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Daylight metrics and requirements:
a review of reference documents for architectural practice

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ABSTRACT: Daylight has always been part of the architectural practice, since architects always used it to define spaces and create complex structures. Daylighting is, nowadays, seen as key strategy for sustainability, energy efficiency and resilience in buildings. This article aims to investigate daylight requirements in reference documents for architectural practice, through the collection and qualitative analysis of documents. To the analysis, primary documents were collected through active searches and through the application of a survey to daylight specialists from different countries. Then, 130 reference documents were analysed, divided into standards, rating systems, building and urban codes, regulations and guidelines. Results show that static and dynamic metrics are common within standards and rating systems, while building and urban codes and regulations often use metrics based on building and urban geometry. Among standards and rating systems, Daylight Factor (DF) is still one of the most used metrics, even if dynamic metrics offer advanced analyses; building and urban codes and regulations are very specific from each location, with predominant use of geometric metrics; and guidelines can use both types of metrics.
KEYWORDS: Daylight requirements, Standards, Rating systems, Building and urban codes, Regulations, Guidelines.

1. INTRODUCTION

Daylight has always been essential to mankind's development: it allows visibility and influences health [1,2,3]. Due to that, it is a vital part of architectural practice: using daylight, architects define spaces and create high complexity structures, in order to provide comfortable and pleasant places [4,5]. Moreover, daylighting is one key strategy to increase energy efficiency and contributes to enhance buildings' resilience against failures of electricity [3,6].

Daylighting requires a wide comprehension of how it affects occupants and spaces, which is not always clear to architects [7,8,9]. In that context, daylight requirements, even though cannot ensure good design, may contribute to better guidance, avoiding poor design decisions and facilitating architectural practice [9,10,11].

The requirements concerning daylight in reference documents are composed by metrics — a combination of quantities and conditions — and parameters — values or boundaries that act as guidance to enable evaluations [10,11,12].

As there is a large number of possible international reference documents, in this article, the documents evaluated were: standards, rating systems, building and urban codes, regulations and guidelines, considered crucial for buildings' and cities' projects. Those documents are developed by international and national authorities, professional organizations or institutions [11].

Standards are official publications with technical recommendations about the quality, safety and other features of a product [13]. In the case of buildings, standards provide guidance about daylight, acoustic, thermal comfort, performance, etc [2].

Rating systems are schemes that measure levels of compliance or performance of buildings, according to specific criteria [14]. Today, rating systems are seen as key drivers of sustainability in architecture, and have a significant commercial appeal [2].

Building and urban codes are elaborated by local authorities, focused on development and construction, defining rules about buildings and urban fabric. Building and urban codes propose design, regulation and planning, with the aim to achieve higher quality spaces [15]. Also, the existing urban fabric can and should be enhanced by the rules defined by codes, as they are expected to assure sustainable strategies, social and ecofriendly development, nature-based solutions, and so on. Usually, codes are legally binding and seen as "models" for jurisdictions [15,16].

Regulations are documents to ensure buildings are secure for people in or around them. Elaborated by the state or local government, regulations contain a series of approved requirements and rules for urban spaces and buildings, covering the technical aspects of construction. Historically, their application is necessary to building construction activities and to compose a city's governance [17,18].

Guidelines are a set of policies, rules and procedures promulgated and/or amended by the developer or the local control authority, that act as a guide for architectural activities [18]. Guidelines also help to preserve the long-term vision and property value of a community, by outlining requirements for builders, regarding styles and exterior features, as well as provide a set of good design practices [19].

This article investigates daylight requirements on reference documents for architectural practice. The work is part of the *Commission Internationale de l'Eclairage* (CIE) Technical Committee 3-61 (TC 3-61), which aims to assess the feasibility of global harmonization of daylight requirements.

2. METHOD

The steps fulfilled during the research were:

- Collection of primary documents: sent by members of TC 3-61 and other specialists, or collected from associations and stakeholders' websites, from Dec/2022 to Feb/2024;
- Application of survey: sent to daylight specialists from research institutes and associations, to gather information from different countries;
- Elaboration of summary tables: according to document, requirements, countries, metrics;
- Analysis of data and conclusions: quantitative and qualitative analysis of the findings.

This article comprehended the analysis of 130 primary reference documents obtained, including standards (45), rating systems (26), building and urban codes and regulations (49) and guidelines (10).

3. RESULTS AND DISCUSSION

The reference documents were received in their original versions or in summaries elaborated by specialists. The documents include not only requirements specifically related with daylight, but also those related to lighting in general, energy efficiency, architecture, and urbanism. This article, though, focused on requirements that influence daylighting in buildings and in urban fabric.

3.1 Daylight requirements and metrics

Daylight requirements are basically composed by parameters and metrics. Those must be accurate enough to evaluate the project's features [9]. A "parameter" is a limit, or a boundary, that acts as a factor that enables judgement or evaluation of something — e.g., a numerical value. As for "metric", it is a way to measure or evaluate something, with the use of figures or statistics [2,12].

Requirements influence directly on building and urban design strategies, since those are crucial references for practitioners [9]. Yet, for their use to be effective in architectural practice, requirements have to be objective, simple, testable, replicable, and able to give robust and reliable results [20].

Daylight metrics are classified between static, dynamic and geometric. Static metrics, the first created, were initially calculated by tables and two-dimensional drawings, based on point-in-time illuminances under a single sky condition [9,21,22, 23]. As main example of static metrics, there is Daylight Factor (DF) and its variations. Dynamic metrics, introduced by year-round climate-based daylight modelling (CBDM) embodying 8,760h/year of climatic data, allowed the acceleration of calculations and provision of realistic and accurate results [9,22]. Therefore, dynamic metrics are based on what time of the year daylight is able to provide the light levels required. As examples of dynamic metrics, there are Daylight Autonomy (DA), Spatial Daylight Autonomy (sDA), Useful Daylight Illuminance (UDI), Annual Sunlight Exposure (ASE), Sunlight Exposure and Daylight Glare Probability (DGP) [2,21,22].

The geometric metrics are those related to areas, distances, angles, as well as building shape and material properties, such as Window-to-Floor Ratio (WFR), Window-to-Wall Ratio (WWR), Outside views, setbacks, lightwells, obstruction and shadowing angles, Visible Light Transmittance (VLT) [20]. Metrics and their definitions are found in Table 1.

Table 1: Definitions of found daylight metrics.

Metrics	Definitions
Daylight Factor (DF)	ratio of illuminance on a horizontal surface to the unobstructed overcast sky, considering reflections [2,21]
Average Daylight Factor (DF_{avg})	ratio of illuminance on a horizontal surface to the unobstructed overcast sky, considering reflections, across a grid of points [2,21]
Daylight Autonomy (DA)	ratio of occupied hours in a year in which a minimum illuminance range is attended only by daylight [23,24]
Spatial DA (sDA)	area of work plane that meets an ideal illuminance ($sDA_{lx/\%}$) [21]
Useful Daylight Illuminance (UDI)	range of illuminances values across the work plane along one year [24]
Annual Sunlight Exposure (ASE)	amount of sunlight reached in a part of occupied hours per year [25,27]
Target Illuminance (E_T)	illuminance achieved across 50% of the reference plane for at least half of the daylit hours [28]
Minimum Target Illuminance (E_{Tmin})	minimum illuminance achieved across 95% of the reference plane for at least half of daylit hours [28]
Sunlight Exposure	sum of the time (h) in which spaces are exposed to sunlight [28]
Outside views	visual contact with the surroundings through openings façades [28]
Daylight Glare Probability (DGP)	probability of discomfort by glare, based on vertical luminance and illuminance of source [7,21]

Daylight Glare Index (DGI)	the ratio of total window area to total floor area [21]
Window-to-Floor Ratio (WFR)	the ratio of total window area to total floor area [29]
Window-to-Wall Ratio (WWR)	the portion of an exterior wall that consists of windows [30]
Obstruction angles	the angle from the centre of the window to the top of the surrounding elements [31]
Shadowing angles	the angle from the centre of the window to the most external point of the solar protection [31]
Setback distances	the minimum distance required between a structure and the front, side, or rear plot boundaries [32]
Visible Light Transmittance (VLT)	the portion of visible light that passes through a glazing system [33]
Lightwell	internal spaces open to the air that allow light and air indoors [34]

3.2 Documents collected

Table 2 shows the distribution of documents in different geographical and climatic conditions, with predominance of European countries. All other continents were also represented.

Table 2: Reference documents received and origin countries.

Document	Country	Quantity
STANDARDS	Europe	2
	Italy	5
	Denmark	1
	Norway	1
	UK	2
	Germany	2
	Netherlands	2
	Slovenia	1
	Greece	2
	Czech Republic	1
	Austria	1
	Turkey	1
	Poland	3
	France	6
	Sweden	1
	Brazil	3
	Chile	1
	Colombia	2
	USA	3
	Canada	1
	China	1
	Russia	2
	South Africa	1
GUIDELINES	UK	2
	Netherlands	1
	Estonia	1
	Turkey	1
	Singapore	1
	Japan	1
	Chile	2
	Colombia	1
RATING SYSTEMS	UK	1
	Netherlands	1
	Italy	1
	Sweden	1
	Germany	1
	France	3
	USA	3
	Canada	3
	Australia	1
	Colombia	1
	Brazil	5
	Chile	2
	Japan	1
	China	1
	South Africa	1
BUILDING AND URBAN CODES/ REGULATIONS	Italy	9
	Netherlands	1
	Norway	1
	Poland	1
	Austria	1
	Belgium	1
	Croatia	1
	Hungary	1
	Denmark	1
	France	4
	Germany	1
	Slovenia	1
	Sweden	2
	Spain	1
	Ireland	1
	Turkey	1
	USA	3
	Canada	1
	Brazil	9
	Chile	1
	Bolivia	2
	New Zealand	3
	Japan	1
	China	1

The documents are applied differently, according to each country. For example: building and urban codes are the common mandatory documents to comply, while rating systems and guidelines are optional. Standards are mandatory when laws give them this status, as happens in Brazil [26].

Different metrics appear on these documents, and the simple analysis of quantities is important to understand which are the most used worldwide. Table 3 summarizes the occurrence of daylight metrics in the 117 documents analysed.

Table 3: Occurrence of daylight metrics in documents.

Type	Metrics	Standards	Rating Systems	Guidelines	Building and Urban Codes / Regulations
Static	DF	30	13	4	8
	DF_{avg}	1	2	3	8

	DGI	2	1	0	0
	Outside Views	18	14	3	10
Dynamic	E_T	16	3	0	1
	E_{Tmin}	16	2	0	3
	DA	2	5	1	1
	sDA	6	6	0	2
	UDI	2	6	1	0
	ASE	4	4	0	0
	Sunlight Exposure	17	2	3	2
	DGP	17	4	2	0
Geometric	WWR	1	5	2	2
	WFR	5	4	3	28
	Window sizes / areas / head heights	2	1	0	6
	Setback distances	3	1	2	12
	Shadowing angles	1	2	2	3
	Obstruction angles	0	1	2	4
	Lightwells	0	0	0	1
	VLT	4	4	0	4

Static metrics, mostly DF and variations, are mentioned 69 times. Nonetheless, dynamic metrics now are more common: together, those metrics (DA, sDA, UDI, E_T, E_{Tmin}, DGP, ASE) are found in 104 of all documents. Sunlight exposure, found 24 times, is especially important to countries with cold winters, in order to ensure natural heating, as other benefits. In sunny climates, excessive sunlight exposure can provoke glare occurrence or elevated heat gains, if not properly regulated.

Outside views are also a recurrent requirement in all documents — mentioned in 45 of them — and are important for all buildings. In several documents, especially those based on EN 17037, there are objective parameters to classify views out (angles, view composition, distance of view, etc), while in other documents this analysis is still very subjective.

WFR is mentioned 40 times; followed by the setback distances, found in 18 of them; WWR was found in 10, while obstruction and shadowing angles appeared in 8 and 7 documents, respectively.

3.3 Standards

Standards, usually, are not mandatory, except when a law or government decree refers to it, or specifically gives the standard that status [26].

The metrics and requirements found were: DF, appearing in 30 documents; Outside views, 18 times; DGP and Sunlight Exposure, 17 times; E_T and E_{Tmin} appeared in 16 documents each; sDA, with 6 mentions; ASE and VLT, mentioned in 4 standards; setback distances were mentioned 3 times, while DA, UDI, DGI, window sizes were mentioned 2 times; other metrics, such as DF_{avg}, WWR and shadowing angles were mentioned in 1 standard each.

EN 17037:2018 is one of the most influent standards, since it became a reference for European countries — which have their versions of EN 17037 — and also for others outside Europe, like the Brazilian standards ABNT NBR 15215:2023 and ABNT NBR 15575:2023. Metrics used are DF, sDA, DGP, views.

EN proposed a climatic adaptation of DF, based on different median external diffuse illuminances and consequently different parameters (values) of target DF, e.g. from 0.2% in Cyprus (for 100 lux) to 5.4% (for 750 lux) in Reykjavik. Despite that, for sunny climates, this could lead to overheating and glare if windows are enlarged to achieve the target DF.

LM 83:2023 is another significant standard, published by the Illumination Engineering Society of North America (IESNA). LM 83 consolidated sDA and ASE in its first version from 2012. In 2023, the revision maintained the ASE method, but unfolded sDA in two parameters: the usual $sDA_{300/50\%}$ in 75% or 55% of used area, and $sDA_{150/50\%}$ in 50% of used area in spaces with less critical visual tasks. sDA and ASE became very common also in other documents.

$sDA_{300lx/50\%}$ and $ASE_{1000lx/250h}$ are the most found parameters for these metrics, meaning that those became the target values independently of the climatic conditions. This may seem a problem at first, but considering that sDA and ASE are dynamic metrics, it is possible to design spaces towards those results through computer simulations.

3.4 Rating systems

Rating systems are non-mandatory [27] but have an important economic appeal for stakeholders. LEED (USA) and BREEAM (UK) are the most popular rating systems worldwide, as they are applied in numerous countries. In most cases, those systems are adopted with the same metrics and parameters as the original American and British versions.

Other Rating Systems analysed were WELL (USA), Protocollo ITACA (Italy), Selo Azul Caixa and INI-C (Brazil), HQE (France), CASA Colombia, DGBN (Germany), Living Building Challenge (USA/Canada), CASBEE (Japan), BCA Green Mark (Singapore), Green Star (Australia), Green Star Rating (South Africa), CES and CVS (Chile) and GB/T 50378-2019 (China).

The requirements found were: DF, with 13 mentions; Outside views were mentioned 14 times; UDI and sDA, 6 times; DA and WWR, 5 times; ASE, WFR and VLT, 4 times; E_T is mentioned 3 times. With 2 mentions each, DF_{avg}, E_{Tmin}, shadowing angles and Sunlight Exposure. Setbacks, window areas, obstruction angles and DGI were mentioned once.

Standards and Rating Systems improved along time in parallel with the evolution of metrics, from static to dynamic, using similar parameters. On one

hand, Rating Systems focus on higher performance and, even though not being mandatory, the sustainability aspect is vital in those schemes. As a way to set higher performance goals, there are more categories — i.e., $sDA_{300lx/50\%}$ in 55%, 75% or 90% of occupied area; outside views for 50% or 100% of spaces, among others. On the other hand, Standards are a reference for professionals, to guide an acceptable performance and avoid design mistakes. Standards and Rating Systems also have in common that both are influential in many countries.

3.3 Building and urban codes/Regulations

As Building and Urban Codes and Regulations are similar, they were analysed together in this article. Codes, as well as Regulations, are the main reference for practitioners during architectural practice, since both are mandatory and legally binding — implying that inconsistencies with the requirements might even withhold constructions.

The found requirements were: WFR, in 28 documents; Setback distances, mentioned 12 times; Views out, mentioned 10 times; DF and DF_{avg}, 8 times each; window areas were mentioned in 6 documents; VLT and obstruction angles, 4 times; E_{Tmin} and shadowing angles, 3 documents; Sunlight exposure, WWR and sDA were found 2 times. Lightwells, DA and E_T are mentioned in 1 document.

Codes and Regulations are focused on a particular area of application and provide orientations for a wide quantity of schemes, projects and situations in that specific place [16,17]. Parameters commonly found for WFR, for example, vary according to the typologies of buildings and needs of the project. For housing, WFR falls into the range of 1/10 to 1/12 and from 1/7 to 1/8; for offices, from 1/8 to 1/10; for schools, kindergartens and classrooms, WFR values above 1/7, sometimes reaching 1/4 to 1/5, are recommended. Static and dynamic metrics do not appear often on these documents.

3.4 Guidelines

In the international context, guidelines are not common in many countries. This may justify why only few documents were found — a low representativity that hinders a wider evaluation. The requirements found were: DF, found 4 times in guidelines; DF_{avg}, found 3 times, as were Sunlight Exposure, Views out and WFR; DGP, WWR, setbacks, shadowing and obstruction angles were mentioned 2 times each. DA and UDI were found once each.

In countries that have Guidelines as manuals, those are elaborated by professional organizations. Guidelines are mostly not mandatory: instead, they can be a reference for practitioners, whether to facilitate the comprehension and application of other documents — e.g. Codes, Regulations — or to guide better design practices. Hence, guidelines' requirements are in between those two groups: those keen to aid professionals to apply mandatory documents regarding building and urban geometry; and those focused on better practices apply static and dynamic metrics.

4. CONCLUSION

This article explored daylight requirements in reference documents, demonstrating the many ways that daylight is treated. Three groups were verified: one composed by standards and rating systems, since those tend to have similar requirements; other by building and urban codes and regulations, also with similar metrics; lastly, the guidelines, that in most cases depend on the focus of the document.

The most well represented were the European countries. North and South America, Asia and Oceania were also represented. Only a few documents from Africa were received, possibly due to the lack of access or few published information.

DF remains a widely used metric, especially in European countries. Even the parameters being different, considering each local condition of median external diffuse illuminances as proposed by EN 17037, it is still limited and performs better for overcast skies. The parameters, in general, are the same for many countries, which could lead to issues with excessive heating, when used in sunny climates.

Dynamic metrics provide more reliable results. The key to dynamic metrics is to have target parameters to comply that truly consider local climates. With a goal set, the strategies used by designers may differ, but the results meet the recommendations. The most used dynamic metrics for daylight provision is Target Illuminance and variations, along with Spatial Daylight Autonomy (sDA). For glare assessment, Daylight Glare Probability (DGP) is the most used, while Sunlight Exposure expresses the access to sunlight indoors.

Metrics based on geometry, instead, influence directly the architectural and urban projects, since they shape the buildings and intermediate their relation to the surroundings. The most used are WFR and setback distances. Similar parameters are used for different locations, which indicates the limitation of this metrics, as used presently. Their main advantage is to be familiar to architects and urban planners, but new parameters should be further developed, to adapt to different climates and sky conditions, providing solutions to control the same variables — i.e., in sunny climates determine a reduced WFR, while colder climates might require more window areas. Connecting geometric to dynamic metrics could clarify how both types of metrics impact each other during the design process, as well as building and urban spaces.

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