

# Optimizing Residential Building Orientation for Sustainable Daylighting in the Tropics: A Case Study in Lagos, Nigeria

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## Abstract:

Daylighting is an essential aspect of sustainable building design as it reduces reliance on artificial lighting, improves energy efficiency, and promotes a healthier indoor environment. However, in the tropics, where excessive solar heat gain and intense sunlight prevail, designing residential buildings that maximise daylight while minimising heat gain relies heavily on correctly obtaining the building orientation. This study explores the challenges faced in achieving optimal residential building orientation in the tropics and proposes guidelines and tools for operationalising residential building orientation in Lagos State. A mixed-method approach was employed by combining field observations, subjective surveys, and physical measurements. The orientations of the sampled residential buildings were identified using field observation procedures. A total of 1,168 residential buildings were sampled across 20 Local Government Areas of Lagos State. The findings reveal variations in residential building orientations across the North and South zones of Lagos State, with the majority having a northwest/southeast orientation. The implications of these orientations on energy efficiency, thermal comfort, and daylighting are discussed. Recommendations were provided for each orientation, suggesting strategies to address potential issues and optimise daylighting. This study underscores the importance of considering building orientation for sustainable design practices in Lagos, Nigeria. By implementing the suggested building orientation guidelines, architects can achieve and enhance the visual comfort and energy efficiency of residential building occupants in Lagos State.

**Keywords:** Building orientation, Daylighting, Energy efficiency, Sustainable design, Tropics

## 1. Introduction

The concept of building orientation refers to the positioning of a building relative to the path of the sun and the prevailing winds. This is an essential aspect of building design, particularly in the tropical regions. According to [1], the correct orientation of a building can significantly impact the building's energy performance and indoor environmental quality (IEQ) by optimising daylighting, reducing energy consumption, and leading to increased occupant comfort. For this purpose, researchers have developed various methods to optimise the building orientation (Muñoz et al., 2014; Anumah & Anumah, 2017; Tabadkani et al., 2018). However, determining the orientation of buildings on site in the tropics presents challenges because of the variability of the local climate, regional physical planning constraints, building design conditions, and preferences. However, it is difficult to apply a universal design principle.

Studies by Yarramsetty et al. (2020) demonstrated that proper residential building orientation can reduce energy consumption for electric lighting, cooling, and heating by 10%–20% in well-oriented residential buildings. Additionally, daylighting has been shown to improve mood, enhance morale, reduce fatigue, and reduce eye strain [6]. Therefore, the importance of achieving the correct building orientation cannot be overemphasised, particularly in tropical regions that are characterised by high solar radiation, intense heat,

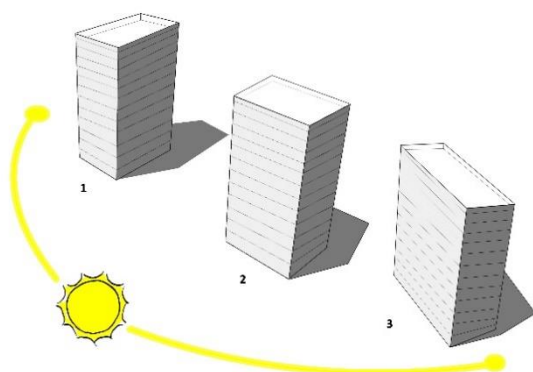
and high humidity, and the sun is nearly overhead at noon throughout the year [7]. This means that the angle of the sun at different times of the day and year is critical for daylighting in sustainable design practices.

This paper is part of a PhD research on *Daylighting and Visual Comfort in Residential Buildings in Lagos State, Nigeria*. It presents the protocol for assessing the orientation of sampled residential buildings during data collection in Lagos State, Nigeria. This is a critical factor in determining the level of daylight that residential building interiors receive, which directly affects the visual comfort of its occupants. It examines the challenges of achieving optimal building orientation and proposes a set of guidelines and tools for operationalising building orientation in Lagos. This contributes to the promotion of sustainable residential building design practices in Lagos, Nigeria, leading to increased visual comfort, well-being, and energy efficiency for occupants.

## 2. Materials

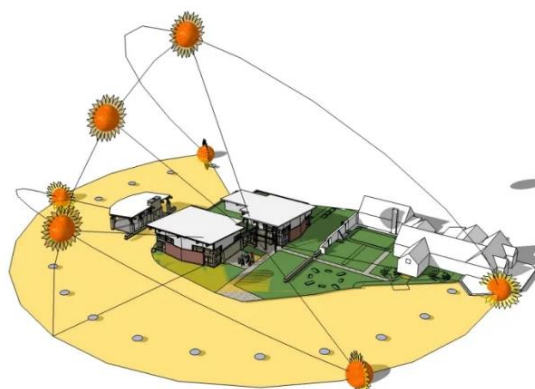
### 2.1 Definitions of Building Orientation

Different authors have defined the building orientation in slightly different ways in the available literature. According to [8], building orientation refers to the "angular direction of the longitudinal axis of a building" with respect to cardinal directions. Similarly, [9], defines building orientation as the "angular relationship between the longitudinal axis of the building and the direction of the sun." Both authors emphasised the importance of building orientation in determining the amount of solar radiation a building receives and its potential for natural ventilation. They agree that the optimal orientation should maximise solar gain in winter and minimise it in summer while maintaining sufficient daylight and ventilation throughout the year. However, they differ slightly in their approach, with one suggesting that the ideal orientation should balance energy conservation and occupant comfort by minimising solar heat gain in the summer and maximising it in the winter, and the other arguing that building orientation is a fundamental design parameter that significantly affects the energy efficiency of a building. (Figure 1)



**Figure 1:** Building orientation for daylight visual comfort - #1 is worst, #3 is good, and #2 is best for daylighting.

Source: Autodesk Sustainability Workshop



**Figure 2:** Orientation of Building relative to cardinal and the surrounding environment.

Source: archi-monarch.com

In contrast, [10] described building orientation as "the position of a building on a site relative to the compass directions." While [11] defined building orientation as "the placement of a building on a site relative to the cardinal directions and the surrounding environment." Both authors suggested that an ideal orientation should maximise the exposure of the south-facing facade to the sun while minimising exposure to the other facades. However, they differ in their approaches to building orientation. One author emphasised the complexity of building orientation and suggested that it requires a holistic approach that considers various factors such as solar radiation, wind direction, topography, and nearby buildings. Another author focused on the importance of considering building orientation to achieve optimal energy performance and occupant comfort. (Figure 2)

While different authors have defined building orientation in slightly different ways, they all agree that an optimal orientation should maximise solar gain in winter, minimise it in summer, and allow for sufficient daylight and natural ventilation throughout the year. Architects should consider various factors, such as solar

radiation, wind direction, topography, and nearby buildings when choosing a building's orientation to achieve optimal energy performance and occupant comfort.

## 2.2 Building Orientation for Daylighting

The technicality of building orientation for daylighting has been extensively studied by researchers, architects, and engineers, who have presented different arguments and findings on the subject.

One argument supposes that the building orientation for daylighting should consider the sun's path and the position of the building relative to the sun's movement. According to [12], the orientation of a building's main façade (the façade with the most windows) should be towards the equator to maximise the solar gain and minimise the risk of overheating. In this study, a south-facing façade was found to be the most effective orientation for maximising daylight and reducing the need for electric lighting, while minimising the risk of glare and overheating. Similarly, [2] suggested that building orientation should take into account the location and climate of the building site, with buildings in high-latitude regions having a more east-west orientation to take advantage of the low-angle sun, and those in low-latitude regions having a more north-south orientation to reduce direct solar gain.

Another argument presented is that building orientation should be site-specific and should consider factors such as the site's latitude and longitude, topography, and surrounding buildings. Sari & Rauzi (2021) argue that the orientation of a building should be determined by the site's specific location and surrounding environment. They found that buildings with a south-facing orientation had the highest potential for daylighting, but this was highly dependent on the site's location and surrounding environment. In contrast, [13] argues that building orientation for daylighting should be determined by a combination of climatic, cultural, and aesthetic considerations. They suggested that the orientation of a building should consider factors such as prevailing winds, local building traditions, and views from within the building.

It can therefore be deduced that building orientation for daylighting is complex and involves multiple considerations, including site-specific factors, building design, local climate conditions, cultural traditions, and aesthetic considerations. However, there is general agreement among researchers that south-facing orientation is ideal for maximising daylighting.

## 2.3 Standardization of Building Orientation for Daylighting

The standardisation of building orientations for daylighting has been a topic of debate among researchers and professionals in the field of building design. Conflicts in standardisation arise from differences in design philosophies, climates, geographical conditions, and local regulations.

### 2.3.1 Climate and Geographical Conditions

According to [14], buildings in high-latitude regions should have an east-west orientation to take advantage of the low-angle sun, whereas buildings in low-latitude regions should have a north-south orientation to reduce direct solar gain. However, Sari & Rauzi (2021), argued that building orientation should be determined by the site's specific location and the surrounding environment. They found that buildings with a south-facing orientation had the highest potential for daylighting, but this was highly dependent on the site's location and surrounding environment.

### 2.3.2 Design Philosophies:

[15] suggest that building orientation for daylighting should be determined by a combination of climatic, cultural, and aesthetic considerations. They argued that the orientation of a building should take into account factors such as prevailing winds, local building traditions, and views from within the building. Therefore, the aesthetic appeal of the building should be prioritised over the functionality of the daylighting system. On the other hand, [16] argued that building orientation should be based on the functional requirements of the daylighting strategy, such as the amount of daylight required and the potential for glare and overheating.

### 2.3.3 Local regulations and building codes

Local regulations and building codes are also seen as contributors to the lack of standardisation of building orientations for daylighting. In some countries, building orientation is regulated by building codes based on

outdated standards. [17] argued that the orientation of a building's main facade should be towards the equator to maximise solar gain and minimise the risk of overheating. However, this standard may not be suitable for all regions and does not consider the potential for glare and overheating.

The review revealed varying views that building orientation for daylighting should be based on functional requirements, whereas others prioritise cultural and aesthetic considerations. This calls for further research and standardisation efforts to ensure that the building orientation for daylighting is optimised for the specific location and functional requirements of each building.

### 3. Methods

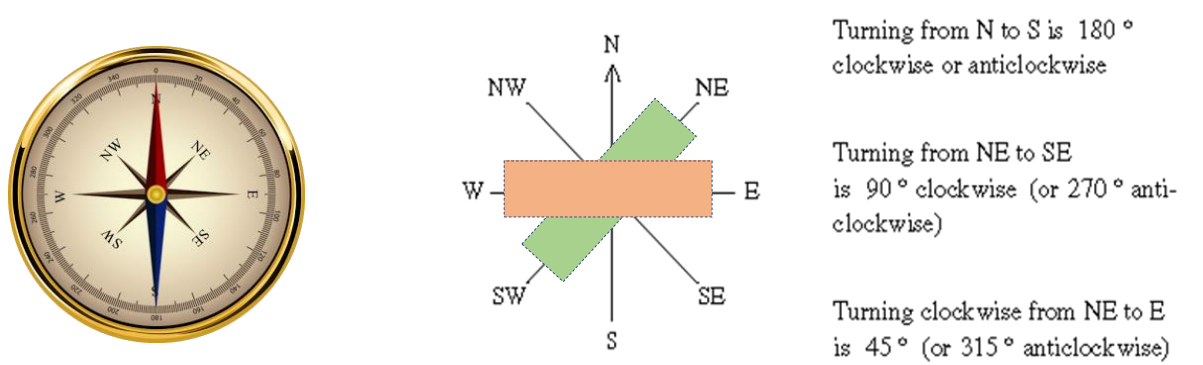
The protocol for the research is a mixed-method approach involving a combination of field observations, subjective surveys, and physical measurements. The orientations of the sampled residential buildings were identified using field observation procedures.

#### 3.1 Sampling

The research is a building base study, involving a 2-step sampling procedure to arrive at the selected residential buildings in Lagos State. Based on the National Population 2006: Regular Household Population and Housing Census, Priority Table, Volume III, April 2010 [18], a quota was selected for each of the 20 Local Government Areas (LGA) in Lagos State proportionate to the size of the population, by a simple random selection of localities within the LGA. Systematic sampling was eventually used to select residential buildings in the streets within the localities. Every third building on the street was sampled until the quota for each LGA was reached. In total, 1,168 residential buildings were sampled.

#### 3.2 Data Collection

A magnetic compass was used to locate the north. A shorter façade of the building was identified, and the façade along the elongated axis was checked against the north direction. According to Elghamry & Azmy (2017), this is the main façade of a building. This information was used to determine the orientations of the residential buildings sampled during the study. The observed building orientations were recorded as north, east, west, south, northeast, northwest, southeast, and southwest. (Figure 3)



**Figure 3:** Procedure for identifying the building orientation on site.

The Brown building has shorter sides facing East/West. Hence has a North/South orientation. While the Green building has a North-West/South-East orientation.

### 4. Results

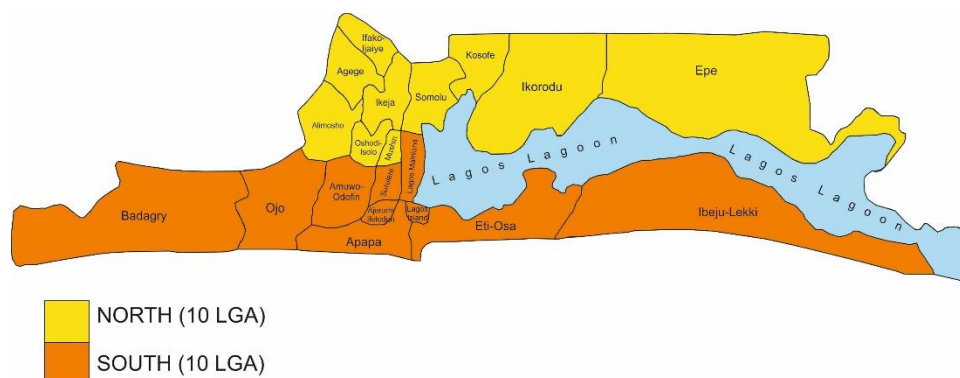
A summary of the findings from the field observation of the residential building orientations for the evaluation of daylighting for visual comfort in residential buildings in Lagos State is presented in Tables 1 and Table 2. The results also reveal that there are variations in the residential building orientations across the different LGA, which were captured in the summary as Lagos zones North and South with the Lagos Lagoon being the divider (Figure 4) and (Figure 6). The observed difference in building orientation is influenced by several factors that are not within the scope of this study.

**Table 1:** Direction of A Shorter Façade of The Sampled Residential Buildings

			Lagos zones		Total
			North	South	
Orientation of a shorter façade	North	Count	53	63	116
		Percentage within Lagos zones	8.4%	11.7%	9.9%
	East	Count	44	55	99
		Percentage within Lagos zones	7.0%	10.2%	8.5%
	West	Count	58	80	138
		Percentage within Lagos zones	9.2%	14.8%	11.8%
	South	Count	62	100	162
		Percentage within Lagos zones	9.9%	18.5%	13.9%
	North-East	Count	165	62	227
		Percentage within Lagos zones	26.3%	11.5%	19.4%
	North-West	Count	82	62	144
		Percentage within Lagos zones	13.1%	11.5%	12.3%
	South-East	Count	98	62	160
		Percentage within Lagos zones	15.6%	11.5%	13.7%
South-West	Count	66	56	122	
	Percentage within Lagos zones	10.5%	10.4%	10.4%	
Total	Count	628	540	1168	
	Percentage within Lagos zones	100.0%	100.0%	100.0%	

**Table 2:** Direction of The Main Façade of The Sampled Residential Buildings

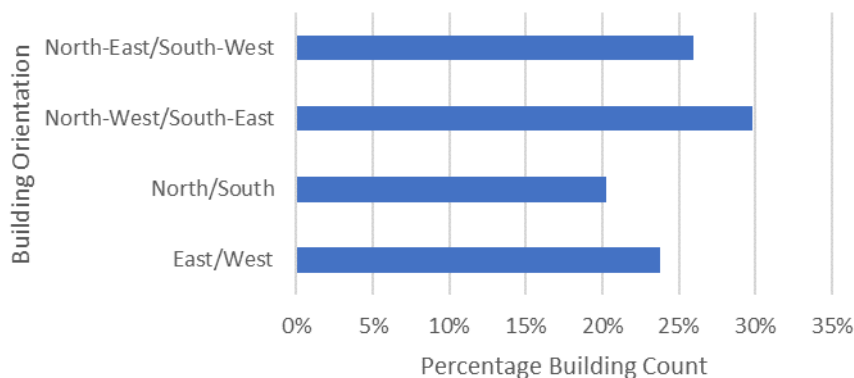
			Lagos zones		Total
			North	South	
Building orientation	East/West	Count	115	163	278
		Percentage within Lagos zones	18.3%	30.2%	23.8%
	North/South	Count	102	135	237
		Percentage within Lagos zones	16.2%	25.0%	20.3%
	North-West/South-East	Count	231	118	349
		Percentage within Lagos zones	36.8%	21.9%	29.8%
	North-East/South-West	Count	180	124	304
Percentage within Lagos zones		28.7%	23.0%	26.0%	
Total	Count	628	540	1168	
	Percentage within Lagos zones	100.0%	100.0%	100.0%	



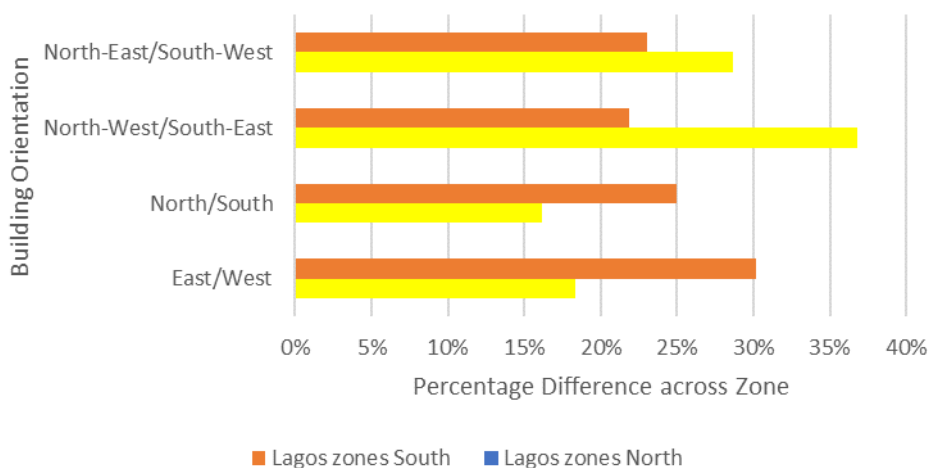
**Figure 4:** Lagos Zones – North and South, with the Lagos Lagoon being the divider. Source: author’s sketch.

## 5. Discussion

This study reveals that the majority of residential buildings in Lagos State have a North-West/South-East orientation, accounting for 29.9% of the total. The North-East/South-West orientation closely follows 26.0%. The East/West orientation accounted for 23.8%, and the north/south orientation was the least common, with 20.3% of the buildings (Figure 5). This result has significant implications for energy efficiency, thermal comfort, and daylighting in residential buildings in Lagos State.



**Figure 5:** Residential Building Orientations in Lagos State



**Figure 6:** Variations in Residential Building Orientations Across Zones

The results show that the majority of residential buildings in Lagos State have a North-West/South-East orientation, accounting for 29.9% of the total. This orientation is beneficial for maximising daylighting for residents in the morning and evening hours but may result in more intense solar heat gain during the middle of the day [19].

The northeast/Southwest orientation, which is the second most common orientation in Lagos State according to the results, provides more balanced daylighting for residents throughout the day, as it allows for morning light on one side of the building and evening light on the other. This orientation also helps to reduce the solar heat gain during the hottest parts of the day, as the building's long axis is acutely inclined to the sun's path [20].

The East/West orientation accounted for only 23.8% of the residential buildings. This orientation may be beneficial for providing good daylighting for residents throughout the day, as the building's long axis is parallel to the sun's path. However, it may also result in higher cooling loads owing to the increased solar heat gain on the east and west facades [19].

The North/South orientation is the least common and accounts for 20.3% of residential buildings in Lagos State, which is beneficial for reducing solar heat gain, as the building's long axis is oriented perpendicular to the sun's path. However, this orientation may also result in less balanced daylighting throughout the day, with more intense light on the east and west facades, and less light on the north and south facades [20].

## 6. Conclusion

Based on the discussion of the research results, recommendations can be made regarding the various residential building orientations observed in the study in Lagos State:

North-West/South-East Orientation offers the advantage of maximising daylighting during morning and evening hours. However, this may result in more intense solar heat gain during the middle of the day [19]. Architects should consider incorporating shading devices or efficient cooling strategies to mitigate the heat gain during peak hours.

The northeast/southwest orientation reduces the solar heat gain during the hottest parts of the day, as the building's long axis is acutely inclined to the sun's path [20]. Architects should leverage this orientation to optimise daylighting and minimise the need for excessive electrical lighting and cooling.

The East/West Orientation results in increased cooling loads owing to the higher solar heat gain on the east and west facades [19]. Architects should, therefore, focus on incorporating effective shading solutions and energy-efficient cooling systems to counterbalance the potential heat gain.

North/South Orientation may lead to less balanced daylighting throughout the day, with more intense light on the east and west facades and less light on the north and south facades [20]. To optimise this orientation, architects can explore strategies such as daylight redirection techniques or reflective surfaces to distribute daylight evenly across buildings.

In conclusion, when considering residential building orientation in Lagos State, architects should consider the advantages and disadvantages of each option. The building orientation should be carefully considered to maximise daylighting while minimising solar heat gain. This may involve a trade-off between different orientations depending on the specific immediate climatic conditions based on the location.

The North-West/South-East orientation provides strong morning and evening daylighting but may result in increased solar heat gain during midday. The North-East/South-West orientation offers balanced daylighting and reduced solar heat gain. The East/West orientation maximises daylighting throughout the day but may require additional cooling measures. The North/South orientation reduces solar heat gain but may result in less balanced daylighting. Other factors such as the shape of the building, shading devices, and interior layout can also have a significant impact on daylighting and should be considered in conjunction with orientation. Ultimately, architects should incorporate appropriate shading, cooling, and lighting strategies based on a specific orientation to optimise occupant comfort, energy efficiency, and overall building performance.

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## Author Profile



Ayomipo Akintunde Fadeyi, PhD, MNIA, blends expertise in architecture with a fervent commitment to sustainable design, carving an indelible mark in academia and professional practice alike. As a Lecturer at the Department of Architecture, Bells University of Technology, Ota, his innovative instructional approach integrates cutting-edge technologies such as Building Information Modelling (BIM), Computer Aided Design (CAD), Building Performance Analysis and Simulation, earning global recognition for his institution from Autodesk Inc. in 2016. Dr. Fadeyi's research delves into diverse facets of sustainable architecture, with seminal contributions on Indoor Environmental Quality (IEQ) to journals and conferences nationally and internationally. Beyond academia, his professional journey spans architectural firms, governmental agencies, and international projects, showcasing a versatile skill set honed through years of hands-on experience. A prolific mentor, administrator, and scholar, Dr. Fadeyi epitomize the fusion of academic rigour and real-world impact, determined to shape the future of sustainable architecture one student, one project, and one publication at a time.