

Metrics for assessing daylight performance in workspaces: A systematic review of research approaches

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Abstract. The use of daylight is a major concern to save energy and decrease the workload of lighting installations. Over the last decades, the methods assessing daylighting performance in workspaces have transitioned from static metrics based on ideal sky conditions and point-in-time photometric descriptors to dynamic models relying on hourly climate data. In parallel, other approaches have been developed, including occupant-oriented perceptual metrics and non-visual indicators aimed at characterizing the potential effects of daylight on physiological and circadian responses. As a result of the considerable amount and broad variety of metrics currently available, evaluating daylighting performance has become challenging. In order to understand the current state-of-the-art, a systematic review of the recent literature on daylighting performance assessment in workspaces has been conducted. Different daylight adequacy metrics were identified from 44 studies and classified into four categories: static metrics; climate-based dynamic metrics; occupant-oriented perceptual metrics; and metrics for assessing non-visual daylight effects. The results obtained demonstrate the consolidation of climate-based dynamic metrics as the predominant method for evaluating daylighting performance, as well as the still limited integration of perceptual and circadian metrics. Other findings include the need to develop integrative conceptual frameworks that ensure a more coherent evaluation of daylighting performance.

Keywords. Energy efficiency; Indoor lighting; Climate-based daylight metrics; perceptual metrics; circadian metrics.

1. Introduction

Exposure to daylight has played a major role in human evolution, shaping our visual system and driving the development of biological mechanisms modulated by daylight cycles. Natural light is characterized by continuous temporal and spatial variations in terms of irradiance, spectral power composition, directionality, and distribution [1]-[2] that differentiate it substantially from artificial lighting systems [3]. However, the implementation of universally applicable lighting solutions is precluded by the inherent variability of natural light, together with the particularities of human vision, the complexity of visual signal processing in the brain, and inter-individual variations in the interpretation of visual signals and the environment [4].

Conceptual and experimental works reveal that lighting conditions should not be addressed from a merely technical perspective alone. Rather, an integrative approach should be adopted to jointly consider the physical, physiological and perceptual aspects of lighting, especially in human-occupied spaces [5]-[6].

Daylight spectral distribution, high irradiance and temporal signal stability contribute to optimal visual performance. Moreover, natural light elicits non-visual responses such as synchronizing circadian rhythms, regulating hormone production, and influencing alertness and sleep patterns. These effects are mediated by the activation of ipRGC photoreceptors, which are especially sensitive to short-wavelength light [7].

The scientific evidence available highlights the necessity to integrate spectral, radiometric, photometric and temporal parameters in daylighting performance evaluation models. However, numerous and heterogeneous metrics are available, including static metrics, climate-based dynamic metrics, perceptual indicators, and circadian stimulation metrics. Such variety challenges the selection and standardized implementation of metrics in architectural design. This paper presents a classification of the metrics used in recent publications on daylighting performance. Additionally, a summary is provided of the conceptual foundations of natural light adequacy. Finally, conclusions are offered about the utility and efficacy of these metrics in assessing daylighting performance in built spaces.

2. From static to multidimensional approaches to assess daylight performance

The methods utilized to assess daylighting performance in workspaces have transitioned from static metrics based on ideal sky conditions and static photometric descriptors to dynamic models where daylight variations in space and time are considered. The evidence available underlines that the dynamic nature of natural light is not contemplated by traditional methods. The influence of local climate, solar geometry or interactions with built environments is also overlooked [8].

The advent of Climate-Based Daylight Modeling (CBDM) [9] represents a breakthrough, since it incorporates hourly weather data. This new approach has made it possible to evaluate and predict daylight performance under real-life conditions. Novel α -opic-based illuminance metrics [7], added to advancements in visual neurophysiology [10]-[11] demonstrating that spectral composition and vertical eye-level illuminance stimulate biological functions [12]-[13] led to the inclusion of biological responses in studies. Likewise, perceptual criteria have recently been integrated into the definition of daylight adequacy [14].

Figure 1 summarizes the evolution of daylight performance assessment approaches as the integration of new assessment dimensions progressively added complexity. In this setting, the need arises for a structured classification of metrics.

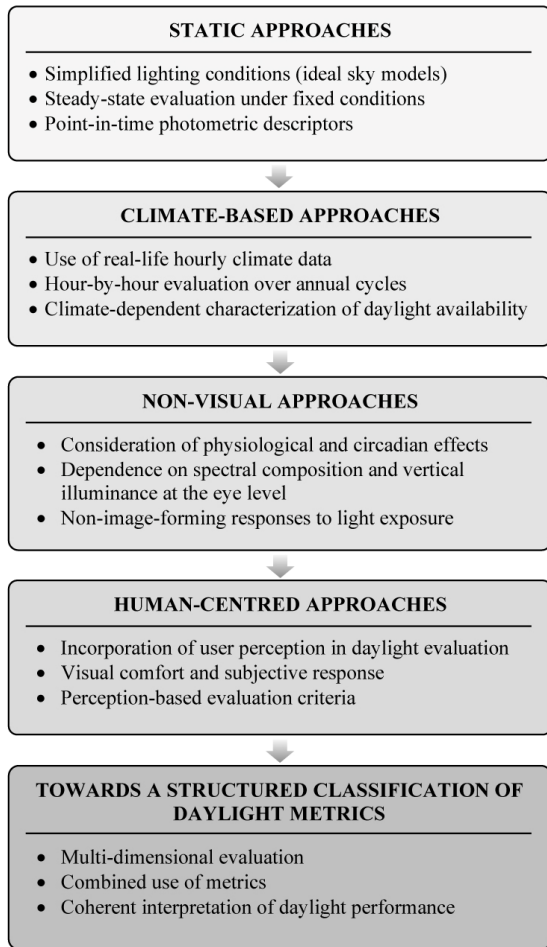


Fig. 1. Evolution of daylight performance assessment approaches.

3. Daylighting performance metrics in the recent literature

Following a thorough review of the 44 works included, the metrics used in the literature on natural light adequacy have been identified and categorized. To provide a snapshot of trends in this field, a systematic search of the Scopus and Web of Science databases was conducted, including journal and conference papers published between January 2024 and January 2026.

The systematic review included studies assessing illuminance under documented daylighting or hybrid

lighting conditions. Non-scientific or non-quantitative studies were excluded. Then, metrics were classified into four categories: static metrics; climate-based dynamic metrics; perceptual indicators; and metrics for non-visual effects. A description of the categories identified and the studies where they were applied is provided below.

It is worth noting that a high proportion of the studies applied daylighting performance metrics along with geometric design parameters, material properties, and energy-related variables as input or control variables; however, the latter are not daylighting evaluation metrics in a strict sense.

A. Static metrics

Static metrics are used to characterize lighting at a given point in time or scenario of reference and continue to be applied in studies assessing daylight conditions in workplaces. Average illuminance on the horizontal work plane (E_m) is extensively used as a descriptor of daylight adequacy in studies assessing daylight availability or evaluating different lighting design options [12],[14]-[27]. Uniformity (U_0) is defined as the ratio between minimum and average illuminance over a working area. This parameter is used in some studies as a complementary indicator to evaluate spatial daylight distribution [15]-[16],[18]-[19],[22],[27].

The recent literature scarcely integrates other metrics such as Daylight Factor (DF) –defined as the ratio of indoor to outdoor light level under standard overcast conditions expressed as a percentage– and its variants, namely Average Daylight Factor (DF_{avg}) and Minimum Daylight Factor (DF_m) [15],[19],[25],[28]. These variables are used either as complementary metrics or to compare them to dynamic metrics and demonstrate their validity or limitations when characterizing natural light performance.

B. Climate-based daylight metrics

Climate-based daylight metrics (CBDMs) incorporate hour-by-hour weather and occupancy data to assess daylight availability throughout the year under realistic conditions.

In a limited number of studies, Daylight Autonomy (DA) was used to estimate the percentage of time that illuminance exceeds a defined illumination threshold set based on the use or activities performed in a workspace [8],[14]-[15],[29]-[31]. Albeit historically relevant, the use of CBDMs is currently constrained to methodological analyses or location-specific daylight availability studies. According to García-Martín et al. the development of the novel metric Continuous Overcast Daylight Autonomy (DA_{o.con}) has raised renewed interest in CBDM [30].

The most commonly used daylight autonomy metric is Spatial Daylight Autonomy (sDA). This parameter measures the percentage of area receiving sufficient daylight for a minimum proportion of annual operating hours under real-life weather conditions. Since this metric includes spatial and temporal variables, it is especially useful for comparative and workspace optimization studies [8],[14],[17]-[18],[21]-[22],[25],[30]-[42].

Useful Daylight Illuminance (UDI) is extensively used to quantify the percentage of time that illuminance remains within the useful illuminance range. UDI is rated as insufficient, useful/sufficient and excessive [8],[15]-[16],[18]-[20],[25],[28]-[33],[36],[38]-[40],[43]-[53]. The spatial variant of UDI, Spatial Useful Daylight Illuminance (sUDI) [27], [31], was integrated into a small number of studies; hence, despite being of interest, the use of this metric is still considerably limited.

Annual Sunlight Exposure (ASE) specifically quantifies the percentage of the working plane receiving excessive direct sunlight for a significant number of hours per year. This parameter is frequently used alongside sDA and UDI to assess the balance between daylight availability and excessive daylight levels [8],[17],[19],[22],[29]-[30],[32],[35]-[37],[39]-[40].

Numerous studies incorporated Daylight Glare Probability (DGP) to assess glare. This metric quantifies the likelihood that an occupant will perceive glare from sunlight. It is widely used as a reference metric for assessing visual comfort under a variety of daylighting designs [15]-[16],[18],[20]-[21],[27],[29],[38],[41]-[43], [49]. Vanage et al. combined DGP with a variant, Simplified Daylight Glare Probability (DGPs), a simplified empirical equation relating to vertical illuminance at the eye level of the occupants and glare [51].

Other authors complementarily utilized annual metrics including Glare Autonomy (GA) [29] and, most commonly, Spatial Glare Autonomy (sGA) [21],[27]-[29],[38],[42]-[43]. These metrics quantify the temporal and spatial fraction where target visual comfort requirements are met according to predefined glare thresholds. These requirements are often established based on Daylight Glare Probability (DGP) values, thereby enabling to measure glare on an annual and spatial basis.

To assess specific daylight availability components, some authors recently incorporated aggregated indicators and ratios not fully quantified by standard CBDM. Song et al. integrated Uniformity of Daylight (UOD), a descriptor of annual daylight uniformity, defined as the ratio of minimum illuminance to average illuminance across different positions or areas [41]. Hao et al. developed the CBDM-based Visual-effective Frequency (VF) metric to evaluate annual visual performance. The authors defined this metric as the percentage of days in the annual analysis period when the horizontal illuminance at a designated location on the desktop reached or exceeded a standard threshold. The authors used this metric to simultaneously evaluate and compare daily visual and non-visual lighting performance in combination with specific melanopic lighting metrics [12].

C. Metrics for non-visual effects

The increasing attention paid to the effects of daylighting in workspaces has led to the development of new metrics that quantify the effects of natural light on circadian rhythms and other non-image forming effects.

As opposed to studies exclusively focused on horizontal illuminance, some studies included vertical eye-level illuminance (Ev) as an input variable to estimate potential circadian responses [23],[25]-[26].

Novel α -opic-based illuminance metrics, including Equivalent Melanopic Lux (EML) [20] and melanopic Equivalent Daylight Illuminance (m-EDI), have been incorporated [12],[13],[20],[25]. These metrics are based on the spectral weighting of the incident luminous signal according to melanopsin-based sensitivity. Although the two metrics measure melanopic stimulation, they rely on different illuminance reference systems. Whereas EML quantifies melanopic stimulation in terms of illuminance equivalent values, m-EDI expresses this stimulation as equivalent standard daylight illuminance values, which facilitates direct conversion between the two metrics [20].

Based on these melanopic metrics, a variety of derived metrics have been designed to characterize circadian light exposure over defined time periods. An example of these indicators is Circadian Frequency (CF), which quantifies the percentage of days in a year where lighting in an area meets or exceeds a given EML threshold over a specific time period, as calculated from average values [12],[25]. Another metric, the Circadian Stimulus Autonomy (CSA), is used to calculate the percentage of days when a threshold for adequate melatonin suppression is met solely by daylight during a specific time of the day, typically in the morning [30],[40].

Wang et al. proposed the Daylight Vertical Illuminance Availability (DVIA) metric to quantify daylight effectiveness in supplying the required eye-level illuminance [42].

D. Perceptual daylight metrics

In some studies, daylight adequacy was defined concurrently considering photometric and perceptual criteria. Arango-Díaz et al. incorporated the Perceptual Daylight Autonomy (pDA) metric and its spatial variant, Spatial Perceptual Daylight Autonomy (spDA). These metrics help establish illuminance thresholds as a function of the likelihood that a percentage of occupants perceives daylight to be sufficient at a given area. For such purpose, the authors developed perceptual models using field data and local climate conditions [14]. Exterior View Quality (EVQ) was assessed in other studies by considering the presence, depth and characteristics of the external surroundings and their association with occupant-reported satisfaction [25]-[26],[51],[54].

Table I summarizes how each family of metrics is focused on specific daylight performance dimensions. No family provides a comprehensive assessment of daylight performance. This table shows a conceptual classification based on their common use in the literature.

Table I. – Daylight performance coverage by metric families

METRIC FAMILY	TEMP	CLIM	SPEC	PERC	NON-V
Static	N	N	N	N	N
CBDM	Y	Y	N	P	N
Perceptual	P	P	N	Y	N
Non-visual	P	P	Y	N	Y

Note. Temp: Temporal; Clim: Climate-dependent; Spec: Spectral; Perc: Perceptual; Non-V: Non-Visual; Y: Yes; N: No; P: Partial

4. Discussion

The findings of this systematic review confirm that climate-based daylight metrics (CBDMs) are the current reference methodological framework for evaluating daylight adequacy in workspaces. Among them, UDI and sDA were the most used metrics, demonstrating extensive integration into contemporary climate-based daylighting models. This high level of acceptance is explained by their ability to describe hourly variations in daylight.

The prevalence of CBDMs over static metrics is primarily due to them accounting for the dynamic nature of daylight. However, other practical considerations also played a role in the dissemination of these metrics, such as the availability of hourly weather data facilitating their application, or the possibility of using these metrics to assess variations in daylighting performance across different architectural designs. In this line, the wide acceptance of UDI demonstrates its usefulness, since with a single annual indicator, insufficient, adequate and excessive daylight can be identified under realistic conditions.

The results of this study reveal a moderate –albeit significant– use of other CBDM indicators like glare metrics (DGP and sGA), or ASE. This finding demonstrates a growing interest in controlling excessive sunlight exposure and visual comfort when evaluating daylight adequacy.

The lack of standardization in CBDMs usage is noteworthy. Considerable variability was noted in the criteria applied to define excessive or adequate daylight. Additionally, differences were observed in the time periods; sDA, UDI, and ASE thresholds; and glare indicators applied. These inconsistencies are most probably due to investigators' efforts to adapt variables to local climate conditions, as well as to the particular purposes and designs of their studies. Although these adaptations may be necessary, they hinder cross-comparison between studies and limits their use for regulatory and standardization purposes.

The coexistence of such a variety of metrics (static, climate-based dynamic, perceptual and non-visual metrics) demonstrates significant advances in the evaluation of daylighting performance and the fragmentation that characterizes this discipline. Many of the reviewed studies use a combination of metrics, but without establishing a clear hierarchy or conceptual structure that explains how their different purposes and scales are related. Variability across local approaches mirrors the multidimensional nature of daylight availability. These findings highlight the necessity of developing integrative models based on a standardized use of photometric, perceptual and physiological indicators.

Notably, the application of perceptual metrics continues to be limited and secondary to the prevailing photometric indicators. The use of specific metrics such as pDA and its spatial variant is still very limited and mostly exploratory. Although the relevance of occupant perception is widely recognized, it has not translated into a progressive integration of subjective variables into daylight availability evaluation studies. This may be explained by the limited

external validity of perceptual models, added to their reliance on contextual and cultural variables.

Likewise, an incipient use of metrics for measuring biological effects of daylighting was observed. A small number of studies integrated α -opic, melanopic stimulation and eye-level illuminance metrics. Moreover, these metrics were used as complementary measures rather than as the primary focus of multimetric studies. The novelty and limited recognition of these metrics may explain their low level of implementation; however, other factors may play a role, including the lack of standard thresholds, difficulties in accurately measuring occupant exposure to natural light, and challenges to their integration in modeling systems and architectural design processes.

In summary, the results of this study reveal the need for standard and integrative daylighting performance evaluation models based on a combination of different types of metrics. The variety of metrics available demonstrates an increasingly deeper understanding of the complexity of daylighting. It is necessary to develop well-structured models that aggregately consider natural light availability, visual comfort, occupant's perception, and non-visual effects. These findings open an avenue for future research and underscore the need to improve the contributions of scientific knowledge to regulatory and architectural design practice.

Figure 2 presents a conceptual diagram of daylight performance showing metric families and their design implications.

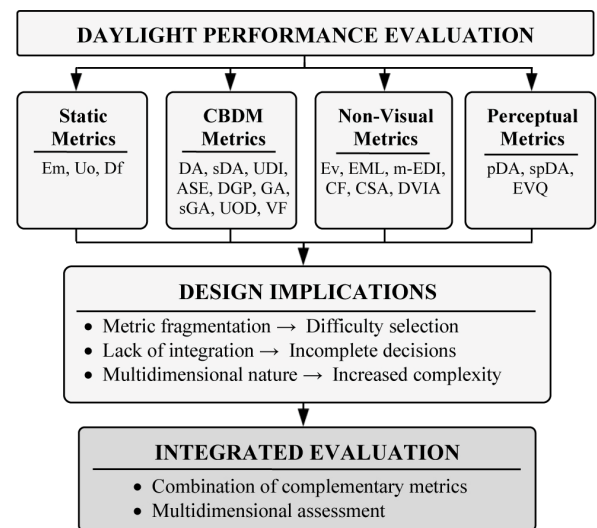


Fig. 2. Conceptual scheme of daylight performance evaluation: metric families and design implications.

6. Conclusions

Given the necessity of methods to optimize energy consumption in electrical installations, this work carries out a systematic review of the recent literature on daylighting performance in workspaces. It provides a structured perspective of the metrics currently used in studies, and its main contribution lies in the classification of documented metrics and the identification of methodological trends in this field of research.

Climate-based metrics are increasingly adopted as the predominant reference approach for evaluating annual daylight performance, albeit their use has not yet been standardized. Perceptual and non-visual metrics still play a secondary role, and their integration with the prevailing photometric metrics is limited.

In conclusion, the main challenge facing daylighting performance evaluation is not the scarcity of metrics, but the absence of an integrative conceptual framework that articulates the different metrics available. This study outlines current trends and provides a foundation for the development of robust evaluation models that improve result interpretability and facilitate their application in architectural design.

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