Evaluation of Climate Responsive Hotels Design: A Case Study of Jos, Plateau State, Nigeria

Albert James Onumanyi & Isa Bala Muhammad
Department of Architecture, School of Environmental Technology, Federal University of Technology, Minna.
Corresponding Author: onumanyialbert@gmail.com

ABSTRACT

In a world faced with environmental challenges, there is an immense requirement for dynamic building envelopes that responds to climatic changes. Responsive buildings comprise of building envelope that adjust to changing climatic conditions. As climatic conditions changes, buildings are affected especially in cases of flooding and extreme heat waves impacting on the comfort of inhabitants and the building efficiency. These are ensured by their rigidity and lack of responsiveness to extreme weather conditions. Jos – Plateau being a region with ~~unstable~~ wide range of climatic conditions, was selected as the study area of which Hotel buildings within this region were examined. Three hotels were selected and modelled together with the climatic conditions of the study area. The models were subjected to computer simulation using Autodesk Ecotect Analysis design simulator and Sketchup Pro modelling software, to ascertain the level of responsiveness to climatic changes. The results showed that most hotel buildings in Jos Plateau State are not climate responsive. The study therefore came up with a hotel design model that is climate responsive to tropical climate. Most importantly is that the new design model could be used for the design of hotels in environments with similar climatic conditions. Furthermore, the research recommended that there is need for adoption of responsive strategies in the design of Hotel buildings that are adaptable to change in climatic conditions.

Keywords: Climate change, Computer Simulators, Hotels, Responsive Buildings.

1.0 INTRODUCTION

Environmental conditions have been a major challenge to buildings ought to the fact that buildings are static edifies, are such there is an immense need to approach design of buildings from a dynamic envelope that respond to dynamic climatic changes in a unique way. This approach will provide the best comfort for occupants and the general indoor environmental quality at the same time providing functionality of the building (Attia, 2017). A responsive building comprises of building envelopes that adjust to changing climatic conditions on an hourly, daily, seasonal, or annual basis. The word "responsive" used here, implies the capacity to react or profit from outside climatic condition to enhance the productivity and functionality of human activities and comfort. (Eleonora, Marco, & Francesco, 2013)

The impacts of climate change pose a significant challenge to existing built infrastructure. Most of the buildings as well as components of energy where not designed to withstand the impending range of climatic conditions and increased frequency of extreme weather events (Cutter, 2014).

Built areas exert significant influence on their local climatic and environment, the impact is faced by the urban population resulting from weather related risks such as heat waves and wind pressure (Ezeabasili & Okonkwo, 2013). Nature itself is a good role model to learn from and over the years' designers have sort to understand and study nature. This responsive building skin solution combines the technological tools to mimic nature in adapting and responding to the environment. Fig 1 and fig 2 shows the architecture has learnt from nature in adapting kinematic movements. Plants have a movement mechanism that folds when the humidity is cold and opens when the humidity becomes hots, buildings have adopted this principle and came up with an intelligent origami module that folds when the humidity is cold and opens when the humidity is hot.

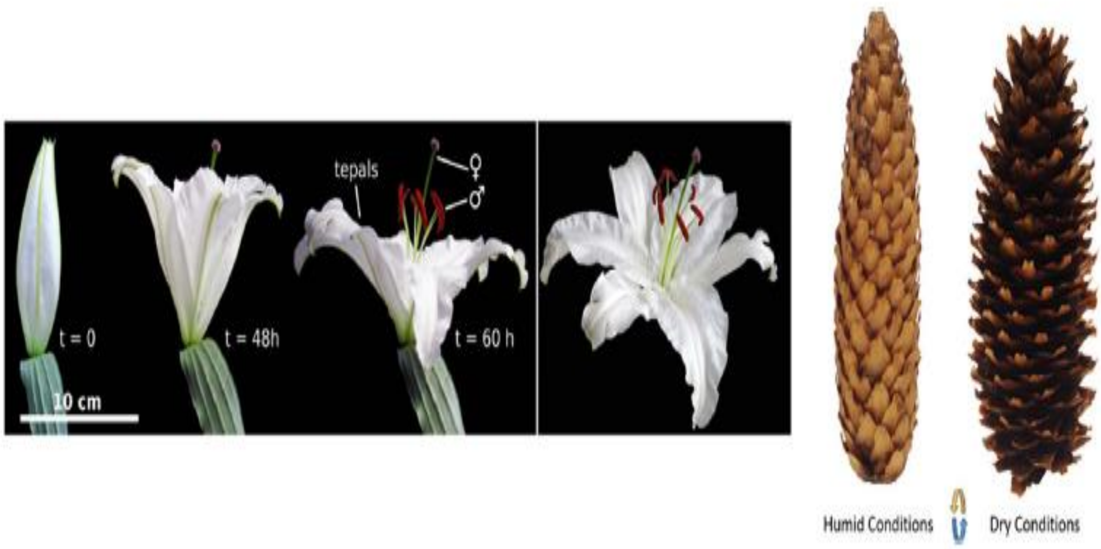

Fig 1.1 Dynamic movements of plants based on response to changing climate. (Tabadkani, Banihashemi, & Hosseini, 2018)

Fig 1.2 Intelligent folding shading façade systems that respond to climate changes. (Elghazi & Mahmoud, 2016)

2.0 Simulation of Climatic modulation of buildings

Climatic modulation can be referred to the unstable dynamic characteristic of climatic changes. Climatic conditions are natural phenomenon that occurs, however the fluctuations in climatic condition has become too frequent and unstable in recent times, in Jos (Ezeabasili & Okonkwo, 2013). This can be attributed to the depletion of the ozone layer caused by green house energy emission from various human activities climate change occurs as a result of natural and anthropogenic causes. The mission of greenhouse gases, of which carbon dioxide is one of the major gases are being emitted into the environment leading to reactions and changes in climate (Dar, et al., 2018). As such with the advance of computer simulation climatic data can imputed into Ecotect software to give detail analysis on how the climate affects and impacts on the building. Ecotect simulation software has the option of subjecting a simulated model to green building studio analysis group, where the model can be rated based on the values obtain from Ecotect.

2.1 Biomimetic as a response to dynamic climatic conditions

Nature has effectively over time solve many issues of mechanical and structural problems without creating residual and active wastes (Royall, 2010). However, mimicking nature involves an in-depth understanding of the difference between biology and technical systems. Nature has developed optimum strategies to project itself from against changing environment conditions. Natural systems are iterative feedback loops of constant processes, like, thermodynamics, acoustics and optics which can be described as self-organisation (Kibert, Sendzimir, & Guy, 2002). For adaptive systems self-organisation is one of the main dynamic and adaptive processes. According to Hensel (2006), it is a process where the interval organisation of a particular system adapts to the environment to develop a particular function without being directly managed.

In biology, many studies described the adaptation process in natural systems of their internal organization by understanding the function of organism in eco-system. For a system to adapt to change, nature uses an insurance effect that creates some level of redundancy that allows adaptation to changing condition at various rates. They present two evolutionary patterns that are dissimilar, biological system have evolved over time and still are, where as technical systems developed based on human designs to perform specific functions (Cohen, Reich, & Greenberg, 2015). Design from nature can be understood in various contexts, as biomimicry, bionic, bio-design, biomimetic, biomorphic, bio-utilisation, bio-derivation and bio-philia. Benyus, (2002) stated that understand nature as a mentor, model and measure is critical to applicability of biomimicry. Pawlyn (2011) explored notions from nature, while, Gamage & Hyde (2012) investigated and explored biomimicry based on ecosystem interaction.

Biomimicry involves three stages: the form, the process and ecosystem. Benyus (2002) describes this stage as to copy the attributes of a particular organism, which includes appearance, visual shapes, materials, components and morphological features. This can be summarised as simply the duplication of the organism. The second stage seeks to mimic the biological procedure of the medium and its natural processes. The third stage requires duplicating the form and processes of the ecosystem. Mazzoleni & Price (2013) gives a unified description as an analogy and execution on diverse stages of an organisms, appearance, behaviour and ecosystem. In engineering bio-mimetic works as a tool to solving problems found as the level of conceptualization of design. (Reap, Baumeister, & Bras, 2005); (Alexandridis, Tzetzis, & Kyratsis, 2016). Biomimetic architecture intends to remedy errors that exist in the design of efficient systems (EL-Mahdy, 2017)

3.0 Methodology

This study evaluates three simulated Hotel models in tropical climate with their climate modulation using Autodesk Ecotect Analysis design simulator and Sketchup Pro modelling software. The analysis considered heat waves, wind pressure and rainfall modulation on the building and evaluated other climatological factors that affect the buildings responsiveness. The report shows a developing innovative approach for simulation analysis of daylighting, visual comfort through a sun responsive shading system. The goal focuses on estimating an annual daylight metrics and indoor thermal discomfort. This was archived through the review of literature to identify three concepts; smart facades, visual comfort and parametric design in other to generate a responsive design.

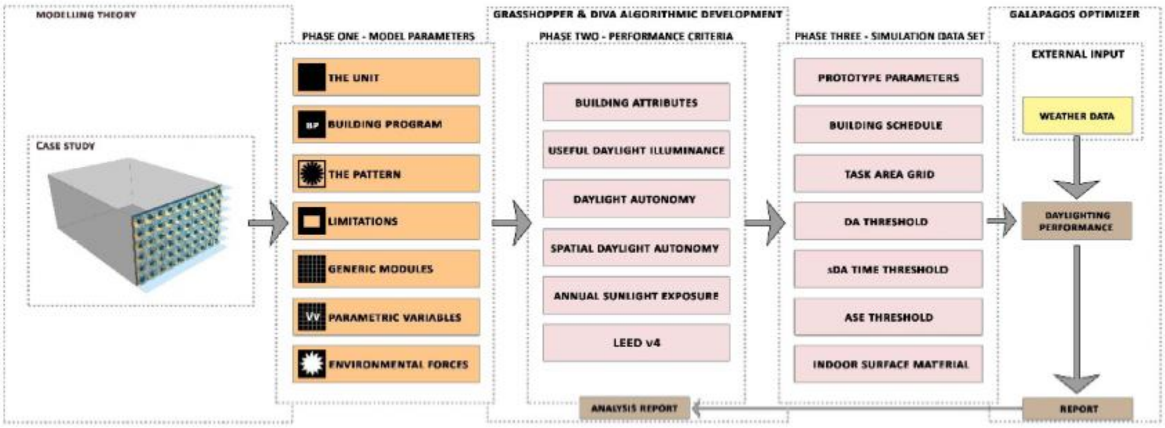

Fig 3.1 Research model diagram (Tabadkani, Banihashemi, & Hosseini, 2018).

4.0 Climatic Modulation of case studies

The case studies are hotels located in Jos Plateau state of Nigeria, the buildings were modelled using Sketchup pro software and the climate modulation was obtained from meteorological studies. The values for the modulation are highlighted in fig 1 and fig 2. It was observed that the maximum temperatures were experienced in the months of march and April with a maximum temperature of 39.6°c and 39.3°c respectively and minimum temperatures of 11.6°c and 11.5°c respectively. These values show that from October to February the climatic conditions are extremely cold and the months of march to June are mostly hot. However, the analysis show that this temperature is not constant throughout the month, in fig 3 and fig 4, the analysis in the month of February shows fluctuating temperatures within the same month. This is a clear indication that the climate is dynamic and fluctuates.

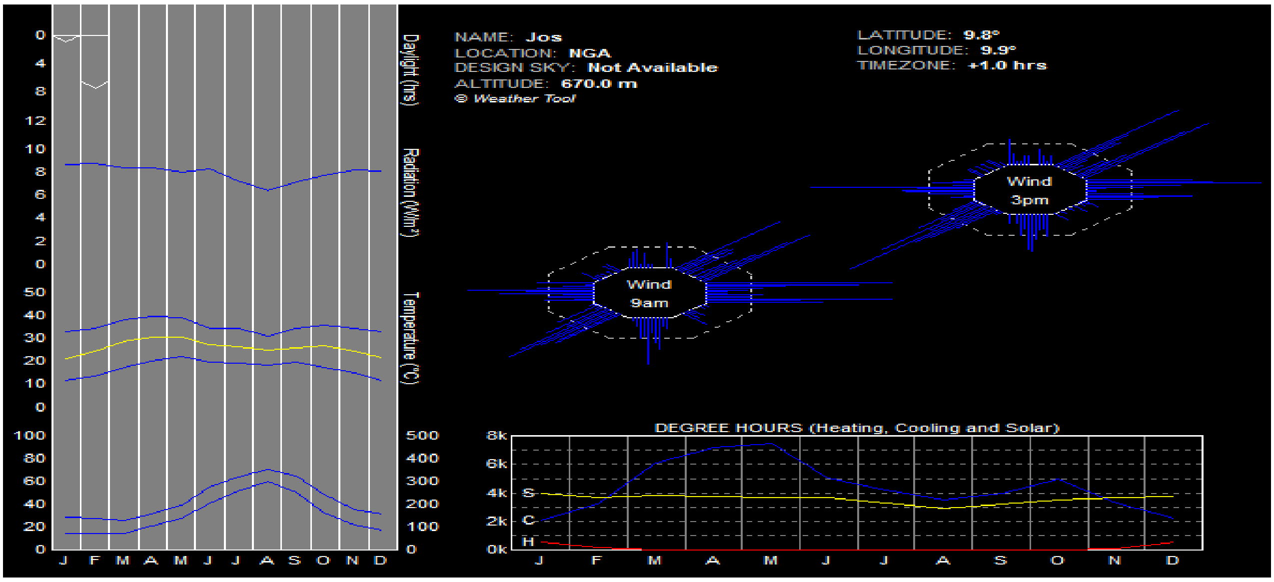

Fig 4.1 Climatic modulation of Hotel in Jos plateau state.

Month	Avg.Temp. (°C)	Min.Temp. (°C)	Max.Temp. (°C)	Sol.Rad.(Wh/m²)
Jan	21.3	11.5	33.1	8678
Feb	24.3	13.4	34.6	8776
Mar	28.5	17.4	38.0	8386
Apr	30.4	20.3	39.6	8426
May	30.4	22.2	39.3	8002
Jun	27.4	19.8	34.2	8295
Jul	26.1	19.4	34.5	7231
Aug	25.1	18.1	30.9	6424
Sep	25.9	19.5	34.5	7166
Oct	27.0	17.5	35.6	7710
Nov	24.2	15.0	34.6	8236
Dec	21.6	11.6	32.8	8141

Fig 4.2 Climatic modulation of average temperatures, min and max temperatures and solar radiation in Jos plateau state.

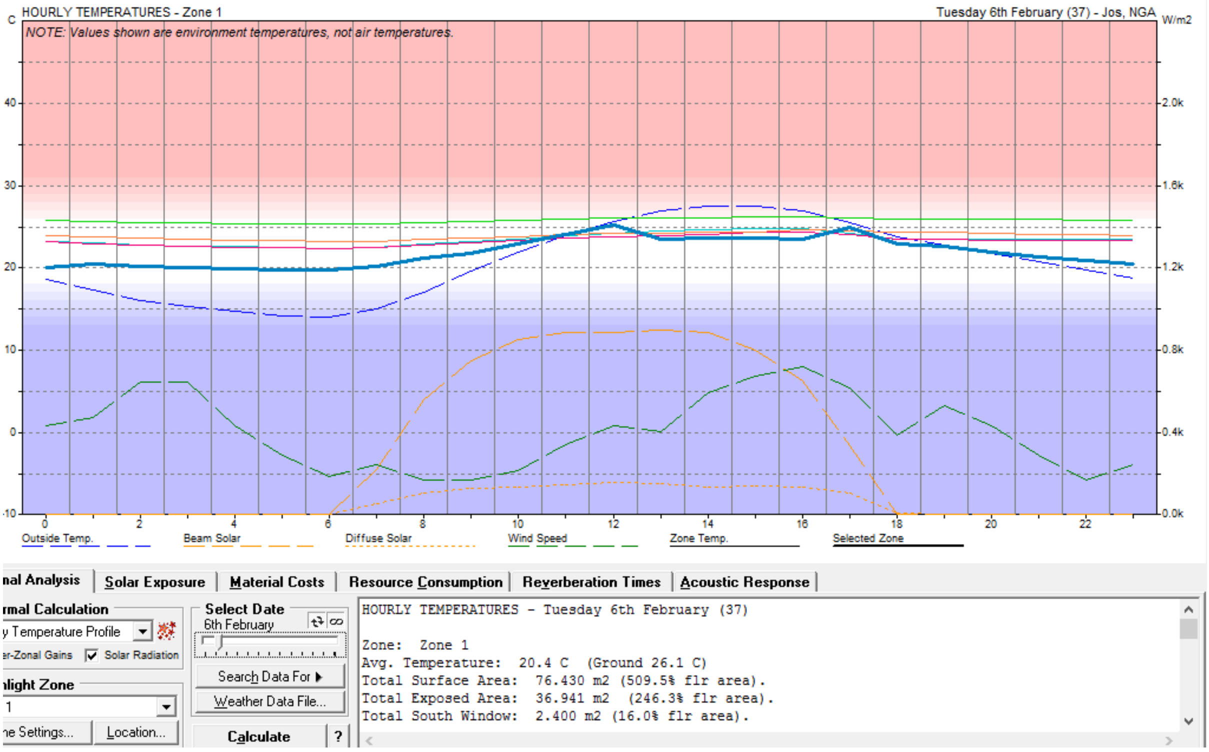

Fig 4.3 Fluctuating temperatures within the same month, an indication of a dynamic climate

4.1 Solar position throughout the year

The solar position of the studies is also analyzed, from the analysis we observed that the position of the sun is constantly changing. This is a critical factor in the way daylighting is perceived by the building, this analysis also takes into consideration the intensity of solar gain in regions affected by the sun. At maximum temperatures of 39.6°c in the month of April the angle of the sun is 135°, 40° SE and at minimum temperatures of 11.5°c in the month of January the angle of the sun is 119.9°,23.6°SE.

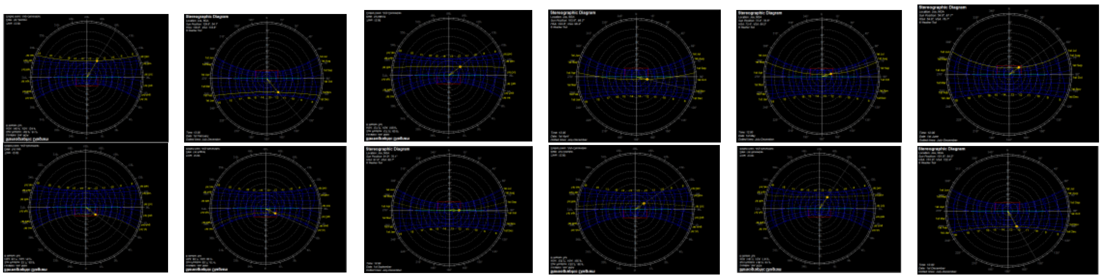

Fig 4.4 Solar position throughout the year.

4.2 Comfort level from thermal analysis

Psychometric chart below shows the effect of the barometric pressure at a maximum of 101.36 kPa. The comfort levels range from 20 AH – 5AH within an average daily temperature of 25°c - 35°c. Each modelled surface was assigned a specific material such as walls (50% reflectance), glazing (80% visual transmittance), ceiling (80% reflectance), floor (20% reflectance) and exterior surface material (30% reflectance) from the observed existing buildings. A set of sensors or nodes was located above finish floor at (0.7m) high. The results showed that these values affected the comfort levels of the building, specific materials like wood for flooring are able to absorb heat.

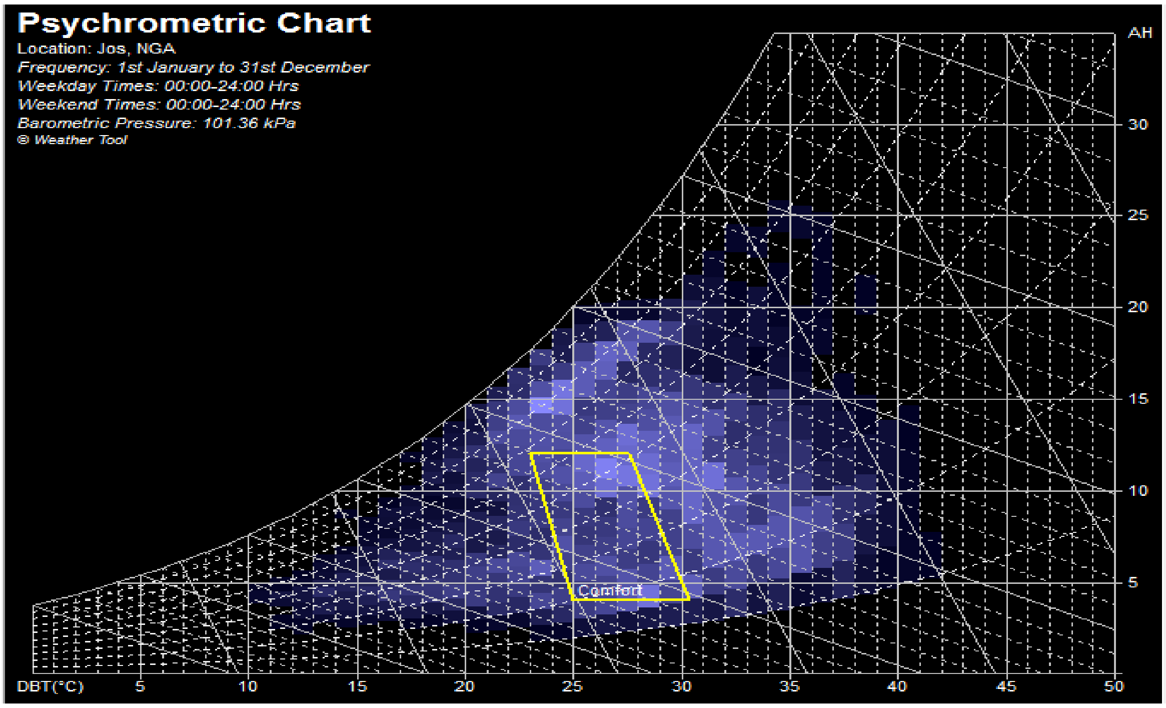

Fig 4.5 Psychometric chart for thermal comfort of the interiors

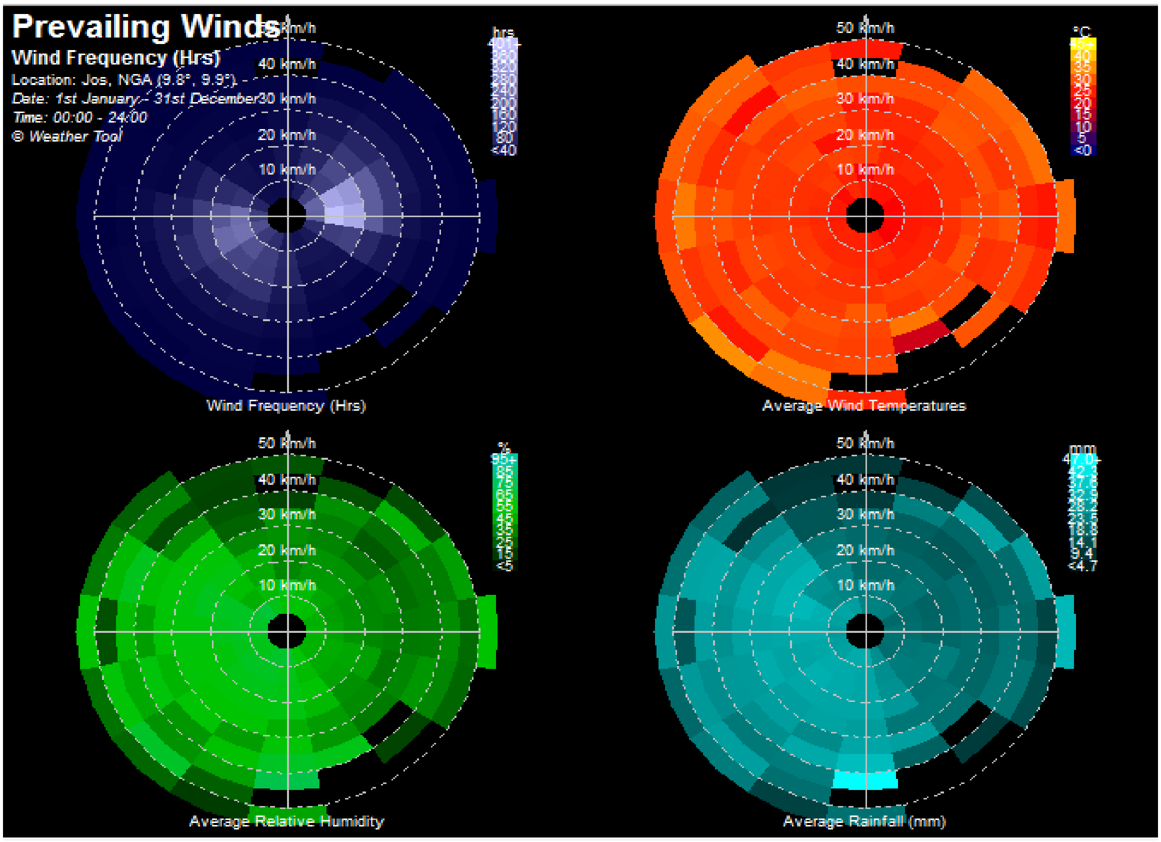

Fig 4.6 Climatic modulation of Hotel in Jos plateau state

The figure above shows the wind frequency, the average wind temperature, average relative humidity and average rain fall. Throughout the year the wind frequency those not exceed 50km/h, this analysis shows that the effects of wind on the building is minimal expect in an unusual circumstance. However, the temperatures at this speed can make the temperature levels during maximum temperatures uncomfortable to users in the building, in the simulation the building was simulated with a wind breaker and the readings show a significant improvement of reduce wind temperature to 25km/h. Within this speed the rainfall remains at normal condition, notwithstanding during peak raining months the thermal comfort is slightly uncomfortable due to the constant rainfall for a duration of 15hrs maximum. The fig 5 below shows the thermal zones of discomfort in the building.

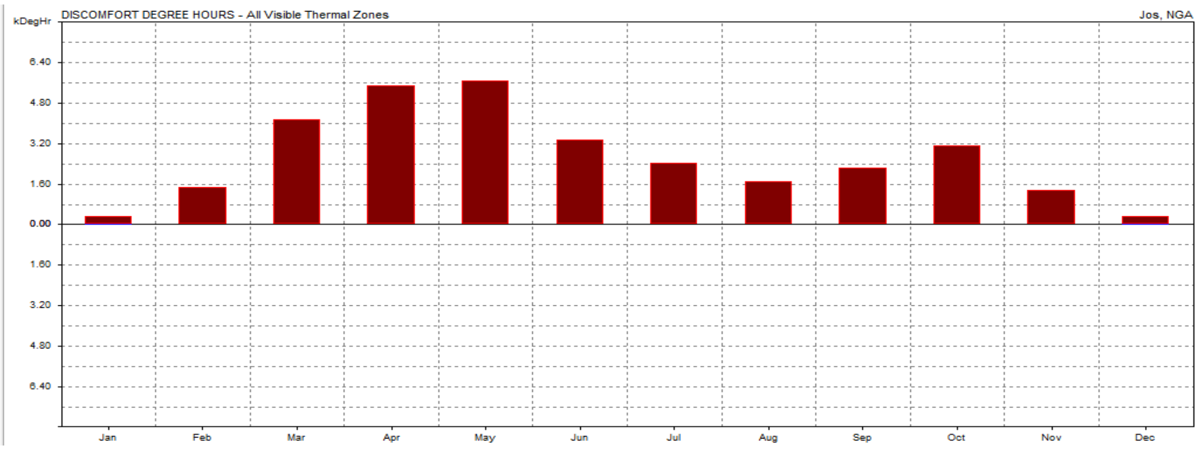

Fig 4.7 Discomfort degree hours on all visible zones

5. Conclusion

The results showed that most hotel buildings in Jos Plateau State are not climate responsive. The study therefore came up with a hotel design model that is climate responsive to tropical climate. Most importantly is that the new design model could be used for the design of hotels in environments with similar climatic conditions. Responsive skins of buildings are expanding remarkably with suitable technology advancement as such more complicated systems that adapt and respond to climate are being researched. As such interactive architecture is a developing research scope, that seeks for solution to relate with outer environment and provide appropriate answers to environmental changes. Furthermore, the research recommended that there is need for adoption of responsive strategies in the design of Hotel buildings that are responsive to change in climatic conditions.

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