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Evaluation of luminance levels. digital tool or traditional device? case study: Alameda Park in Saltillo, Mexico

Evaluación de niveles lumínicos ¿herramienta digital o dispositivo tradicional? caso de estudio: la Alameda en Saltillo, México

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Abstract

Assessing luminance levels in outdoor public spaces is relevant for the lighting design of architectural and urban environments. This article compares a digital tool and a traditional device for measuring luminance levels in outdoor settings, aiming to explore the pros and cons of each method and offer guidance to public space designers. The study involves a literature review of luminance measurement techniques and a comparative analysis of the results obtained using Fusion Optix software and a lux meter. Both methods exhibit benefits and drawbacks, with the choice of method hinging on the specific context and evaluation objectives. Generally, digital tools provide a more efficient and precise measurement of luminance levels, while traditional devices contribute to a broader understanding of the lighting environment. It is recommended that a combination of digital tools and traditional devices be employed in luminance assessments to achieve the most accurate and comprehensive results.

Daylight, Iuminance maps, Public space

Resumen

Evaluar los niveles de luminancia en espacios públicos exteriores es de gran importancia para el diseño de iluminación de entornos arquitectónicos y urbanos. Este artículo presenta una comparación entre una herramienta digital y un dispositivo tradicional para medir los niveles de luminancia en entornos exteriores, con el objetivo de explorar los pros y los contras de cada método y ofrecer orientación a los diseñadores de espacios públicos. El estudio implica una revisión de la literatura sobre técnicas de medición de luminancia y un análisis comparativo de los resultados obtenidos utilizando el software Fusion Optix y un luxómetro. Ambos métodos exhiben ventajas e inconvenientes, y la elección del método depende del contexto específico y los objetivos de la evaluación. En general, las herramientas digitales brindan una medición más eficiente y precisa de los niveles de luminancia, mientras que los dispositivos tradicionales contribuyen a una comprensión más amplia del entorno de iluminación. Se recomienda emplear una combinación de herramientas digitales y dispositivos tradicionales en las evaluaciones de luminancia para lograr los resultados más precisos y completos.

Espacio público, Luz natural, Mapas de luminancias

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Introduction

Evaluating luminance levels in outdoor public spaces is a fundamental aspect of lighting design. Luminance refers to the amount of light emitted or reflected by a surface and is measured in candelas per square meter (cd/m2) (Rea, 2019). In outdoor settings, luminance is influenced by several factors, including the position of the sun, locations of light sources, and the reflectivity of the surface (Krawez et al., 2021).

Measuring luminance is essential to ensure lighting design is appropriate for the intended use of outdoor spaces and to comply with safety and energy efficiency standards (Kwong, 2020). Natural light in built environments allows for comfortable and environmentally sound conditions for occupants, while providing the necessary light levels to meet human visual requirements (Córica & Pattini, 2005).

Using light as art can create comfort and various sensations, such as spaciousness and safety. The qualities of light, whether from natural or artificial sources, can be evaluated through either qualitative or quantitative parameters (Hosamo et al., 2023). In lighting, two terms are to be considered: illuminance and luminance:

- Illuminance is the amount of light needed to distinguish what we see, measured in lux or lm/m^2.

- Luminance is the amount of brightness or luminous energy perceived by the human eye from a surface, caused by a light source, measured in cd/m^2 or fL.

The difference between the two is that illuminance is a measure of light (quantitative) and luminance is related to visual perception and psychological sensations of light in relation to brightness (qualitative).

Visual comfort is an essential aspect of the design of both interior and exterior spaces. Therefore, studies using various tools and devices to evaluate outcomes and enhance proposals for the benefit of users are necessary.

Córica & Pattini (2005) suggest that predicting the behavior of natural light in urban settings requires an appropriate method that considers both objective (measurement-based) and subjective (occupant visual comfort evaluations) parameters.

Gutiérrez, Quintero, and Bermeo (2016) note that the performance of a digital camera as a luminance measuring instrument directly depends on the image format in which the camera processes and delivers the files. The amount of light the electronic sensor can capture and convert into an electrical signal depends on user-configurable parameters.

Rodríguez, Dumit, and Pattini (2019) compared illuminance values obtained with an LMT Pocket Lux 2 lux meter (as a gold standard) to illuminance readings from three Android applications installed on two different mobile devices in various scenarios with decreasing illumination levels, from 19 to 7495 lux. Their results showed an average error of 81.8%, indicating that these applications are still not suitable for ergonomic practice. The values obtained varied depending on the application and device used, without statistical significance, so it's not possible to recommend a specific application based on its accuracy. However, the selection criteria for illuminance measuring applications should be based on usability.

Digital tool or traditional device?

Evaluating luminance levels in outdoor spaces is an important aspect of lighting design. Luminance refers to the amount of light emitted or reflected by a surface and is measured in candelas per square meter (cd/m2) (Rea, 2019). In outdoor spaces, luminance is affected by various factors, including the position of the sun, the location of light sources, and the reflectivity of surfaces (Maskrenj et al., 2022). Measuring luminance is crucial to ensure that the lighting design is appropriate for the intended use of the outdoor space and to comply with safety and energy efficiency standards (Lamphar, 2023).

There are two main methods for measuring luminance levels in outdoor spaces: digital tools and traditional devices (Pan & Du, 2021). Digital tools include luminance meters that use digital cameras to capture images and software to analyze the images and calculate luminance levels (Kamath et al., 2022). Traditional devices include luminance meters that use photometers to directly measure light levels (Pan & Du, 2021). Both methods have their advantages and limitations, and the choice of method depends on the specific context and evaluation objectives.

Below is a comparative chart summarizing the advantages and disadvantages of digital tools and traditional devices in measuring luminance levels in outdoor spaces.

This chart aims to provide a quick visual comparison of the key features of both measurement methods, see Table1.

Aspect to Compare	Digital Tools	Traditional Devices
Efficiency	Fast and accurate in measuring luminance in outdoor spaces	Laborious and slow process in large areas
Complex Lighting Environments	May be more accurate than traditional devices	Possible difficulty in capturing all variations in luminance levels
Visual Representation of the Environment	Provide images showing the distribution of luminance levels	Limited ability to provide a visual representation of the lighting environment
Dependence on Software and Algorithms	Yes	No
Measurement of Other Light Parameters	Limited ability to measure color temperature and color rendering	Ability to measure color temperature and color rendering
Comprehensive Lighting Evaluations	May be limited in their utility due to the inability to measure other parameters	Provide more comprehensive evaluations of the lighting environment
Reflective Surfaces and Shadows	Possible difficulty in capturing all variations in luminance levels in these areas	Possible difficulty in capturing all variations in luminance levels in these areas
Identification of Luminance Areas	Facilitate the identification of areas of high and low luminance levels for design adjustments	Limited utility to identify areas of high and low luminance levels
Accuracy in Simple Environments	May be less accurate compared to traditional devices	Higher accuracy in simple lighting environments with low surface reflectivity

Table 1 Comparison of digital tools and traditional devices regarding various aspects of luminance measurement in outdoor spaces
Source: Miriam Mery-Ruiz 2023

Based on what has been previously stated, the main objective of this study is to compare a traditional device with a digital tool in evaluating luminance levels in outdoor spaces during daylight conditions. This analysis will take place in the children's play area of a public space known as La Alameda, located in the city of Saltillo, Coahuila.

Heat map images, a form of qualitative data visualization, have gained importance in various fields due to their ability to transform quantitative data into easily understandable visual representations (Kochhar et al., 2020). These visualizations help identify patterns, trends, and areas of interest, leading to more informed decision-making (Dzidic, 2023).

Revealing patterns and trends: the impact of qualitative visualization through heat maps from quantitative photographs

Heat maps have become a predominant tool for visualizing data and revealing patterns and trends in quantitative data (Khder et al., 2021). With the advancement of new technologies, they have evolved to include luminance maps as a way to visualize qualitative data from quantitative photographs (Zuo et al., 2022).

Heat maps are graphical representations of data that use color to represent data values. They are used to visualize large amounts of data and are particularly useful for identifying patterns and trends in complex datasets. They are created by plotting data values in a matrix format and using color to represent the data values. (Crameri et al., 2020). The color used in a heat map typically ranges from cool colors like blue and green to warm colors like red and yellow (Tham et al., 2020). This color representation allows users to quickly identify areas of high and low data values in the dataset.

Luminance maps, on the other hand, are a type of heat map that uses luminance values to represent data values (Stoelzle & Stein, 2019). These are created by plotting data values in a matrix format and using luminance values to represent the data values. The luminance values used in a luminance map usually range from dark to light, where darkness represents low data values and light represents high data values (Hattab et al., 2020).

Luminance maps have gained popularity in recent years as a means to visualize qualitative data from quantitative photographs. This is because luminance maps allow users to visualize the relative brightness of an image and identify areas of the image with high and low brightness values. Luminance maps are particularly useful for analyzing photographs because they allow users to identify patterns and trends in the image's brightness values. This can be used to identify areas of the image that are more likely to be of interest to the viewer and to emphasize areas that might require further investigation (Kheradmandi & Mehranfar, 2022).

The application of luminance maps as a method for visualizing qualitative data has had a significant impact on the analysis of patterns and trends in qualitative data (Levit et al., 2021). Luminance maps allow users to identify patterns and trends in the data that may not be immediately apparent when viewed in their raw form. This can be particularly valuable for identifying patterns and trends in large datasets, where it can be a challenge to identify patterns and trends simply by examining the data (Li et al., 2021).

Methodology

The research was conducted with a quantitative approach and at an explanatory level. A selection and map of the study area was elaborated, see Figure 1.

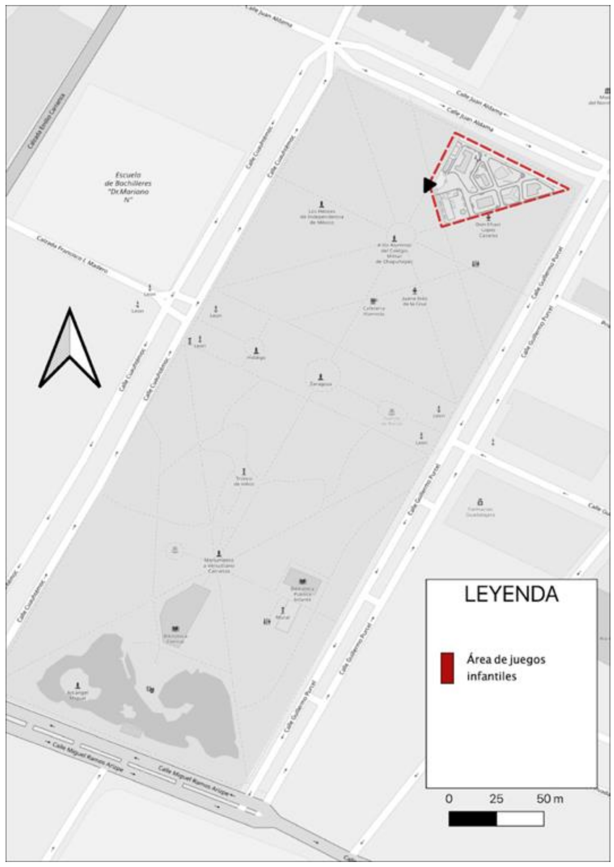

Figure 1 GIS ubication map of children's playground at Alameda "Zaragoza" Park in Saltillo
Source: Miriam Mery-Ruiz, based on OpenStreetMap, 2023.

The method used was fieldwork in which measurements were made using a lux meter (traditional device), and the Fusion Optix digital tool, an application that identifies the amount of luminance in the space through photographs (Fusion Optix, 2023; Espinoza Cateriano et al., 2020). This free application was installed on a Samsung A71 cellphone and set up to measure luminance in units of cd/m^2.

The Klein Tools ET130 lux meter is an automatic digital light meter that can measure light intensity in both foot-candles and lux. It has a wide measurement range of 0 to 40,000 fc or 0 to 400,000 lux, making it suitable for a variety of applications. The meter features an easy-to-read LCD display, a hold function to freeze the current reading, and a low battery indicator. It also has a data hold and max/min function to capture and display the highest and lowest readings. The meter is compact and durable, with a protective rubber casing and a handy built-in stand. It also comes with a 9V battery and a carrying case for easy transportation and storage (Klein Tools, 2023).

The Samsung Galaxy A71 cellphone is a mid-range smartphone with a strong focus on camera capabilities. The A71 has a quad-camera setup on the back, featuring a main camera with a 64MP sensor with an f/1.8 aperture, a 12MP ultra-wide camera with a 123-degree field of view and an f/2.2 aperture, a 5MP macro camera with an f/2.4 aperture, a 5MP depth camera with an f/2.2 aperture, and a 32MP front camera with an f/2.2 aperture (GSMarena, 2020).

Fusion Optix is an advanced application designed for professionals in the optics and photonics industry. It provides a comprehensive set of tools and features to simulate, analyze, and optimize optical systems. Key features of the software include an easy-to-use interface, extensive optical component libraries, and powerful algorithms for ray tracing, radiometry, and diffraction analysis. With Fusion Optix, users can efficiently design and optimize complex optical systems, reducing development time and costs while ensuring optimal performance and accuracy (Fusion Optix, 2023).

|A map, GIS in QGIS, of the study area was created. A measurement plan was established that included the selection of 17 measurement points and the hours at which the measurements would be made (one measurement every hour between 2:00 pm and 5:00 pm), see Figure 2.

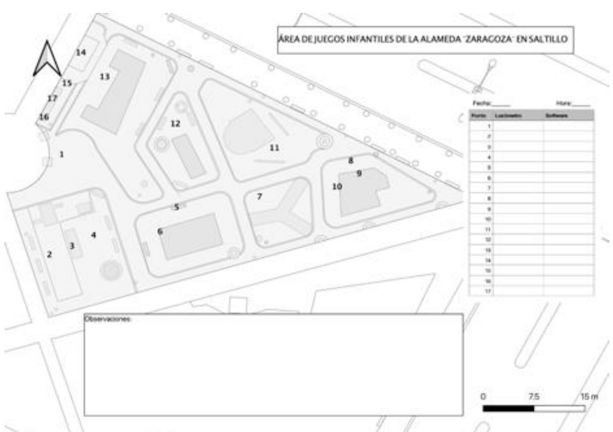

Figure 2 Instrument for measurements
Source: Miriam Mery-Ruiz, 2023.

Results

The children's playground at Alameda Zaragoza in Saltillo is a recreational space located in Coahuila, Mexico.

According to the city government's website (Municipal Government of Saltillo, 2022), the playground was designed with the intent to promote physical activity and healthy habits among children and families in the area. The playground is equipped with a variety of features, including swings, slides, climbing structures, and a central play area, see Figure 3.

Figure 3 Photographs of children's playground at Alameda "Zaragoza" Park in Saltillo
Source: Miriam Mery-Ruiz. 2023.

The measurements with the lux meter and luminance maps using the Fusion Optix software were carried out between 2:00 pm and 5:00 pm on December 21, 2021, at the measurement points shown in Figure 4.

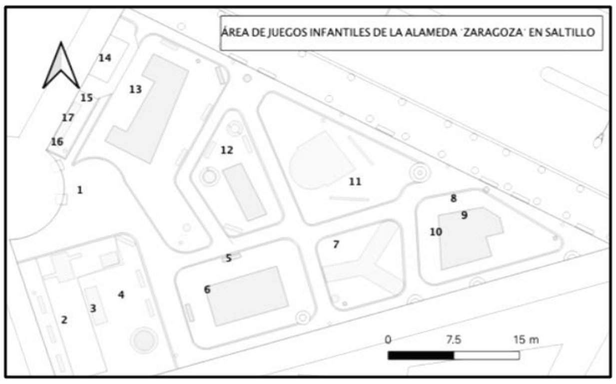

Figure 4 GIS Map with measurement points in children's playground at Alameda "Zaragoza" Park in Saltillo
Source: Miriam Mery-Ruiz. 2023

A photograph was taken every hour to capture the different points. The luminance maps were obtained, which can be seen in Figure 5, Figure 6, Figure 7, Figure 8, Figure 9, Figure 10, Figure 11, Figure 12, Figure 13, and Figure 14.

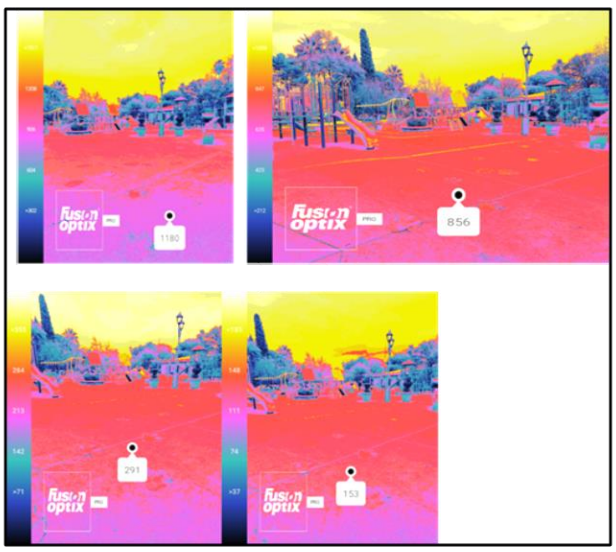

Figure 5 Luminance maps 14:00, 15:00, 16:00 and 17:00h at point 1
Source: Miriam Mery-Ruiz. 2023. Photographs taken with Fusion Optix app.

Figure 6 Luminance maps at 14:00, 15:00, 16:00 and 17:00h at points 2, 3 and 4
Source: Miriam Mery-Ruiz. 2023. Photographs taken with Fusion Optix app

Figure 7 Luminance maps 14:00, 15:00, 16:00 and 17:00h at points 5 and 6
Source: Miriam Mery-Ruiz. 2023. Photographs taken with Fusion Optix app

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Figure 8 Luminance maps 14:00, 15:00, 16:00 and 17:00h at point 7
Source: Miriam Mery-Ruiz. 2023. Photographs taken with Fusion Optix app

Figure 9 Luminance maps 14:00, 15:00, 16:00 and 17:00h at points 8, 9 and 10
Source: Miriam Mery-Ruiz. 2023. Photographs taken with Fusion Optix app.

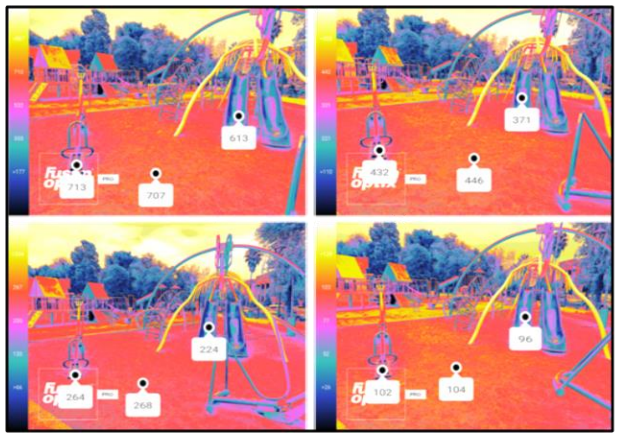

Figure 10 Luminance maps 14:00, 15:00, 16:00 and 17:00h at point 11
Source: Miriam Mery-Ruiz. 2023. Photographs taken with Fusion Optix app.

Figure 11 Luminance maps 14:00, 15:00, 16:00 and 17:00h at point 12
Source: Miriam Mery-Ruiz. 2023. Photographs taken with Fusion Optix app.

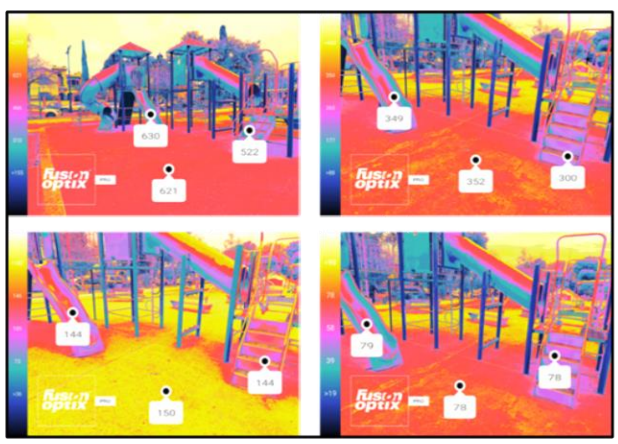

Figure 12 Luminance maps 14:00, 15:00, 16:00 and 17:00h at point 13
Source: Miriam Mery-Ruiz. 2023. Photographs taken with Fusion Optix app.

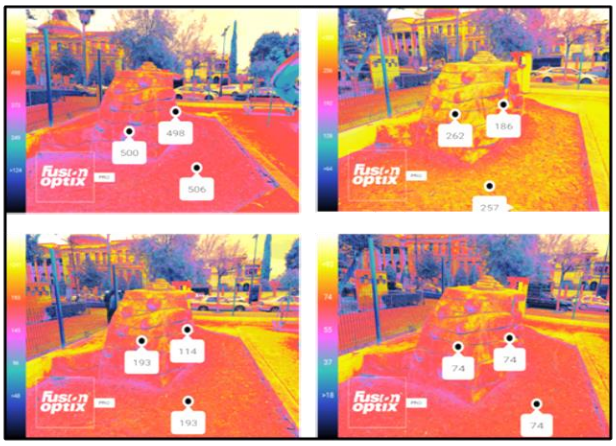

Figure 13 Luminance maps 14:00, 15:00, 16:00 and 17:00h at point 14
Source: Miriam Mery-Ruiz. 2023. Photographs taken with Fusion Optix app.

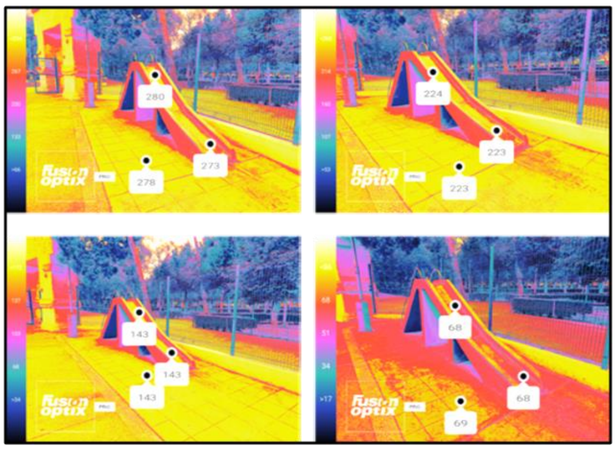

Figure 14 Luminance maps 14:00, 15:00, 16:00 and 17:00h at points 15, 16 y 17
Source: Miriam Mery-Ruiz. 2023. Photographs taken with Fusion Optix app.

Subsequently, the information was processed into a table to identify the variations of light energy based on the time and the device or tool, see Table 2.

	Measurement with lux meter (traditional device)				Points on luminance maps with digital tool (Fusion Optix)			
Measurement hour	14:00	15:00	16:00	17:00	14:00	15:00	16:00	17:00
Measurement point	FC				cd/m^2			
1	2086	2044	626	184	1180	856	291	153
2	1906	1868	703	220	429	419	161	77
3	2339	2222	786	237	430	425	163	77
4	2506	2471	756	228	438	426	161	76
5	2268	2158	846	266	730	627	200	101
6	2539	2295	851	273	836	657	237	101
7	2359	1702	884	281	821	511	256	94
8	2650	2043	888	255	1042	811	349	148
9	2737	2101	909	241	1046	804	348	148
10	2757	2130	917	259	1060	822	363	149
11	2480	1776	982	206	707	446	268	104
12	2268	1958	1083	200	564	384	223	94
13	1954	1852	986	175	621	352	150	78
14	1836	1772	908	163	506	257	193	74
15	1713	1497	793	140	278	223	143	69
16	1606	1470	756	132	280	224	143	68
17	1595	1341	743	123	273	223	143	68

Table 2 Measurement results with luxometer and in heat map photographs with luminances. (Fusion Optix)
Source: Miriam Mery-Ruiz. 2023

Comparison between luxmeter measurements and photographs

Luxmeter measurements generally yielded higher luminance values compared to the Fusion Optix photographs at all measurement points and times.

The greatest difference between luxmeter and Fusion Optix measurements was observed at point 1 at 14:00, with a difference of 906 FC (2086 FC for the luxmeter versus 1180 FC for Fusion Optix) and 864 cd/m^2 (2044 cd/m^2 for the luxmeter versus 1180 cd/m2 for Fusion Optix).

The smallest discrepancy between the two measurement methods was observed at point 17 at 17:00, with a difference of only 6 FC (123 FC for the luxmeter vs. 117 FC for Fusion Optix) and 5 cd/m^2 (68 cd/m2 for the luxmeter versus 63 cd/m^2 for Fusion Optix). Differences between luxmeter and Fusion Optix measurements tended to be more pronounced with higher luminance values, whereas differences were relatively smaller with lower luminance values.

The general trend of luminance values at different times of the day was similar between luxmeter and Fusion Optix measurements, with higher values recorded at 14:00 and 15:00, followed by a decrease at 16:00 and 17:00.

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Conclusions

The analysis of measurements with the luxmeter and luminance points in Fusion Optix photographs showed significant variations in luminance values throughout the day.

Specifically, peak luminance values were identified between 14:00 and 15:00 hours, with a noticeable drop between 16:00 and 17:00 hours. Such data is instrumental for enhancing lighting conditions and furthering energy efficiency, as highlighted by (Córica & Pattini, 2005).

To gain deeper insights into these fluctuations, it may be beneficial to delve into influencing factors such as the angle of light incidence, surface attributes, or the presence of shading elements.

When comparing the data from the luxmeter and Fusion Optix, there were evident discrepancies. Typically, the luxmeter reported higher values. However, despite these disparities, both methodologies showcased a parallel trend in daily luminance values. It becomes pertinent to understand the factors behind these discrepancies, which could stem from diverse measurement techniques, calibration differences, or varied sensitivities to light conditions. Exploring these nuances further can help in discerning the most precise luminance assessment method in varying settings, as indicated by research from Córica & Pattini (2005) and Sosa Domínguez (2016).

The choice of method to measure outdoor luminance levels depends on the specific needs of the lighting designer or researcher. In some cases, digital tools might be more suitable, especially in large or complex lighting environments, while in others, traditional devices might be more appropriate, especially when a more comprehensive analysis of the lighting environment is needed.

It is pivotal to understand that utilizing digital tools for outdoor luminance measurements is still a burgeoning approach. As such, comprehending their precision, reliability, and efficacy necessitates more extensive research.

Further studies can offer clarity about the strengths and limitations of digital tools in varied contexts. They can also guide the creation of more precise and trustworthy software and algorithms designed for the analysis of outdoor lighting visuals.

The choice between digital tools or traditional devices to measure outdoor luminance levels depends on several factors, such as the complexity of the lighting environment, the accuracy and precision required, and the specific needs of the lighting designer or researcher. Ultimately, combining the use of digital tools and traditional devices can provide valuable insights into the lighting environment and contribute to the development of more efficient and sustainable lighting designs for outdoor spaces.

Existing literature underlines that both digital tools and traditional apparatus come with their set of strengths and limitations in the context of outdoor luminance measurements. While digital tools offer efficient and precise luminance measurement capabilities, traditional devices grant a more exhaustive comprehension of the lighting environment.

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