar-shading (SDAPP, 2015).

3.2.4. Provision for adjustability

Different users have different needs that they want when using different Solar-Shading Systems, hence the need for different provisions for the users to adjust the Solar-Shading Systems to match their needs. However, in buildings where there is a large number of people accessing, it is preferred to opt for fixed Solar-Shading Systems to equally serve the needs of the users accessing the building. There is an option of utilizing fixed or adjustable Solar-Shading Systems, However, most internal Solar-Shading Systems are adjustable since they are on the inside of the building hence easily changeable, unlike ones that are external which would be cumbersome to adjust. The adjustability of the different systems is dependent on the needs of the users.

3.2.5. Material used for solar-shading

The materials selected for the different Solar-Shading Systems are also constituents of the overall design. Different materials offer different variations in the functionality of the various Solar-Shading Systems. Having durable systems made of materials like concrete or ceramic, which will serve for a prolonged time, serves a greater purpose compared to systems made of materials like timber or textile which require maintenance over time. Different materials can also be used to improve the aesthetics of the building. Hence selecting a design that incorporates materials that better serve the user's needs would play a huge role in meeting and satisfying the overall requirements of the users.

3.3. Factors influencing user's satisfaction from the use of different solar-shading systems

Different building occupants have distinctive user's needs that they require met when using various types of solar-shading systems. These needs vary in between different users from place to place, because it is in human nature for human beings to have different needs that they want to be fulfilled. In relation to solar-shading systems, each different solar-shading system serves different purposes all in accordance with the specific wants or needs each building occupant has. The factors that influence the different selection of the various solar-shading systems can therefore be directly tied to the different user needs the different building occupants to require. The factors include;

3.3.1. Thermal functionality

According to Salihoğlu (2019), thermal comfort is a design function that ensures that the thermal temperatures of the people, animals, and even machines used inside the building are within the recommended normal values. The main purpose of a solar-shading system is one that provides a habitable and comfortable thermal comfort to the occupants of the buildings. It should be one that should shade enough solar radiation in the summer while still permitting enough daylighting inside and also be effective in the winter to allow maximum solar radiation to penetrate inside to heat the indoors without the need for secondary heating.

Indoor solar radiation penetration can be favorable and pleasant, or at the same time extremely unfavorable, depending on weather, season, building function, and user behavior. This involves the use of sun-shading devices to control the amount of solar radiation reaching the interior of buildings. External sun-shading systems are a more conservative approach to design and are most widely used to control the rise in solar heat in buildings and to affect energy efficiency. Solar heat can be reduced more efficiently than indoor equipment such as air conditioners, ventilators, and other cooling systems (Olgyay and Olgyay, 1957). The efficiency of external shading depends on the proper selection of the devices in accordance with the different user's requirements.

According to Tavares and Silva (2008); he suggests that thermal functionality is a huge requirement that needs to be addressed if the user's needs in regards to the use of solar shading systems are to be met. With the thermal comfort of the users being a paramount need that needs to be met, the application and use of solar-shading systems cannot be understated. They work all with a common goal of keeping the indoor living conditions habitable and comfortable, so the users have the option of selecting which solar-shading system works optimally in accordance with their different needs and requirements.

3.3.2. Daylighting

Daylighting in consonance with Ander (2003) is the guided admission into a building of natural light, direct sunlight, and diffused-skylight to minimize electric lighting and conserve electricity. This system has the capacity to minimize electric lighting power when sufficient ambient lighting is provided from daylight alone. Alternatively, appropriate glare remediation Solar-shading systems such as blinds or shades must be made available and chosen to prevent direct sun penetration on work surfaces or in the eyes of the occupants (Corona and Lemos, 1987). Faisal and Aldy (2016) in the article on the "Typology of building shading elements on Jalan Sudirman corridor" in Pekanbaru; Suggested that sunlight assists us with illumination indoors without the use of other lighting sources. Furthermore; Kuhn et al. (2001) supported the fact that a good Solar-Shading System allows enough natural light during the day so as to enable visibility.

The User's need of having enough daylight penetrating inside the building is essential to be met and this is done by selecting a Solar-Shading System that also permits enough sunshine inside to the interior of the building, while also limiting the glare to the occupants' eyes.

3.3.3. Solar-shading materials

SDAPP (2015) suggested that the materials used to design the Solar-Shading Systems also matter with their effectiveness, Solar-shades made out of fabric are exposed to wear and tear compared to the ones made of concrete fins which can stand harsh environmental conditions. The materials should also be cost-efficient so that the users can be able to get maximum value for their money.

3.3.4. Statutory requirements

Different countries and regions are governed by different statutory laws; these laws govern how different structures would be undertaken. These Laws are basically put into consideration due to the government's understanding of the region and also the different needs and requirements users have when using different Solar-Shading Systems. Hence a good Solar-Shading System is one that meets all the statutory regulations set aside in the region while also meeting its functionality and achieving the needs required of them by different Users.

3.4. Analysing how different designs of solar-shading systems in public buildings increase the user's satisfaction

Designers and Architects, when selecting which design to input in the buildings, usually have the needs of the users in mind this is because different designs serve different roles and functions. While some systems serve the same function, it goes down to which Solar-Shading System offers the best functionality and this calls for the need for the design team to effectively and properly understand how the various designs have a corresponding effect on the meeting and satisfaction of the needs of the users.

Having an understanding of the various principles that play part in the composition of the overall design is much needed if the designers want to satisfy the user's requirements when using these Solar-Shading Systems. The principles that influence the Solar-Shading Systems design selection include; the position the Solar-Shading is placed, the type of Solar-Shading selected, the provision of adjustability, and the material used for Solar Shading. The combination of these principles altogether constitutes the overall design. The satisfaction of the users is met once these designs meet their laid out purposes be it, thermal functionality, daylighting, glare reduction, improving aesthetics, energy efficiency, or helping to maintain privacy. The meeting of the needs and requirements users have from using these Solar-Shading Systems generally leads to more satisfied users.

There are different types of designs based customarily on the various principles that compute the overall design. The designs can basically be of the same structure but vary in the type of material used or place placed. This goes to show that there is no definite selection or finite choice of a Solar-Shading System Design, it is all dependent on the different needs the users have and the ingenuity the designers and architects have in wanting to realize and achieve those needs. Table 3 shows a basic analysis of some types of Solar-Shading Systems designs and how they meet the user's requirements generally.

Table 3: Analysis of various solar-shading designs and their effect on the overall user satisfaction

Solar-Shading Design	Description	Analysis of its effect
No External Shading System	Completely dependent on the thermal efficiency of windows and glazing systems to minimize heat transfer, which is typically the most vulnerable location in buildings. Within, blinds and other internal shading devices will be minimally effective.	• Not effective • Good during winter, for it allows total heat penetration. • Worst during summer. • Not Efficient due to the fact those building components themselves do not have solar-shading capabilities.
Integrated or 'built in' Solar-Shading	Solar shading is typically constructed within the structure of a building, such as an eave, overhang, or balcony, and cannot be easily changed and is considered to be part of the overall design of the building.	• For North facing buildings; Ideal if built with the 45 percent rule. • For buildings facing East / West: will have some effect but will not be sufficient. • Moderately to very effective in thermal functionality.
Fixed Horizontal Systems	Usually, this solar shading system is mounted to the building's facade above the glazing. It is made of wood, aluminum, or other material slabs carefully placed around the glazing in selected spaces and added to the façade.	• Ideal for North Facing Buildings. • Can prevent overlooking. • Will reduce daylight penetration. • It Will have some impact on East/West faced Buildings but is not sufficient, extra internal shades will be recommended.
Fixed vertical Systems	Vertical elements cover the glazing, which is mounted on the facade of the house. Usually, these elements provide shade in one direction and block much of the western sun. Spacing and angles are also significant because if the sun is parallel to the angle of the solar-shading system, the shading would be at least equal to the angle of the solar-shading system.	• Slightly efficient for buildings facing north, since the glazing would not be obscured at optimal times. Sun hits the window at noon, which is good in winter but unwelcome in summer. • Can prevent overlooking. • Lowers light penetration • Very Effective for East/West faced buildings.
Adjustable vertical Systems	Adjustable vertical parts, such as sliding laths or rotating fins, are usually made of wood, aluminum, or shading fabric and are either integrated into the fabric or attached to the exterior façade. This can be done either manually or automatically.	• Quite reliable for buildings facing North, East or West, if they are adapted to the movement of the light. • Can prevent overlooking. • Effective in Low-Rise Buildings.
Fixed Egg-Crate Systems	Consists of a mixture of vertical and horizontal shading components to form what resembles a box-like configuration. Horizontal elements control the glare of the ground from the reflected solar rays and work well when inserted on the outer walls.	• Very Efficient for North, East or West faced Buildings for it shades the building from all angles. • Glare reduction from the Horizontal elements. • Very Effective in High Rise Buildings

4. Britam Towers

One of the tallest buildings in Kenya; Britam Towers, a commercial building which is owned by the British American Investments Company (Britam) has taken up the talk of the town due to its cutting-edge designs and sustainability. The building with a floor area of 31,500m^2 is aligned to the north-east and can be located using the 1°18'00.6"S 36°48'47.5"E GPS coordinates. This shows that the building lies almost close to the equator which favors more of a tropical climate. The building receives almost an average of 12 hours of daily sunlight all year round. Fig. 6 shows a map View of the Britam Towers.

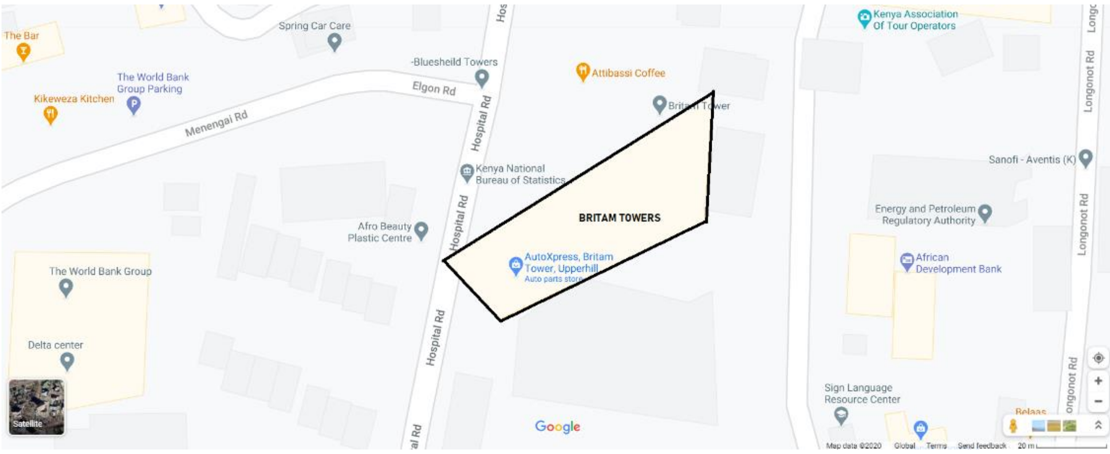

Fig. 6: Map view of the Britam Towers

The building designed by GAPP Architects and Triad Architects stands 656ft tall and has 32 floors above the ground. Its compelling shape; a prismatic 3D geometrical shape with fascinating façade covered with Egg-Crate shaped ceramic rods Solar-shades all around up to the top of the building giving it a very majestic aesthetic feel. These Solar-Shading Systems enable the offices of the building to be properly ventilated while also performing its main core purpose which is thermal control and daylighting. The Egg-Crate shaped ceramic rods Solar-shades are placed on top of the glass façade on the external side of the building. These Egg-Crate ceramic rods are fixed and permanent and serve the role of cooling the building all year round by permitting the required amount of solar radiation through. The ceramic rods are a new invention to the Solar-Shading Systems which have through time used concrete fins for the Solar-shades. The ceramic rods are cheaper and easy to install and are more favorable for installations in tropic regions (CTBUH, 2018).

Britam Towers being a commercial Building hosts different companies which call the building its residents. With the large number of users occupying the building, their different user needs in relation to Sun-shading Systems will for sure vary. However, even with a large number of people accessing the building on a daily basis, there are basic user needs from the use of Solar-Shading Systems which are common all through. Functions like Thermal Comfort, Daylighting, and glare reduction are some of the User's Needs that can be found to be common all through. To be Specific with Britam Towers, the User's Needs for Solar-Shading Systems can be classified as in Table 4.

Table 4: User's needs for solar-shading systems by users in Britam Towers

USER'S NEED	EXPLANATION
Thermally Comfortable and Habitable spaces	With Kenya being a Tropical Climate, which means it receives Equal Temperatures and Solar Radiation all year round, brings with it the Need to ensure the Working-Spaces meet the required room temperature of 25°C which is Thermally Cool enough all through the Year to give good Working Conditions.
Daylight Penetration	There is a Need to having enough Sunlight Penetrating to the Indoor Working-Spaces for Illumination. This is because this is a Commercial Building the required lux values of 500 lux are needed for enough Illumination helps users be more satisfied when performing their functions.
Energy Saving	Due to having Equal temperatures all Year round having a System that ensures the indoor temperatures stay at the required comfortable room temperature of 25°C and enough Natural Light penetration to the Indoor Working-Spaces without the need for Auxiliary Power Hungry Sources is much needed.
Reduced Glare from windows	Reflected or Direct Sun-Rays can be really disturbing to the eyes for they pose a difficulty when seeing. Having a system that ensures there is reduced Difficulty in Seeing Due to the Reflection or Direct Sun-rays.
Aesthetics	Having an overall Appealing Outlook is one Need that for sure most Users Need. With Britam Towers being a Commercial Building, having more Appealing Looks helps it stand out from other different Buildings.

4.1. Fixed external egg-crate solar-shading systems made of terracotta ceramic rods

For the Solar-Shading System Design, Britam Towers Opted for the use of permanent fixed Egg-Crate External type of Solar Shading Systems. The option of using External Solar-Shading Systems was due to the fact that they perform better at thermal functionality than Internal Solar-Shading Systems. The fact that Britam Towers is aligned to the north, the most preferred Solar-Shading System that would be reliable all year round is the Egg-Crate Shading device. The use of the egg-crate devices increases annual performance, improves the amount of natural lighting, reduces window solar incident radiation, and reduces the consumption of artificial lighting. This is because Kenya and Nairobi City to be specific are located in the tropics and this means that there is an average warm climate all year through. With this the Egg-Crate External Solar-Shading Systems design would be the best design to be employed for it will ensure the required temperature of 25°C is obtained all year round by permitting just the required solar radiation inside the building all year round.

The option of using a permanent and fixed Solar-Shading System design is due to the fact that the building is located in a warm tropical climate all year round and hence there is no need for adjustability of the Solar-Shading System for the temperature will be constant all year round. Also, the option of using Fixed Solar shading design is because of the fact that the building is a commercial building, each individual cannot adjust in accordance to his/her needs but having a uniform fixed design that meets the overall average user needs for the users is appreciated. The preference of using the egg-crate design for Solar-Shading is because of its function ability. Egg-Crate Solar-Shading Systems usually have high shading efficiencies for they are box-like with a combination of both the vertical and horizontal Solar-Shading Systems which often harbor the unwanted Solar Radiation from penetrating to the inside, making the interior working spaces habitable and comfortable. They also allow the required lux value for daylight which is 500 lux for commercial buildings while limiting glare which comes from direct sun-rays. The Horizontal Elements of the Egg-Crate Solar-Shading Systems help reduce the glare from the direct sunshine rays.

The alternative of opting for the use of Terracotta Ceramic Rods designs for the Egg-Crate Solar-Shading Systems provides a more durable and distinct factor. Using a more durable material that is easily maintainable ensures the longevity of use. The Terracotta Ceramic Rods also improve the overall aesthetic appearance and feel of the building. Fig. 7 shows Britam Towers, exterior with fixed egg-crate Solar-shading system design made of terracotta ceramic rods.

Fig. 7: Britam Towers, exterior with fixed egg-crate solar-shading system design made of Terracotta Ceramic Rods (PamGolding, 2018)

4.2. Use of adjustable horizontal Venetian blinds for interior solar-shading made in a metallic-like fabric

Horizontal Venetian Blinds are a type of Solar-Shading Systems that are placed to the interior of Building Spaces to provide Solar-Shading, glare reduction, privacy and also improve the aesthetics of the building space by itself (As shown in Fig. 8). Britam Towers to be specific opted to employ the use of Adjustable Horizontal Venetian Blinds for indoor spaces. With spaces like offices, Board rooms, and common rooms, comes the need for Solar-Shading Systems. The option of using adjustable blinds is due to the fact that these spaces even though the building is commercial, are more personal, where the users have their own needs when using their spaces. The blinds offer privacy, Solar-Shading, and also glare reduction to the users. The option to use the metallic-like fabric is because of the durability it possesses for the system is in use actually most of the time being drawn up and down, hence a more durable and versatile material comes in very handy.

Fig. 8: Britam Towers interior, showing the horizontal Venetian blinds, Nairobi, Kenya (Welch, 2018)

4.3. Tinted blue glass for the exterior windows on the façade

Britam Towers opted for a variation from the regular norm of clear glazed windows. The choice of using tinted blue glass as a Solar-Shading design offers advantages even from its use (As shown in Fig. 9). It serves the purpose of glare reduction caused by direct or reflected sun-rays which can be harmful to the human eye. The required lux value of 500 lux for commercial buildings is met for although tinted, they allow in the required natural light inside. Opting to use this design also helps improve the overall aesthetics of the building, leaving the users even more satisfied with the appealing looks.

Fig. 9: Britam Towers outside façade, showing solar-shading system and tinted blue glass, Nairobi, Kenya (Welch, 2018)

Britam Towers, to satisfy the needs of its users, different provisions were put into place so as to ensure the different requirements from the different users are met. These provisions for the various user's needs include the following items.

4.4. Provisions for thermal comfort

With Kenya being a Tropical Climate, which means it receives Equal Temperatures and Solar

Radiation all year round, brings with it the Need to ensure the Working-Spaces are thermally cool enough to meet the required room temperature of 25°C all through the Year without need for auxiliary power sources. A proper working environment that is cool enough all through leads to more satisfied users. Britam Towers has put in place the following provisions for thermal comfort.

- Use of Fixed External Egg-Crate Solar-Shading Systems for North Facing Buildings to help cut direct solar radiation hence reducing the building's solar load and radiation, therefore, making the indoor working-spaces thermally comfortable and habitable(As shown in Figs. 7 and 10).
- Application of Internal Horizontal Venetian Blinds to offer Solar-Shading. (As shown in Fig. 8)
- Placement of activities governed by the solar path allowing for the sheltering of thermally sensitive spaces.

Fig. 11 shows Britam Towers interior, showing the entrance well-lit hallways, Nairobi, Kenya.

Fig. 10: Britam Towers, exterior with fixed egg-crate solar-shading system design made of terracotta ceramic rods (PamGolding, 2018)

4.5. Provisions for day-lighting and glare reduction

There is a Need to having enough Sunlight Penetrating to the Indoor Working-Spaces for Illumination. This is because this is a Commercial Building that needs to meet the required 500 lux value hence enough Illumination helps users be more satisfied when performing their functions (As shown in Fig. 8). It is also important to understand that Reflected or Direct Sun-Rays can be really disturbing to the eyes for they pose a difficulty when seeing. Having a system that ensures there is reduced Difficulty in Seeing Due to the Reflection or Direct Sun-rays is highly beneficial to the users, the provisions include:

- Full height Tinted Blue Glass glazing allowing for maximum day-lighting. Reflective Tinted Blue Glass glazing on the facade windows to provide glare reduction to the interior working-spaces.
- Placement of activities in relation to the amount of day-lighting within the building with activities that require more daylight-like boardrooms and offices closer to the windows and those that don't require that much daylighting like toilets and common areas farther away.
- Also, the Horizontal Elements of the Egg-Crate Solar-Shading Systems help reduce the glare from the direct sunshine rays.

4.6. Provisions for energy saving

Due to the location of the building in a warm tropical climate region and having average equal temperatures all year-round, having a System that Cools and Lights the Indoor Working-Spaces without the need for Auxiliary Power Hungry Sources is much needed. The provisions to reduce and save energy in Britam Towers include:

- Use of Fixed External Egg-Crate, Horizontal Venetian Blinds Solar-Shading Systems as seen in Fig. 7 and Fig. 10 to help cool the interior working spaces without the need for auxiliary cooling sources.
- Tinted Blue Glass as seen in Fig. 9 that enables enough daylighting hence no need for additional lighting sources.

Below are extra additional Pictures of Britam Towers; Upperhill, Nairobi Kenya. Fig. 12 shows Britam Towers, Façade construction, Nairobi, Kenya, and Fig. 13 shows Britam Towers, outside façade outlook, Nairobi, Kenya (Welch, 2018).

Fig. 11: Britam Towers interior, showing the entrance well-lit hallways, Nairobi, Kenya (Welch, 2018)

Fig. 12: Britam Towers, Façade construction, Nairobi, Kenya (Welch, 2018)

5. Results, conclusion, and recommendations

5.1. Summary of the findings

Different users in public buildings have different needs and this is evident even with the need for various Solar-Shading Systems. The diverse needs and requirements users have for the various Solar-Shading Systems include; thermal comfort, energy-saving, daylight and glare reduction, improving aesthetics, and also habiting a sense of privacy. This supports Wilkinson et al. (2011) idea that there are different factors that affect the User's Satisfaction in buildings. A Solar-Shading design basically comprises the combination of different components which altogether form a Solar-Shading System structure which can be of great effect to meeting the needs of the users. They are guided by various design principles which include; the position the Solar-Shading is placed, the type of Solar-Shading selected, the position of the building in relation to the sun, the provision of adjustability, and the material used for Solar Shading. The combination of these principles altogether forms the overall design.

Fig. 13: Britam Towers, outside façade outlook, Nairobi, Kenya (Welch, 2018)

In regards to the Case Study of Britam Towers, which is located in Nairobi, Kenya which is directly in the tropics, supported the idea by Kuhn et al. (2001) that Egg-Crate Solar-Systems offer better functionality when meeting the needs of the users. With the Use of; Fixed External Egg-Crate Solar-Shading Systems made of Terracotta Ceramic Rods, Adjustable Horizontal Venetian Blinds for Interior Solar-Shading made in a metallic-like fabric and Tinted Blue Glass for the exterior windows on the Façade has played a direct role in meeting the user's requirements for the use of Solar-Shading Systems in Britam Towers. The understanding of the various principles behind the designing of Solar-Shading Systems, helps designers come up with various design types like incorporating the building structure's components like overhangs and balconies for Solar-Shading, having different designs like Fixed vertical/horizontal systems or adjustable systems. The Case Study also found out that for more commercial buildings, the user requirements are done in a more collective way for it will be difficult to meet each individual user's requirement. This can be seen by the Fixed External Egg-Crate Solar-Shading Devices and tinted glasses to meet the overall needs of all the users. Therefore, the designers and architects should work around the common User's needs to come up with a design that basically serves all the users better. This goes to show that there is no definite selection or finite choice of a Solar-Shading System Design, it is all dependent on the different needs the users have and the ingenuity the designers and architects have in wanting to realize and achieve those needs.

5.2. Conclusion

With the understanding of the needs users have for the various Solar-Shading Systems, Designers and Architects can effectively map out designs that would properly serve and satisfy their needs better. These designs can vary from building to building but the main fact to observe is the issue of functionality, for the Solar-Shading Systems should be able to meet the needs of the users effectively. For example; Designers and Architects of public buildings can opt to choose fixed egg-crate Solar-Shading Systems Designs for buildings facing either North, East, or West for such a design works very well with any building for Solar radiation is shaded from all sides. Horizontal components directly track the glare of the ground from reflected solar rays, making users more comfortable and relaxed. These Egg-Crate Solar-Shading Systems are most effective and efficient for High Rise Buildings and although they will work optimally in Low Rise Buildings, Adjustable Solar-Shading System Designs which can be adjusted either automatically or manually to the user's needs are more preferable.

5.3. Recommendations

The understanding of the different needs and requirements of the users must be taken more keenly for different designers and architects to design solar-shading systems without even taking keen consideration for the needs users have of those systems making them ineffective. There is also a need for awareness of the various solar shading systems and how they affect different ecosystems. This will help users and also designers are more cognizant and apprehensive of the major role Solar-Shading Systems play in the day-to-day way of life.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Ander DG (2003). Daylighting performance and design. John Wiley and Sons, Hoboken, USA.

Corona Y (1976). Man, climate and architecture. Applied Science Publishers, London, UK.

CTBUH (2018). CTBUH year in review: Tall trends of 2018. Council on Tall Buildings and Urban Habitat, Chicago, USA.

Faisal G and Aldy P (2016). Typology of building shading elements on Jalan Sudirman corridor in Pekanbaru. In the IOP Conference Series: Materials Science and Engineering: International Conference on Innovation in Engineering and

Vocational Education, Bandung, Indonesia, 128: 1-9. https://doi.org/10.1088/1757-899X/128/1/012029

Fayek G (2017). Solar shading louvre systems. Colt Group, Waterlooville, USA.

Grynning S, Lolli N, Wågø SI, and Risholt BD (2017). Solar shading in low energy office buildings-design strategy and user perception. Journal of Daylighting, 4: 1-14. https://doi.org/10.15627/jd.2017.1

Kuhn TE, Bühler C, and Platzer WJ (2001). Evaluation of overheating protection with sun-shading systems. Solar Energy, 69: 59-74. https://doi.org/10.1016/S0038-092X(01)00017-2

Mygov.scot (2020). User needs. Available online at: https://resources.mygov.scot/content-standards/content-delivery/content-discovery/user-needs/

Nagy Z, Svetozarevic B, Jayathissa P, Begle M, Hofer J, Lydon G, and Schlueter A (2016). The adaptive solar facade: From concept to prototypes. Frontiers of Architectural Research, 5(2): 143-156. https://doi.org/10.1016/j.foar.2016.03.002

Olgoy V and Olgoy A (1957). Solar radiation and shading devices. Princeton University Press, Princeton, USA.

PamGolding (2018). Britam Towers brochure. Available online at: https://www.pamgolding.co.za/Uploads/developments/5d323739-8140-4db8-9f05-b3e32e592db5/Brochure/britam-towers-brochure.pdf

Requena I (2012). Modern architecture as environmental construction: Methods and prototypes in le Corbusier's work. In the 2nd Congrès International Sur Les Ambiances, Montreal, Canada: 525-530.

Salihoğlu T (2019). Importance of porch in Mediterranean architecture. European Journal of Sustainable Development, 8(4): 204-213. https://doi.org/10.14207/ejsd.2019.v8n4p204

SDAPP (2015). Sunshading: Building design for a sustainable future. Sustainable Design Assessment in Planning Process, Yarra, Australia.

Tavares SG and Silva HC (2008). Brazilian solar architecture: An analysis of Mesp daylighting system. In the International Solar Energy Society World Congress, 1-5: 476-480. https://doi.org/10.1007/978-3-540-75997-3_85

Welch A (2018). Emporis skyscraper award. Available online at: https://www.e-architect.com/awards/emporis-skyscraper-award-2018

Wilkinson SJ, Reed R, and Jailani J (2011). User satisfaction in sustainable office buildings: A preliminary study. In the 17th Pacific Rim Real Estate Society Annual Conference, Pacific Rim Real Estate Society, Gold Coast, Australia.

Zulkifli MAR (2011). Shading device as strategies achieving thermal comfort for office building in tropics. M.Sc. Thesis, Universiti Teknologi Malaysia, Skudai, Malaysia.