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DAYLIGHT QUANTITATIVE ASSESSMENT OF THE URBAN DISTRICTS IN A HOT ARID REGION

Abstract: Daylight plays a crucial role in defining the overall urban experience, influencing thermal comfort, energy consumption, and visual appeal. This research aims to study the light environment in arid urban settings. The study focuses on a quantitative analysis of the light environment based on the morphological characteristics of significant city districts. We examine how urban morphology impacts illumination levels, considering factors such as street orientation, Sky View Factor (SVF), Height-to-Width (H/W) report, surface textures and coatings, and the presence of vegetation, among others. Using a C.A 813 lux-meter, our research involves an on-site measurement campaign across various quarters in Biskra to assess the effectiveness of different lighting control and adjustment strategies. The study reveals that natural illuminance in urban streets is influenced not just by SVF, but by a combination of morphological factors including H/W report, street orientation, and surface reflectance. Contemporary districts with higher H/W report and well-organized layouts achieved the best daylight performance, while traditional areas, despite high SVF, showed the lowest illumination due to dense and irregular forms.

Keywords: daylight environment, urban morphology, illumination level, onsite measurement, arid region

Introduction

The daylight environment in urban areas is a crucial factor that affects planning decisions, energy efficiency, and human comfort (Yang et al., 2023; Yahia & Johansson, 2014). In arid

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regions, characterized by extreme solar radiation, modest humidity, and sparse vegetation, the daylight conditions present unique challenges and opportunities (Fathy, 1986; Ali-Toudert & Mayer, 2007; Yahia & Johansson, 2013). These hot arid zones habitually face extreme temperatures and intense sunlight, which can intensify the influences of urban heat islands and increase energy demands for cooling (Nazanin and Shokri, 2016; Al-Haddid & Al-Obaidi, 2022). Consequently, identifying and optimizing the daylight environment in arid urban locations is fundamental for generating sustainable, comfortable, and aesthetically pleasing urban spaces (Nazanin & Rostami, 2023; Šprah et al., 2024).

Arid urban environments are described by severe climatic conditions, which have a considerable impact on natural lighting (Givoni, 1998; Baker & Steemers, 2002). Intense solar radiation can lead to overheating of buildings and outdoor spaces, while clear skies and high visibility can establish noticeable contrasts between light and shadow (Ma et al., 2024; Al-Masri & Abu-Hijleh, 2012). These factors demand a complicated balance between maximizing natural light to reduce reliance on artificial lighting and executing shading strategies to mitigate excessive heat gain (Brotas & Wilson, 2006).

Recent research highlights the significance of daylighting as a key strategy for enhancing environmental quality and energy efficiency in hot arid urban districts (Emmanuel & Steemers, 2018; Belakehal et al., 2004) examined traditional urban forms and architectural typologies in arid Islamic regions, identifying effective sunlighting strategies embedded in the design of urban spaces and buildings. These strategies, developed in response to harsh climatic conditions, offer valuable insights for designing daylight-responsive urban environments today. Similarly, Strømann-Andersen and Sattrup (2011) investigated the impact of urban density on daylight access and passive solar gains using the urban canyon concept. While based in a temperate climate, their findings underscore the need to balance compact urban forms with daylight penetration, an essential consideration for urban planning in arid regions.

Additional studies further reinforce the importance of quantitative and sustainable approaches to lighting design (Salat & Bourdic, 2012; Boukhatem et al., 2019; Skarżyński && Żagan, 2022) introduced new parameters for assessing architectural lighting in terms of energy use and environmental impact, offering tools that could be adapted to evaluate outdoor luminous environments in arid urban settings. Smael et al. (2024) focused on the contribution of daylighting to urban microclimate regulation, particularly its role in reducing urban heat island effects, thus supporting its broader environmental value. Lastly, Mander et al. (2023) provided a systematic review of light pollution measurement methods, identifying key gaps and offering benchmarking data that could inform future assessments of luminous conditions in arid urban contexts. Together, these studies form a foundation for the quantitative assessment of daylight in urban districts exposed to extreme solar conditions.

This study aims to explore the complexities of the light environment in arid urban areas by examining how these environments can be effectively managed through thoughtful design and planning. By studying various parameters such as building orientation, façade treatments, and the integration of shading devices, we seek to identify strategies that improve luminous comfort and maintain visual quality. Through field measurements in district case studies from an arid region, this research will provide a comprehensive overview of best practices in lighting design within these challenging contexts.

The importance of this research lies in its potential to inform sustainable urban development in arid regions. By assessing the impact of urban morphology on the light environment, urban planners and architects can reduce light effects and create more comfortable living and outdoor usage conditions. Ultimately, this study aims to contribute to the development of resilient, energy-efficient, and livable arid urban environments, addressing both current challenges and future sustainability goals.

The Study Area

Located in northeastern Algeria, Biskra is recognized for its hot and arid climate. The municipality encounters high temperatures, intense solar radiation, and minimal precipitation. Numerous urban districts in Biskra, demonstrating diverse architectural styles and urban layouts, were selected for the study to include a large range of daylighting conditions. These neighborhoods include residential areas with diverse morphological characteristics as well as zones with varying levels of vegetation and shading. Research conducted by Zemmouri (2005) resulted in the classification of Algerian territory into four lighting zones. The Biskra province is classified as the illumination zone where the illumination levels are 42 Klux (Fig. 1).

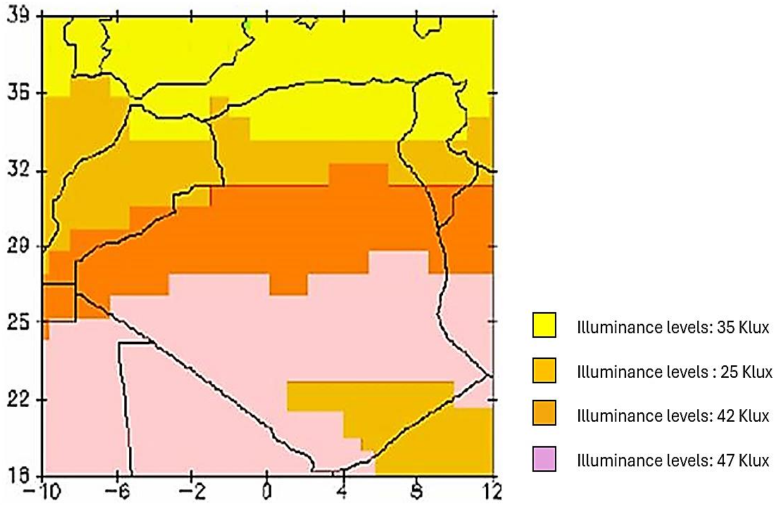


Fig. 1. Illumination zones in Algeria (Source: Zemmouri, 2005).

Table 1 below summarizes the results from ten years of cloud cover measurements obtained from satellite data. It displays the percentage of cloud coverage in the sky throughout the day for our study area, which is the city of Biskra. The monthly results are shown in the following table.

Table 1. Results of ten years of measuring cloudiness in Algeria using satellite data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Average of 10 years measurement of the cloudiness of the day (%)	52.5	53.6	55.9	54.3	55.0	47.1	31.3	35.0	41.4	56.3	56.0	52.2

Zemmouri, 2005

Case study presentation

A systematic measurement campaign was conducted to collect quantitative data on illumination levels in selected urban districts. The campaign included the following steps:

Step 1: Selection of specific urban configuration of the districts of Biskra:

The current urban landscape of Biskra is a synthesis of its historical development stages (Fig. 2). Its urban fabric allows for easy chronological reading, three urban districts of Biskra were selected based on their distinct characteristics, including urban density, building height, and the presence of vegetation and shading devices (Qaoud, 2023). Revealing distinct layers:
- The ancient core, which forms the foundation of the city.
- The colonial grid, reflecting a period of organized planning and development.
- Recent expansions, including communal subdivisions and cooperatives, representing the latest phase in the city's growth.

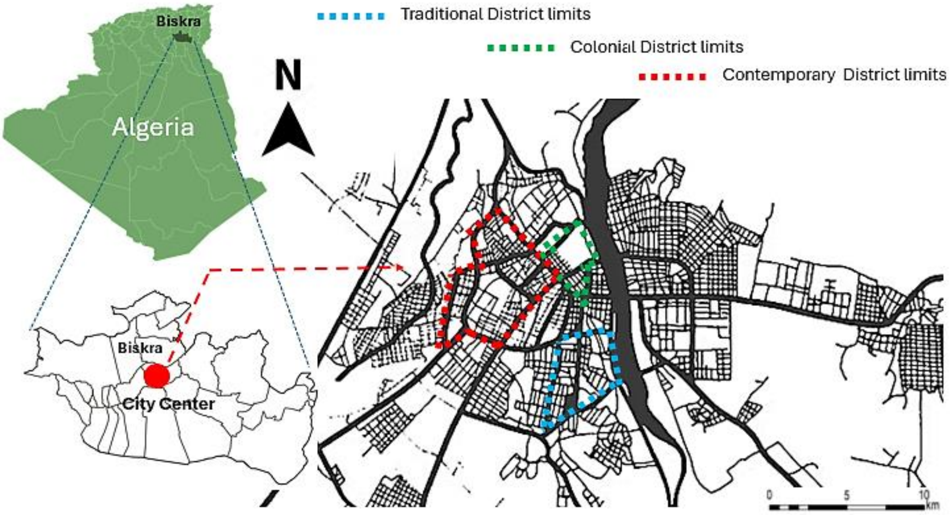
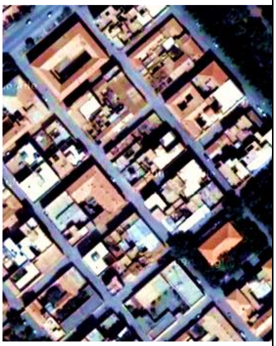


Fig. 2. The case study location

This chronological layering provides a rich tapestry of Biskra's evolution, showcasing its diverse architectural and cultural influences over the centuries. The ancient core represents the city's historical roots, while the colonial grid highlights the influence of past colonial rule. The spontaneously developed popular neighborhoods illustrate the organic growth patterns that have shaped much of Biskra's residential areas. Finally, the recent expansions, marked by planned subdivisions and cooperative housing projects, demonstrate the ongoing development efforts aimed at accommodating the city's growing population and modernizing its infrastructure (Barkat et al., 2019). Together, these elements paint a comprehensive picture of Biskra's urban identity, rooted in its past yet continually evolving (Tab. 2).

Table 2. The characteristics of the urban fabric of the districts studied

Traditional district	Colonial district	Contemporary district
		
- Dense fabric - Narrow streets - Ground floor to R+1 dwellings - Earth texture (Local materials) - Height/width report (H/L): low	- A checkerboard plan - Ground floor to R+03 constructions - "Arabisance" façade style Height/width report (H/L): average	- Housing ranges from ground floor to R+4 - Planned subdivision type housing - Height/width report (H/L): high - Different façade styles - Very varied façade colors

Source: Google Earth, 2024

Step 2: Selection of streets and measuring points:

In each neighborhood, a representative selection of streets was undertaken to encompass the diverse morphological and physical attributes of urban fabric. The objective was to ensure the inclusion of all potential street orientations, varying building heights, and physical transformations, such as the presence of vegetation or chromatic differences, that influence both the quantity and quality of natural light (Fig. 3). The criteria for street selection include:

a. A comprehensive range of street orientations.
b. Variability in sky view factor (*SVF*) values.
c. Diversity in height-to-width (H/W) reports.
d. Presence of vegetation in multiple configurations (e.g., tree alignments, small gardens, verandas).
e. Variations in the materiality and texture of horizontal and vertical surfaces.

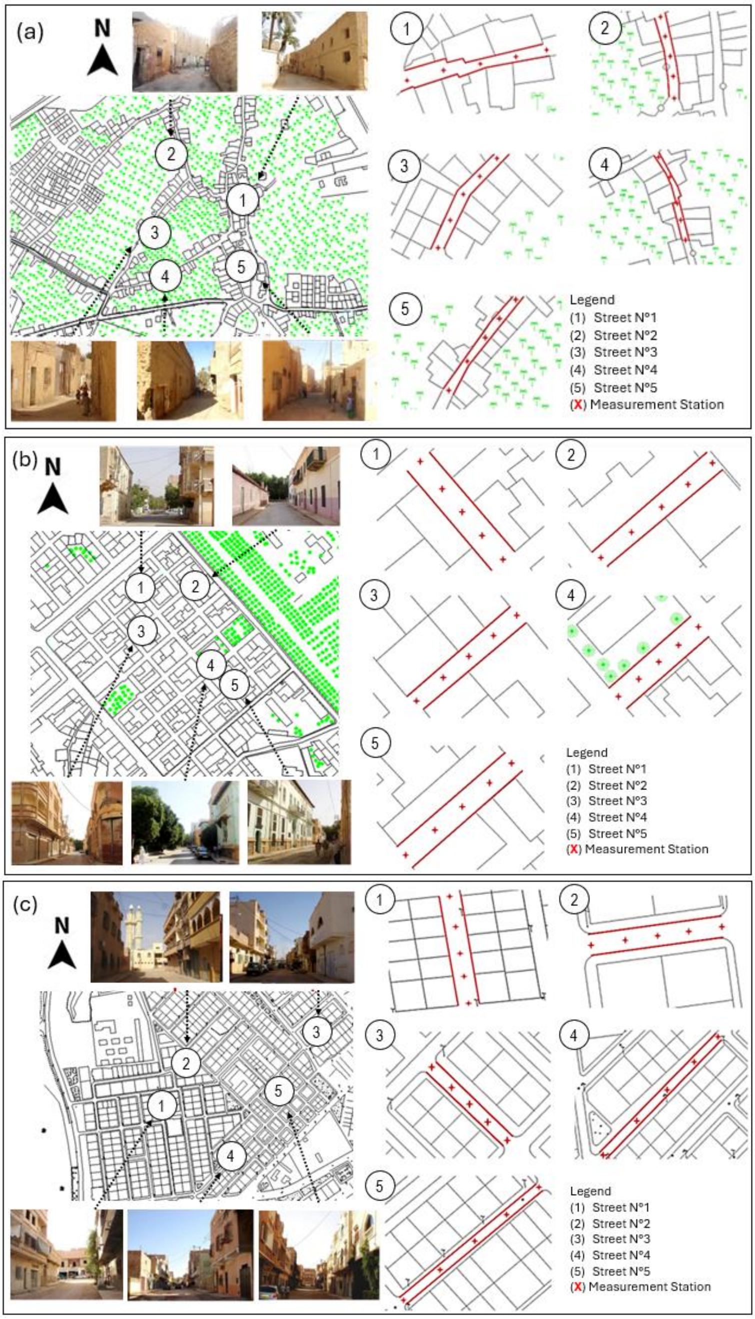


Fig. 3. Selection of streets and measurement points of the studied districts: (a) Traditional District, (b) Colonial District, (c) Contemporary District

Selecting representative measurement points is challenging because each location in an urban environment has a unique level of illumination, influenced by its surrounding conditions. Our approach focuses on the horizontal plane and the middle of the street, assuming it captures the overall light (both direct and reflected). To address the complexity of light propagation in urban settings, we increased the number of measurement points within the selected streets, taking five-point measurements from the beginning to the end of each street at three different times of the day (morning at 9 am, noon at 12 am and Evening at 4 pm). These points were chosen based on the criteria and remained consistent throughout the measurement campaign, precisely located and documented using plans and photos. Additionally, streets dimensions were documented on-site to ensure precise data collection.

Material and Methods

This study assesses illuminance levels in various urban districts of Biskra, Algeria, using a quantitative on-site measurement campaign (Belakehal et al., 2005). Biskra, characterized by its hot and arid climate, presents diverse lighting conditions across its residential, commercial, and mixed-use areas (Bacha et al., 2024). High-precision digital lux-meters, portable data loggers, and a weather station were used to measure illuminance levels and environmental parameters. Three distinct districts were selected: traditional, colonial, and a contemporary district. Measurements were taken at multiple points within each district at different times of the day at ground level. Continuous monitoring was conducted on selected sites to capture diurnal variations. The data were analyzed using descriptive and comparative statistical methods, and the relationship between illuminance levels and environmental factors were examined. Instruments were calibrated, and data quality was ensured through replicate measurements and error checking. The results provide detailed insights into Biskra's light environment, informing strategies for optimizing and regulating lighting in arid urban settings. Figure 4 below schematizes the methodology flowchart of the research work.

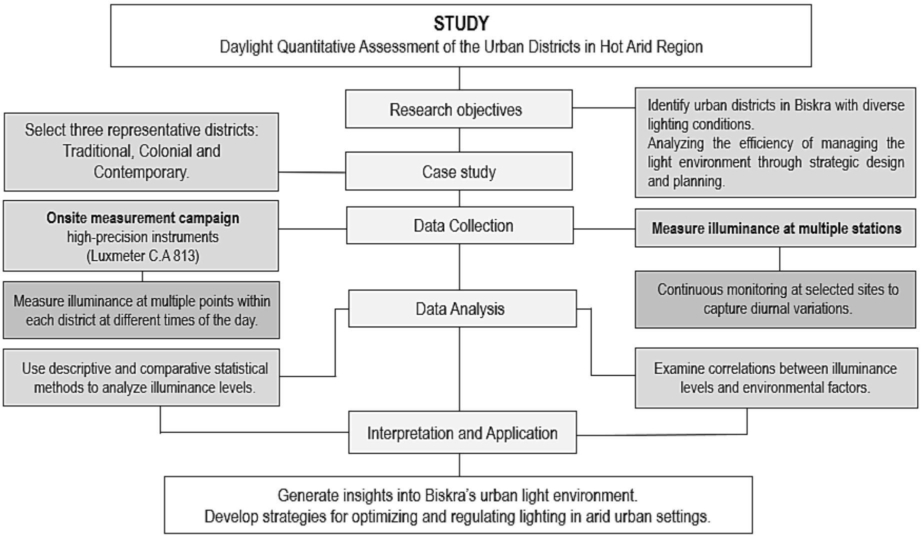


Fig. 4. The study workflow

Measurement instrumentation

The device employed to record horizontal illumination levels in this study was the C.A 813 Luxmeter factory-made by Chauvin Arnoux. This device is counted for direct measurement of illuminance, with an extensive measurement range from 0 to 200,000 lux, making it well-suited for recording illumination levels in various urban settings. It uses a silicon photodiode sensor with a spectral filter that estimates the human eye's response in the visible spectrum, permitting for realistic valuation of lighting conditions from the perspective of visual comfort (Fig. 5).

Fig. 5. The measuring instrument used a C.A 813 luxmeter (Source: Author)

Among the key advantages of the C.A 813 are its portability, ease of use, and capability to deliver instantaneous real-time readings, which are critical for mobile in situ data collection. Its compact design permits efficient positioning across multiple urban sites. However, it also has numerous limitations. Particularly, the C.A 813 does not feature data logging or internal memory, necessitating that all values be logged manually by the field team. Also, it only serves instant measurements, there is no capacity for averaging readings over time intervals such as seconds or minutes. The accuracy of readings differs on stable environmental conditions and cautious sensor handling to avoid direct sunlight, reflections, or shadow interference.

On-site measurements and data collection

Illuminance levels were measured at each point at different times of the day (morning, noon, and evening) to account for variations in natural light. Measurements were taken at ground level to simulate the illuminance received by the lowest horizontal plane on the street in an urban setting.

Measurement protocol

The measurements are taken three times in the day: at 9 am, noon and at 4 am. These times were selected based on several criteria:

- To measure daily variations in illuminance levels.
- To capture periods when natural light prominently illuminates urban spaces.

- To compare the manifestation of natural light in urban settings at the beginning, middle and end of the day.

Measurements are conducted using mobile instruments in selected districts. These measurements occur on the 21st of each month (March, June, September, and December) in 2024, corresponding to the solar equinoxes and solstices. A team of three people performs the measurements, with each session lasting up to 20 minutes per site. This approach ensures that data collection across the different measurement points is tightly synchronized within a narrow time window, avoiding extended sampling periods and enabling precise comparisons.

Statistical analysis of data

In this part, we will quantitatively estimate the illuminance levels obtained in situ. The results from a year of on-site measurements, conducted across various selected streets within each quarter in the city. Later, it will be interpreted for comparison across different variations. This analysis will provide a more detailed view of the illuminance levels in the area studied. The comparison will highlight the impact of urban settings concentrated within the streets and their characteristics on the light environment of the selected sites.
The average values (the mean of the average illuminance readings along the same street) will help identify the average illuminance levels for each district, indicating how the urban space and its characteristics influence illuminance levels in each sample. It is important to note that illuminance levels are measured directly, while the averages illumination levels are calculated using statistical formulas for mean values.

Processing of measured illuminance values

After completing a year-long measurement campaign, covering different seasons on the 21st of March, June, September, and December (the solar solstices and equinoxes), which represent a defined light source. After that we will proceed with the calculation of the following average illumination levels:

Seasonal Average illumination of the street (E_{SAS})

The calculation of average illuminance levels for a street will be conducted for each season. This will culminate in an aggregate of seasonal and annual illuminance levels. During the analysis, we will attempt to explain the observed phenomena and identify the causes of any increases or unusual variations in illuminance values within the same street.

$$E_{SAS} = (E_{SP1} + E_{SP2} \dots + E_{SPN})/N \quad (1)$$

With:
E_{SAS}: Average of the illuminance level value of the street
E_{SP}: Illuminance level value of a measured point in the street
N: Number of measured points in the street (N=5 in our case)

Seasonal Average illuminance of the district (E_{SAD})

$$E_{SAD} = \sum(E_{SAS1} + E_{SAS2} \dots + E_{SASN})/N \quad (2)$$

With:
E_{SAD}: Average value of the illumination of a district (in Lux)
E_{SAS}: Seasonal average value of street illumination (in Lux)
N: Number of streets selected in a district (N=5 in our case)

Seasonal Illuminance cumulus of the street (E_{SCS})

After calculating the seasonal averages for each street within each neighborhood, we can infer the illuminance levels of each street in relation to the overall and neighborhood averages. This approach allows us to assess the illuminance levels at various stages, considering their morphological characteristics.

$$E_{SCS} = \sum(E_{SAD1} + E_{SAD2} \dots + E_{SADN})/N \tag{3}$$

With:
E_{SCS}: Seasonal cumulus illumination of the street (in Lux)
E_{SAD}: Spring cumulus illumination of the street (in Lux)
N: Number of streets selected in a district (N=5 in our case)

Seasonal cumulus illumination of the district (E_{SCD})

The average illuminance levels for each neighborhood will be calculated for each season to determine the annual variations in illuminance across neighborhoods throughout the seasons. During the analysis, we will strive to provide explanations for the observed phenomena and outline the methods used to evaluate the illuminance values among the different selected neighborhoods.

$$E_{SCD} = \sum(E_{SCN1} + E_{SCS2} + \dots + E_{SCSN})/N \tag{4}$$

With:
E_{SCD}: Seasonal cumulus illumination of the district (in Lux)
E_{SCS}: Spring cumulus illumination of the street (in Lux)
N: Number of streets selected in a district (N=5 in our case)

Annual illumination cumulus of the district (E_{ACD})

$$E_{ADC} = E_{SCD1} + E_{SCD2} + E_{SCD3} + E_{SCD4}/N \tag{5}$$

With:
E_{ADC}: Annual illumination cumulus of the district (in Lux)
E_{SCD}: Seasonal cumulus illumination of the district (in Lux)
N: Number of seasons (N=4 in this case)

To verify the uniformity of illuminations across different points in the same street, an examination of possible variation in illumination levels within the same street for three timings in the day (9 am, noon and 4 pm). Furthermore, a verification for variations in illumination levels between streets within the same district, for all selected neighborhoods. The second comparison will also focus on the same neighborhood, but this time, it will involve comparing the average seasonal illumination results. This comprises comparing the average illumination levels of different districts, the average illumination levels of different streets within the same quarter, and finally, estimating the cumulative annual average illumination levels.

Illuminance levels were compared between districts to identify significant differences and understand the effect of urban morphology and environmental factors on the daylight environment. After calculating the averages for each street within every district, it permitted us to establish the illuminance levels of each street relative to the overall average and the neighborhood average. This approach enables us to assess illuminance levels at various stages in relation to the streets' morphological characteristics.

Results

Seasonal Average illumination of the street (E_{SAS})

Traditional district

The assessment of illuminance levels beyond the traditional district shows manifest spatial and temporal variability, as illustrated in Figure 6. This heterogeneity is apparent even within the similar climatic season; for example, during the summer period, illuminance values range from 958 lux in Street No. 2 to 1159 lux in Street No. 1. Such differences can be recognized as variances in urban morphology, counting street orientation, height-to-width ratios, and the presence of shading elements such as vegetation or building projections. Additionally, significant seasonal variation is perceived within specific streets, emphasizing the dynamic interplay between solar altitude, atmospheric conditions, and the physical configuration of the built environment. Particularly, Street No. 5 explains an evident seasonal period, with illuminance increasing from 147 lux in winter to 1118 lux in summer. These findings attention the importance of reflecting both spatial context and temporal dynamics in evaluating natural lighting conditions within traditional urban districts.

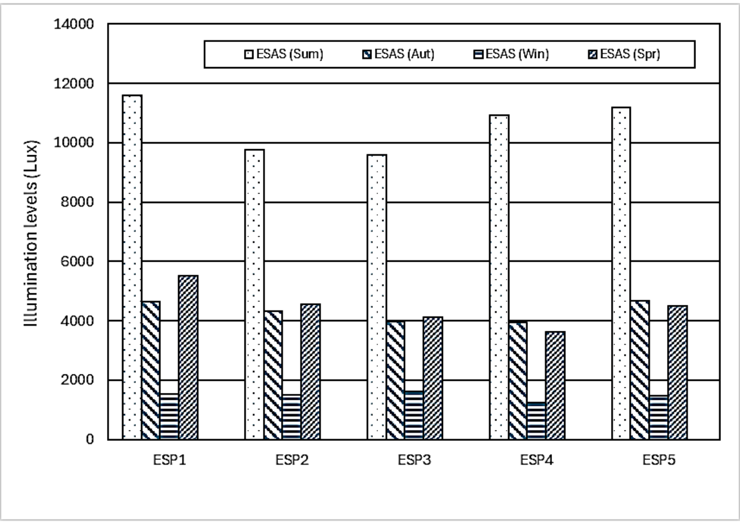


Fig. 6. Seasonal Average illumination of the street E_{SAS} (Traditional district)

Colonial district

The colonial district, as depicted in Figure 7, demonstrates significant variation in illuminance values across streets in the same season. During the winter period, for instance, measured values range from 1340 lux in Street No. 1 to 2960 lux in Street No. 5, emphasizing the effect of street orientation and morphological variations on solar exposure. Furthermore, pronounced seasonal variability is evident within individual streets. On Street No. 4, illuminance levels rise significantly from 2260 lux in winter to 12,350 lux in summer. These findings propose that, in dissimilarity to the more compact and irregular morphology of traditional quarters, the colonial district's broader street profiles and more regular grid orientation increase exposure to solar radiation, especially during summer months. The results feature the role of urban form in adapting daylight availability and the potential implications for thermal comfort and urban daylighting strategies.

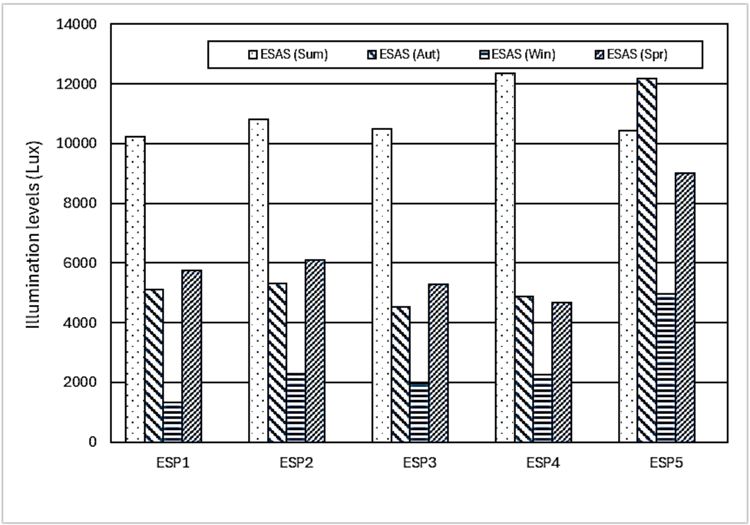


Fig. 7. Seasonal averages of illumination (ESAS) of each street by season in the colonial district

Contemporary district

The contemporary neighborhood, as illustrated in Figure 8, also demonstrates notable intra-seasonal and inter-seasonal variations in illuminance levels. During the spring season, illuminance values range from 5490 lux on Street No. 1 to 7090 lux on Street No. 2, indicating that even within a planned urban fabric characterized by wider street profiles and consistent building alignments, differences in orientation and surface reflectivity can significantly affect light availability. Moreover, substantial seasonal variation is observed within the same street; in Street No. 1, the illuminance difference between seasons reaches a magnitude of 8150 lux, underscoring the strong influence of solar path changes and atmospheric conditions over the year. These findings confirm that, despite the relatively homogeneous spatial layout of the contemporary district, environmental and morphological factors continue to play a critical role in shaping natural lighting conditions.

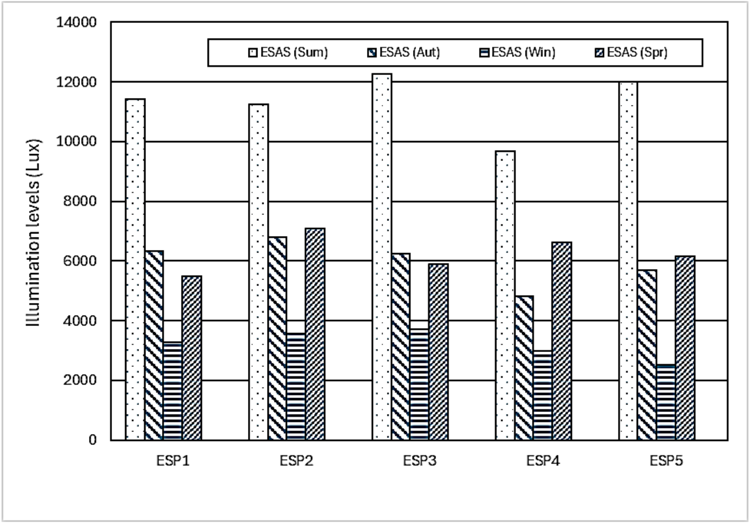


Fig. 8. Seasonal averages of street illumination in the contemporary district (ESAS)

Generally, the analysis proves that average illuminance levels within each district demonstrate significant seasonal variability, determined principally by the distinct morphological features of specific streets. These dissimilarities reflect the consequence of urban form on daylighting performance, where elements such as the height-to-width (H/W) report, Sky View Factor (*SVF*), surface colors and textures, and the presence or absence of vegetation significantly control light penetration and distribution.

This analysis compares daylight conditions across three urban fabrics. In the Traditional district, a low H/W report (0.25) and high SVF (64%) balance shading and daylight, typical of arid-region vernacular design. The Colonial district shows a higher H/W report (0.50) and lower SVF (47%), creating deeper shading but offset slightly by reflective white facades. The Contemporary district, despite a high H/W report (0.75), has moderately higher SVF (51%) due to wider pathways, resulting in increased direct solar access. These variations highlight how geometry, materials, and design intent shape daylight performance and thermal experience in streetscapes.

Therefore, each urban district, whether traditional, colonial, or contemporary, imposes unique constraints and opportunities for daylight access, shaped by the spatial configuration and materiality of its constituent elements. These findings underscore the critical role of urban morphology in determining seasonal daylighting conditions and feature the necessity for context-sensitive design strategies that account for such variations in urban planning and environmental performance valuations.

Seasonal averages of illumination of each district

As illustrated in Figure 9, seasonal average illuminance levels exhibit notable disparities among the three neighborhoods, reflecting the differential impact of urban morphology on natural lighting conditions. For instance, under equivalent measurement conditions, same season (winter), time of day, and sensor positioning, a difference of 1460 lux is recorded between the traditional and contemporary neighborhoods. This divergence underlines the degree to which urban form impacts daylight accessibility. Key contributing factors incorporate variations in the height-to-width (H/W) report of streets, building heights, Sky View Factor (*SVF*), pavement materials, façade textures and colors, and the presence or density of vegetation.

The Traditional district, with its low-rise, irregular layout (H/W: 0.25, SVF: 64%), achieves consistent daylight through high sky exposure and reflective surfaces, ensuring visual comfort year-round. The Colonial district (H/W: 0.50, SVF: 47%) offers moderate daylight and seasonal variation, with some diffuse lighting aided by reflective facades and intermittent vegetation. The Contemporary district (H/W: 0.70, SVF: 51%) suffers from excessive illumination due to vertical enclosure with wide pathways, dark materials, and minimal greenery.

Each of these elements adjusts light transmission, reflection, and absorption within the street canyon, thereby generating distinct luminance environments. These findings reinforce the significance of considering morphological parameters in urban lighting assessments and in the development of design strategies aimed at optimizing daylight access.

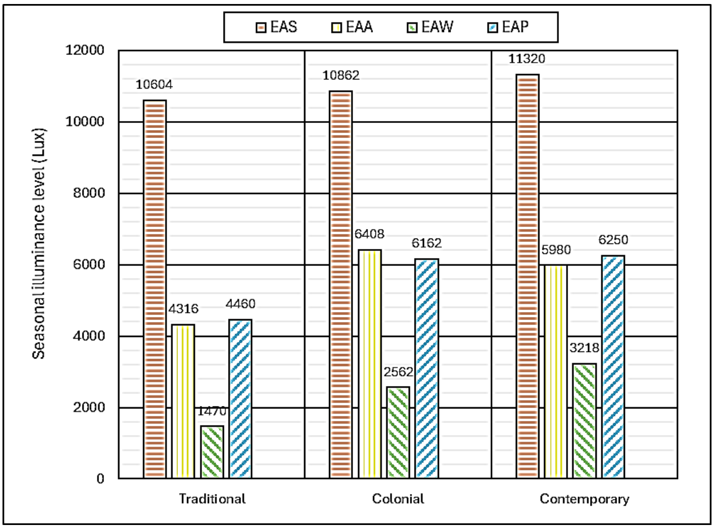


Fig. 9. Seasonal averages of illumination (ESCD) of each district studied

Average annual illumination in each district

Figure 10 presents the cumulative average illuminance levels within the three districts studied, exposing a clear gradation in values that aligns with the morphological characteristics of each urban composition. Under consistent measurement conditions, the lowest cumulative illuminance was recorded in the traditional district (5212,5 lux), followed by the colonial district (6498,5 lux), while the contemporary district exhibited the highest value (6592 lux). These results imply that the traditional district, shaped by a compact and inward-oriented urban form, efficiently moderates natural light exposure. Its spatial configuration, characterized by narrow streets, high building-to-street ratios, and adaptive architectural elements, performs to be well-suited for controlling illuminance levels. This design not only reflects an understanding of the local climate but also mitigates detrimental lighting effects such as glare, excessive contrast, and disruptive surface reflections. The findings emphasize the traditional district's passive strategies for achieving visual comfort, advancing valuable perceptions for sustainable urban design in hot-arid environments.

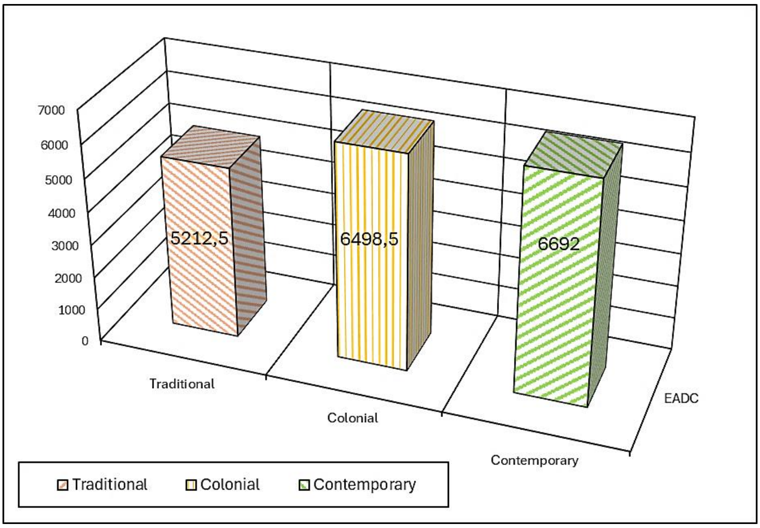


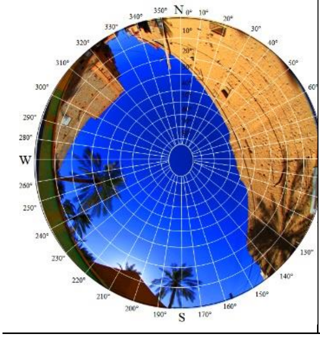
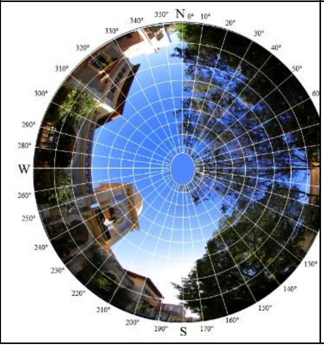
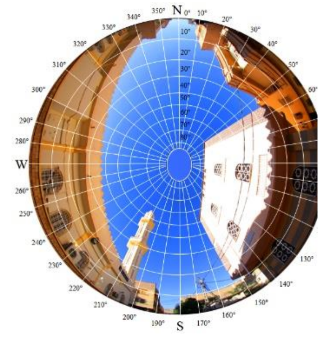
Fig. 10. Average annual illumination EADC (all districts)

Discussion

SVF impact on Average annual illuminations E_{SAS}

SVF is one of the most important urban factors that have an impact on urban microclimate, especially the light environment. The table 3 below shows how the different types of urban streets with different *SVF* influence the illuminance levels.

Table 3. Different SVFs of street samples in the districts studied

SVF = 64%	SVF = 47%	SVF = 51%
		

The research findings disclose a meaningful correlation between Sky View Factor (*SVF*) and annual illumination levels across different urban districts. In the traditional district, where the sample street demonstrates a high *SVF* of 64%, annual illumination levels are moderately low, with a minimum illuminance level of the street E_{SPMin} 1230 lux, a maximum illumination level of the street E_{SPMax} of 11590 lux, and an annual illuminance level of the street E_{ADC} of 5212,5 lux. This recommends that despite a wide sky exposure, the traditional urban morphology, characterized by narrow, winding streets and dense building arrangements, may limit the amount of direct sunlight penetrating the street level due to shading from adjacent structures. On the contrary, in the colonial district with a lower *SVF* of 47%, illumination levels are notably higher (E_{SPMin} 1340 lux, E_{SPMax} 12350 lux, E_{ADC} 6498,5 lux). This paradox can be attributed to the colonial street's rectilinear geometry, greater building setbacks, and more regular orientation, which may facilitate increased solar access even with a lower visible sky fraction (Fig. 11).

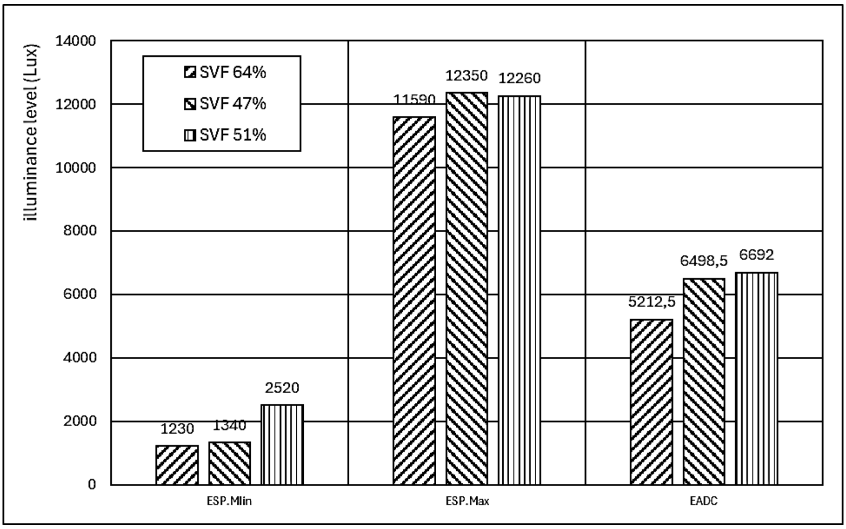


Fig. 11. Impact of SVF on the annual illuminance levels EACD (all districts)

In contrast, the contemporary district, with an intermediate *SVF* of 51%, registers the highest annual illumination level (E_{ACD}) at 6692 lux, ranging between 2520 and 12260 lux. This result highlights the influence of not just *SVF* but also the overall urban form and material reflectance on lighting conditions. Contemporary street layouts often incorporate wider roads, lower building heights relative to street width, and fewer obstructions, allowing more consistent and higher levels of solar radiation to reach ground level. Therefore, while *SVF* provides an essential metric for understanding sky openness, it alone does not determine illumination levels; the spatial configuration, building orientation, surface albedo, and urban design typology critically modulate the final lighting conditions in urban environments. These results underscore the complexity of urban microclimates and the need for integrated morphological and environmental analyses in sustainable urban design.

H/W street report impact on Average annual illuminations E_{SAS}

The research findings highlight a clear relationship between the Height-to-Width (H/W) report of urban streets and their annual illumination levels (Fig. 12). In the traditional district, where the H/W report is lowest at 0.25, illumination levels are also significantly lower, with a minimum illumination level of the street ($E_{SP.Min}$) value of 1230 lux, and a maximum annual average illumination level ($E_{SP.Max}$) value of 11590 lux, and an annual illuminance E_{ADC} value of 5212,5 lux. This suggests that wider streets relative to building height may limit direct sunlight penetration due to shallow solar angles being obstructed by surrounding structures, especially in dense urban fabrics with complex shading patterns of palm trees and earth constructions. The narrow and organic street layout typical of traditional districts may further reduce sky visibility and reflective light, thereby lowering overall illuminance. This demonstrates that while a low H/W report may increase openness at ground level, it does not guarantee high exposure to sunlight if other morphological features obstruct direct and diffuse light, such in curved earth construction (Street No. 2).

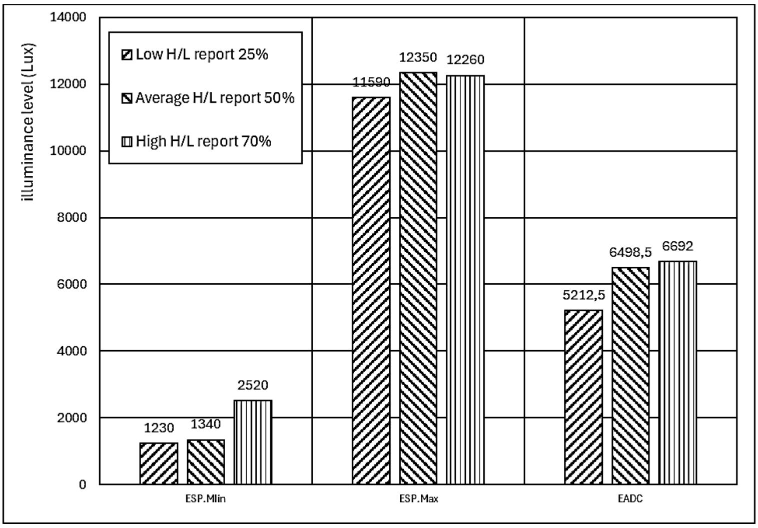


Fig. 12. H/W street report impact on the illuminance levels (all districts)

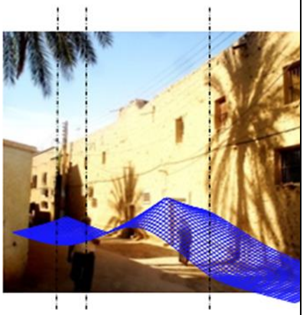
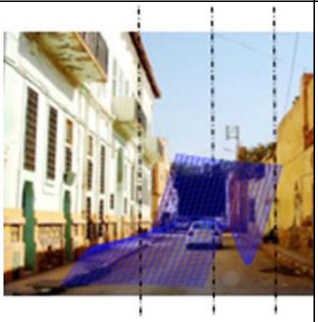
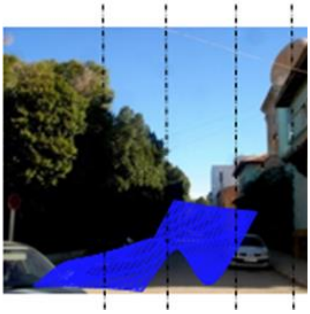
In contrast, the colonial and contemporary districts, with higher H/W reports of 0.50 and 0.70 respectively, show a substantial increase in illumination levels. The colonial district records an annual average illumination level cumulus (E_{ACD}) value of 6498,5 lux, while the contemporary district reaches an annual average illumination level cumulus (E_{ACD}) value 6692 lux. These higher E_{ACD} values can be attributed to the greater verticality relative to street width, which, when coupled with more regular and linear street geometries, enhances solar penetration by aligning with sun paths and reducing the shadowing effect of adjacent buildings. The contemporary district, despite having the highest H/W report, benefits from modern design principles that optimize solar access through building spacing and façade orientation. Thus, the findings demonstrate that increasing H/W reports, when integrated with thoughtful urban layout, can significantly enhance daylight availability, emphasizing the importance of proportional urban morphology in achieving sustainable and well-lit urban environments.

Impact of facade composition on the illuminance levels

The observed increase in illuminance levels can be primarily attributed to the morphological and dimensional characteristics of the urban street environment. Specifically, the penetration of substantial quantities of natural light is facilitated by the relatively low height of built structures, including buildings and surrounding walls, which results in minimal obstruction of sunlight and an expanded sky view factor. This openness enhances direct solar access, especially during midday periods. However, the presence of penumbras, partial shading zones cast by urban elements, plays a significant role in modulating the distribution and intensity of reflected light. Penumbras generated by both built structures and vegetation significantly reduce surface reflectivity, thereby tempering peak illuminance values and preventing excessive brightness (Street No. 4: Colonial district).

Building penumbras, generated by vertical surfaces and overhangs, reduces the reach of direct sunlight to certain spaces of the street, advancing more diffuse lighting conditions. Vegetative penumbras, resulting from tree canopies or planted elements, produce dynamic shading patterns that further attenuate glare and soften light contrast. These interactions highlight the importance of considering both structural dimensions and shading mechanisms in understanding and managing urban illuminance levels (Tab. 4).

Table 4. Impact of façade composition on the illuminance levels

Buildings and vegetations penumbras	White constructions reflectivity	Vegetations lighting non reflectivity
		

Vegetation applies a considerable effect on the horizontal variation of illuminance, even when exposed to direct solar radiation. The interaction between vegetative cover and received sunlight creates alternating zones of shade and illumination, resulting in a heterogeneous light distribution within the street surface. These contrasting zones influence local variations in illuminance, generating perceptible contrast effects that impact visual comfort and spatial perception. In the absence of direct solar exposure, such as under overcast conditions, daylight distribution tends to be more uniform, reducing contrast and promoting visual consistency.

Furthermore, surface reflectance, specifically building fronts, plays a significant role in influencing the luminous environment. White facades (Street No. 5: Colonial district), due to their high reflectivity properties, produce intense glare and visual discomfort, particularly when directly illuminated by sunlight. In extreme cases, the reflection from bright, smooth surfaces indicates dazzling effects within the field of view. However, these high-albedo surfaces also influence positively to street-level lighting by enhancing ambient luminance through reflected light. Therefore, the balance between favorable reflectance and potential visual disturbance must be carefully managed in urban lighting strategies.

Table 5. Luminous effects resulting in different configurations in the districts studied.

		
The color and the textures tune with the light environment	Effect of composition Form, Nature, Culture and Light	The low brightness embellished the field of view

Different urban morphologies fundamentally produce distinct illuminance levels, shaping the daylight environment and participating in the overall urban aesthetics and functionality. Light attends as a foundational element in defining urban form, inducing both the perception of space and the sustainability of the built environment (Tab.5). The quantitative variations in horizontal illuminance are primarily attributed to several key factors:

- The morphological and dimensional characteristics of the street.
- The effect of vertical surfaces, particularly urban facades.
- The color and texture of both horizontal and vertical surfaces.
- The influence of shadows and penumbras.

The perception of an urban ambiance is often based on quantitative light variations, as changes in illuminance directly impact visual comfort and spatial experience. Notably, abrupt transitions from shaded to illuminated areas can result in uncomfortable glare, which can disrupt the visual experience. In particular, facades with exceptionally white or reflective surfaces have a heightened potential to cause glare, due to their high reflectance properties.

However, both high and low illuminance levels can contribute to creating pleasant lighting environments, depending on the context and the balance of light distribution. While this study primarily addresses the visual aspects of urban lighting, it does not attempt to define the complete urban ambiance. Further research is required to explore additional sensory dimensions such as thermal, acoustic, and olfactory factors, which collectively influence the experience of urban spaces.

Conclusion

This research has demonstrated the significant impact of urban morphological parameters, particularly Sky View Factor (*SVF*), Height-to-Width (H/W) report, and façade characteristics, on the levels and distribution of natural illuminance within various urban districts. The findings reveal that while *SVF* is a critical indicator of sky openness, it does not act alone in determining street-level illuminance. Instead, the combination of *SVF* with other urban form variables, such as street orientation, façade reflectance, street width, and vegetation, more comprehensively explains the observed variation in light conditions. The contemporary district, which exhibited moderate *SVF* ratio and high H/W report, consistently recorded the highest average annual illuminance, highlighting the efficiency of modern planning principles in optimizing daylight access. In contrast, the traditional district, despite its high *SVF*, presented the lowest illuminance levels due to its dense, organic layout and narrow, shaded pathways. Similarly, higher H/W reports in colonial and contemporary districts correlated with improved light penetration, provided they were integrated with coherent geometric layouts and reflective surfaces.

This study also reveals that urban morphology meaningfully affects daylight performance in hot arid regions. The traditional district, with a low H/W ratio of 0.25, narrow winding streets, and a high SVF of 64%, presented the lowest average annual illuminance (5212.5 lux), revealing its inward-oriented organization that passively regulates light through multifaceted shading and reduced surface reflectivity. Otherwise, the colonial and contemporary districts, with higher H/W ratios of 0.50 and 0.70 and lower SVFs of 47% and 51%, respectively, registered higher illuminance values (6498.5 lux and 6692 lux), due to their straight-lined geometries, wider streets, and reflective facades. The examination releases that while SVF alone is not a definitive forecaster of light accessibility, the relationship of street proportions, building orientation, surface materials, and shading elements such as vegetation and penumbras communally adjust illuminance levels. These findings underline the importance of combined urban plan strategies that balance light admission and shading, principally in hot arid climates, where intense solar rays must be carefully moderated to reach visually comfortable and sustainable public spaces.

Conversely, this research is not without its limitations. While it reviews the spatial and seasonal variability of daylight in different urban morphologies, it does not report the perceptual and physiological qualities of urban daylighting such as glare, visual comfort, or the qualitative incident of light. Furthermore, this study was conducted under specific geographic and climatic conditions, which may not be generalizable to other regions. Future studies should aim to feature multi-sensorial urban ambiance assessments, incorporating thermal, acoustic, and olfactory dimensions, to develop a more general understanding of environmental quality in public spaces. Additionally, longitudinal studies using simulation and real-time monitoring could improve the analysis by assessing the dynamic interaction between urban design and natural lighting throughout the day and year. Ultimately, the results underscore the necessity of integrated urban planning approaches that prioritize both environmental performance and human well-being through informed morphological design.

Conflicts of Interest: The authors declare no conflict of interest.

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