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Daylight is a key component of green building; however, no prevailing metric has emerged to help identify buildings that are well-daylit buildings. This paper proposes a 'daylighting dashboard'; a visual representation of a design's potential to meet eight design goals: average illuminance, coverage, diffuse daylight, daylight autonomy, circadian stimulus, glazing area, view and solar heat gain. This metric allows for informed decisions to be made early in the conceptual phase of design, and highlights aspects of design that may need further development, while there is still the opportunity to make modifications. These eight goals should be prioritized as appropriate for individual projects, rating systems or code requirements. This early indication of performance of conceptual design alternatives is likely to guide architects to better daylit buildings.

1. Introduction

The most critical decisions for capturing daylight for building interiors come during the conceptual phase of architectural design, when the building's site, configuration and fenestration are formulated. These decisions affect lighting quality and quantity, cost, view, solar heat gain and energy use. Simple metrics, applicable during conceptual design, can help designers choose among alternative configurations to be further developed and forewarn designers when further attention will be needed during design development to improve the final building performance. This paper introduces a daylighting dashboard, a visual representation of a design's potential of meeting eight design goals:

- Average illuminance: Provide sufficient daylight to perform tasks.
- Coverage: Avoid under-lit areas by distributing ambient light throughout the space.
- Diffuse daylight: Control glare by minimizing direct sun in all spaces with critical visual tasks.
- Daylight autonomy: Save energy by maximizing the time when electric lights can be turned off.
- Circadian stimulus (CS): Provide sufficient light to promote circadian stimulation.
- Glazing area: Control construction costs by minimizing the area of windows or skylights.
- View: Provide views to the outside.
- Solar heat gain: Reduce building energy requirements and improve comfort by monitoring solar heat gain through glazing.

In the online version of this paper, the daylighting dashboard gives a simple green, yellow or red rating for each of these goals for any design alternative. Green indicates that the designer is well on the way to fully meeting that goal. Yellow indicates caution, where further evaluation or development is warranted. Red is a warning that the goal is unlikely to be met with the current design. In this printed version, red is denoted by white, yellow is denoted by grey and green is denoted by black.

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2. Background

Daylighting is often cited as a key component of green building. Rating systems and energy codes seek ways to quantify a building's daylighting performance to encourage better daylit buildings. The development of daylighting metrics has been the subject of considerable effort and debate, but to date no widely accepted metric has emerged to help recognize buildings that are, indeed, well-daylit buildings.

An online survey[1] conducted in 2004 regarding daylight software usage found that the majority of respondents, who identified themselves as designers and engineers, used experience and rules of thumb as their primary method to estimate daylighting during schematic design rather than computer simulation tools. Only during design development did these respondents indicate that they used both experience and computer simulation tools more than 50% of the time.

The survey also asked these respondents which computer simulation outputs they were using and how those outputs influenced their daylight analysis. The respondents' responses align with seven of the eight design goals put forward in this paper as those needed to assess a building's daylight potential. The CS is an emerging topic that was not part of the broad lighting discourse when the aforementioned survey was completed.

Experts agree that a well-daylit building must have a daylight control system, meaning the ability to switch or dim electric lights when sufficient daylight is present. While this is an important component to saving energy, the design of the daylighting control system is often specified later in the design process, long after the critical form, orientation and glazing decisions have been roughed out. Simple metrics are needed that are relevant for this conceptual design phase. Such evaluations, however, face multiple barriers. First, one must specify which sky condition(s), time(s) and month(s) are needed for the evaluation to be performed. Next, simulations are dependent on design inputs such as surface reflectance, window glazing type and shading systems that may not be known until the design is further developed. Further, daylighting design, like most design, must prioritize sometimes conflicting design goals. Architects weigh the importance of the eight daylighting goals listed above differently for different projects. Sometimes cost is the driver; other times view or energy savings most influence the building design. Energy program managers or code officials may only care about performance on some of the goals to permit the building or certify compliance with rating systems such as the US Green Building's Council's (USGBC) Leadership in Energy and Environmental Design (LEED) program.[2] They may want energy savings and view criteria but may not care about cost or CS.

Recently, several new approaches and tools have been proposed[3–8] that provide an alternative methodology to using only a single date and time[1] or a series of discrete dates and times[3] that designers currently use to evaluate daylight performance in the built environment. Many of these approaches recommend using simulation software that require an expert hand,[3,5,6,8] while another recommends the use of rule of thumb sequences[4] to simplify the decision-making process during conceptual design. The downside of these approaches lies in their complexity[3,5,6,8] or conversely, in overly simplified assumptions.[4]

Applying evaluation metrics to a design presents an inherent conflict between simplicity/ease of use and accuracy. Evaluation of the design at a single point in time, such as the winter condition under cloudy skies, simplifies the analysis but fails to adequately represent year-round performance. As the evaluation becomes more complex and time consuming, fewer alternative designs may be able to be evaluated. So called, climate-based daylight modelling approaches (CBDM)[3,5–7] may provide a more nuanced analysis than an analysis using a series of discrete dates and times, but the lighting information obtained may not change the design decisions enough to justify their inclusion in the conceptual design phase.

The daylighting dashboard described favours relatively simple evaluations that can be performed with the simple inputs available during the conceptual design phase. Eight simple goals are evaluated for each design alternative. This allows the designer to weigh the relative importance of each goal and then select candidate patterns for further analysis during design development. The design precision, calculation software or bracketing values for each of the eight goals selected by the authors are not the point of this paper. These could easily be changed by different designers, or certification and code bodies, but the benefit provided by the dashboard would be the same.

The daylighting dashboard is also the first integrative approach that includes a validated CS model,[9–11] while other authors suggest their own circadian metrics.[6]

3. Generating the daylighting dashboard

As soon as the basic dimensions of a typical space and its daylight apertures are sketched, the daylighting dashboard can be constructed to guide further development. The designer chooses the location and orientation of the space to be evaluated. Illuminance is calculated for points on a horizontal grid located at the work plane height using a daylight calculation program chosen by the designer, excluding any electric lighting that is to be installed. The authors use AGi32 version 2.13 lighting software (Lighting Analysts, Inc., Littleton, Colorado. Download available at www.agi32.com). The calculation points measuring illuminance are spaced on a grid 1.5 m apart, 0.8 m above the floor. The calculations are run for both clear and cloudy skies for typical days and times in each season. The authors use 9:00 a.m., 12:00 p.m. and 3:00 p.m. on March 21, June 21, September 21 and December 21, although other dates and times may be used instead or in addition, depending on the space and usage patterns. Three times of day on four days yield twelve simulation runs under each clear and cloudy sky condition. The solar heat gain is also estimated using a building energy simulation program appropriate for schematic design. The authors use eQuest version 3.64 building energy simulation tool. (eQUEST is a registered trademark of James J. Hirsch & Associates. Freeware is available at doe2.com/eQUEST). Finally, the design horizontal illuminance, E_d, is selected for the space. Using the output, each of the eight goals above is evaluated and shown graphically (see Figure 2 for an example).

3.1. Average illuminance

3.1.1. Goal: Provide sufficient daylight to perform tasks

Average illuminance on the horizontal work plane is an indicator of daylighting availability for performing visual tasks. Low illuminance levels can make seeing difficult without supplementary electric light. Excessive illuminance may cause discomfort and disability glare, fade materials and could be an indicator that there is more glazing than necessary in the space.

3.1.2. Metric

Black indicates that the average illuminance from daylight is usually sufficient for all tasks typically performed in the space. White indicates that there will often be insufficient daylight to perform tasks of small size and low contrast. Grey indicates that daylight levels are often below the target illuminance or that there is excessive illuminance, which may produce glare.

3.1.3. Approach

The design illuminance (E_d) for sufficient daylight was guided by the values for horizontal illuminance recommended by the Illuminating Engineering Society of North America (IESNA).[12] The relative visual performance (RVP) model was used to select a low illuminance criterion (E_{min}) based on the dominant tasks for the space being designed (e.g., to see an obstacle in a corridor).[13] As a simpler alternative approach, designers could divide E_d by the IESNA recommended average-to-minimum illuminance ratio for the given task to determine the E_{min} value. A high illuminance (E_{max}) of 5000 lux was used to determine the maximum illuminance allowed based on a maximum illuminance criterion of 5000 lux given in LEED 2009 IEQ credit 8.1.[2]

The average illuminances of all the work plane points in the space are calculated for each of the 12 typical months/times for each clear and cloudy sky so each typical evaluation time may be individually examined. The overall dashboard rating is determined by the average illuminance (E_{avg}) of all the evaluated points as follows:

- Black if E_{avg} is greater or equal to E_d and less than E_{max}.
- Grey if E_{avg} is greater than E_{min} but less than E_d, or if E_{avg} is greater than E_{max}.
- White if E_{avg} is less than E_{min}.

3.2. Coverage

3.2.1. Goal: Avoid under-lit areas by distributing ambient light throughout the space

Coverage is the percentage of the work plane that is above the minimum illuminance criterion specified in the average illuminance metric (E_{min}). A coverage percentage of 100% is an indicator that most parts of the room are receiving adequate amounts of daylight to perform visual tasks. A low coverage percentage of 80% or less indicates there are under-lit areas from daylight. A space with under-lit areas juxtaposed with well-lit areas may contribute to visual discomfort.[14]

3.2.2. Metric

Black indicates that the entire space is above the minimum illuminance criterion. Grey indicates that most of the space is above the minimum illuminance criterion. White indicates that a significant portion of the space is under-lit.

3.2.3. Approach

The percentage of all work plane calculation points above the minimum illuminance criteria (E_{min}) is tabulated for all simulation runs on each sky condition.

- Black if 100% of points are equal to or greater than E_{min}.
- Grey if 80–99% of points are equal to or greater than E_{min}.
- White if less than 80% of points are greater than E_{min}.

3.3. Diffuse daylight

3.3.1. Goal: Control glare by minimizing direct sun in all spaces with critical visual tasks

Diffuse daylight is the percentage of the work plane that has daylight without direct sunlight. Patches of direct sun may be welcome in corridors or lobbies, but direct sun in interiors with critical visual tasks is an indicator of glare, uneven light distribution and potential thermal discomfort.[14] When daylight is not diffuse in these spaces, sun-shading strategies should be considered by the designer. These could include overhangs, window blinds or louvers.

3.3.2. Metric

In spaces with critical visual tasks or computer work (e.g., offices and classrooms), black indicates that the entire work plane has diffuse daylight without direct sun. Grey and white indicate progressively more direct sun on the work plane. Some direct sun is permissible in certain spaces (e.g., gymnasiums and lounges), which are characterized by simpler visual tasks, including viewing of objects with high contrast and/or larger size than those typically interacted with in classrooms or offices, and greater occupant mobility within the space. These spaces with mostly diffuse daylight receive black and others receive grey, depending on the amount of direct sun on the work plane. Black is always indicated for spaces where direct sun is welcome (e.g., corridors and lobbies, since direct sunlight can be desirable as an aesthetic element).

3.3.3. Approach

Points with horizontal illuminance above a direct sun illuminance criterion (E_{sun}) are assumed to be receiving direct sun. The minimum horizontal illuminance value for E_{sun} is assumed to be 10,000 lux or higher in March, June and September. The E_{sun} for December is lowered to 5000 lux to account for low sun angles in the winter months. The percentages of all work plane points equal to or below E_{sun} are tabulated for all simulation runs on each sky condition.

For spaces with critical visual tasks:

- Black if 100% are equal to or less than E_{sun}.
- Grey if 80–99% are equal or less than E_{sun}.
- White if less than 80% are equal to or less than E_{sun}.

For spaces where some direct sun is acceptable:

- Black if 80–100% are equal to or less than E_{sun}.
- Grey if less than 80% are equal or less than E_{sun}.

For spaces where direct sun is welcome:

- Black.

3.4. Daylight autonomy

3.4.1. Goal: Save energy by maximizing the time when electric lights can be turned off

Daylight autonomy is the percentage of the work plane having an illuminance above the design illuminance, E_d.[15] High daylight autonomy indicates a potential to save electric lighting energy if a suitable control system is installed to dim or switch off electric lights.

3.4.2. Metric

Black indicates a high energy savings potential because electric lights can be switched or dimmed during most of the daylight hours. Grey indicates a moderate potential for energy savings. White indicates that the potential for energy savings is much lower.

3.4.3. Approach

The percentage of work plane calculation points above E_d is tabulated for all simulation runs on each sky condition.

- Black if 80–100% of points are equal to or greater than E_d.
- Grey if 50–79% of points are equal to or greater than E_d.
- White if less than 50% of points are greater than E_d.

3.5. Circadian stimulus

3.5.1. Goal: Provide sufficient light to promote morning circadian stimulation to occupants

The CS is tabulated using a 0–24 scoring system to indicate daylight's potential impact on people's circadian systems. Light of certain illuminance, spectrum and duration during the day, especially during the morning hours, has the potential to improve sleep patterns for people who wish to be alert during daytime hours and asleep at night.[9–11]

3.5.2. Metric

Black indicates a high level of circadian stimulation throughout the year for a given sky condition. The CS value is predicted by sufficient horizontal illuminance on the work plane (and by inference, at the eye) to stimulate the circadian system of occupants. Grey indicates moderate circadian stimulation potential. White is an indication that occupants are more likely to be in 'circadian darkness' while in the space because they are not receiving enough light to stimulate their circadian systems.

3.5.3. Approach

For both clear and cloudy skies, a CS value for each of the illuminance values for the twelve simulated dates and times of year is calculated, yielding an average CS value. This average CS value is assigned a score of 0–2, depending on the percentage of CS, yielding a maximum possible score of 24 for the year. A score of 2 is given when the average CS is above 35% (120 lux or more from daylight at the eye), a score of 1 is given when the average CS is between 10% (40 lux or more from daylight at the eye) and 35% and a score of 0 is given when the CS is below 10% (less than 40 lux at the eye). The CS value shown in the daylighting dashboard equals the sum of the scores for all 12 simulated dates and time.

The CS is calculated using a model of human circadian phototransduction.[16] This model predicts nocturnal melatonin suppression by accounting for the light level at the cornea, the spectrum of light, the duration of exposure and the pupil size. For this calculation, pupil size has been fixed at 2.3 mm and the duration of exposure is 1 hour. The light level at the cornea (e.g., the vertical illuminance at the eye measured in lux) is conservatively estimated by taking the average horizontal illuminance (in lux) on the work plane and dividing that value in half. Circadian stimulation in this application equals predicted percentage melatonin suppression in the middle of the night and this percentage suppression is being used as a surrogate for stimulation of the circadian system during the day.

- Black if the CS score is greater than 16.
- Grey if the CS score is 9–16.
- White if the CS score is less than 9.

3.6. Glazing area

3.6.1. Goal: Control construction costs by minimizing the area of windows or skylights

Glazing area (A_g) is the percentage calculated from the total window, monitor and skylight area compared to the floor area of the space. Windows and skylights generally cost more than solid walls, so a small glazing area can be an indicator of lower construction costs. Large glazing areas provide good views and daylight access, but they can also contribute to glare and higher heating or cooling costs.

3.6.2. Metric

Black, grey and white indicate increasingly high amounts of glazing, associated with increasingly high construction cost.

3.6.3. Approach

For each space, the total area of all skylights, monitors and windows is divided by the floor area of the space.

- Black if A_g is below 10%.
- Grey if A_g is between 10–20%.
- White if A_g is greater than 20%.

3.7. View

3.7.1. Goal: Provide views to the outside

People like a connection to the outdoors. Views provide information about what is happening in the environment. Views of just the sky are adequate, but interesting scenes with portions both above and below the horizon are preferable. Baffles or translucent glazing, which inhibit view clarity, are least preferred.[17]

3.7.2. Metric

Black indicates that the view is likely to include both the ground and the sky. Grey indicates that there is a view of just the sky. White indicates that there is no view at all. An example of a daylight aperture providing no view would be a translucent skylight.

3.7.3. Approach

Typically, clerestory and roof monitor windows with transparent glazing have views of the sky only and windows have views of the sky and ground. Apertures with translucent glazing (such as skylights with prismatic or diffuse glazing) have no view.

- Black if view includes both ground and sky.
- Grey if view of only sky exists.
- White if there is no view of sky or ground.

3.8. Solar heat gain

3.8.1. Goal: Reduce building energy requirements and improve comfort by monitoring solar heat gain through glazing

Solar heat gain is the daily average heat radiated from the sun into the space through the glazing, measured in Watts per square meter (W/m^2) of floor area. Solar heat gain is a good source of passive heating during cold months. However, many large buildings require cooling for most of the year due to warm climates and/or high internal loads from occupants.[18] In these cases, high solar heat gain increases cooling equipment and operation costs. Designers need to match the solar heat gain strategy to their thermal design objectives.[18] Solar heat gain is a function of climate and glazing area, materials, shading, tilt and orientation.[17]

3.8.2. Metric

Since solar heat gain can be a benefit or a disadvantage, no daylighting dashboard ratings are given. Rather, the amount of solar heat gain for each pattern is shown so that designers can have a simple comparison of the relative yearly solar heat gain resulting from alternative daylighting designs.

3.8.3. Approach

The average daily solar heat radiation per day into the space is calculated using the detailed *LS-L Management and Solar Summary* simulation report generated by eQUEST. The result is divided by the floor area of each space to get the W/m^2 of floor area/day.

4. An example

A south-facing classroom, located in Albany, New York (NY), United States, is being designed for daylighting. The daylighting goals are: To offer a well-daylit space for students and teachers with acceptable daylight levels for visual tasks; to provide a CS for the school year (September–June); to maximize energy savings by allowing electric lighting to be switched off regularly; and to minimize building costs. Figure 1 shows images of the three designs being considered: a classroom with a large south-facing window, a classroom with a roof monitor and a classroom with small windows and skylights.

For each design, a daylighting dashboard was generated. A design illuminance (E_d) of 300 lux and a low illuminance criterion (E_{min}) of 100 lux are selected. Table 1 shows the simulation results for all 12 runs under the clear sky. The average of these data is used to generate the graphic used in the daylighting dashboard shown in Figure 2. Figure 3 shows six daylighting dashboards used to compare the performance of the three classroom designs under both clear and cloudy conditions. The daylighting dashboard facilitates side-by-side comparison of the design alternatives. The black, grey and white colour scheme of the daylighting dashboard draws attention to those aspects of the daylighting design that are performing well and those that are underperforming.

At first glance, the daylighting dashboard shows that the classroom with small windows and skylights has achieved more 'black' daylighting goals for both clear sky and overcast sky conditions, suggesting that it is a higher performing design. This is a good first-order assessment, but before choosing a particular design the individual goals should be assessed based on the project's needs.

By design, the daylighting dashboard allows each goal to be evaluated individually, which, in turn, allows designers to make meaningful comparisons of the appropriate design goals. For example, Albany, NY, has predominately cloudy skies (and more so during the school year), therefore the daylighting design should perform well under a cloudy sky condition. The roof monitor design has white ratings for coverage, daylight autonomy and CS under a cloudy sky condition, suggesting that the design performs poorly under cloudy skies. Conversely, the large south window design and the small window with skylight design provide better performance with a mixture of grey and black ratings for the same goals. Based on the daylighting dashboard results, the roof monitor will not provide sufficient daylight under cloudy skies to distribute daylight throughout the classroom, switch off electric lighting or provide much of a CS. Therefore, the roof monitor design should be removed from consideration.

The daylighting dashboard shows that the large window design and the small window with skylight design share similar performance ratings for the cloudy sky condition. For the clear sky condition, the large window design's illuminance rating is grey due to the design having an average illuminance greater than 5000 lux, which suggests over lighting on clear days. Over lighting can be mitigated by a shading device. In fact, both designs will

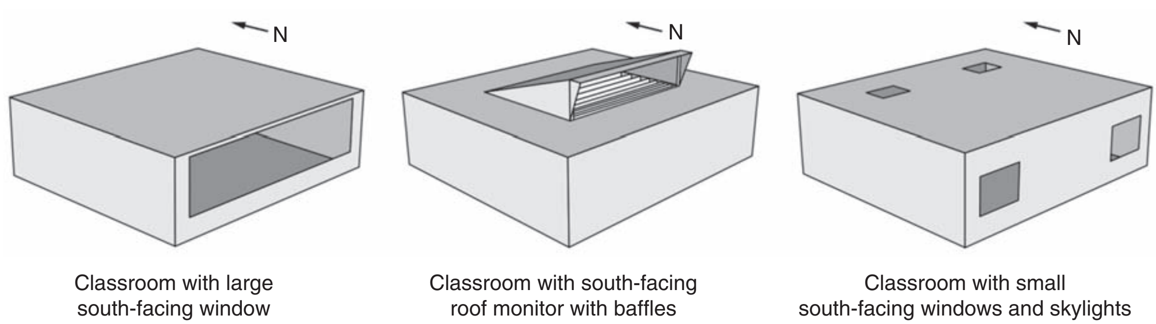

Figure 1 Three classroom designs used in the example (from Leslie *et al.*[19])

Table 1 Data used to develop the daylighting dashboard for classroom with large south-facing window under clear sky (Leslie *et al.*[19])[a]

	Clear sky											
	Mar			Jun			Sep			Dec		
Time	9 a.m.	12 p.m.	3 p.m.	9 a.m.	12 p.m.	3 p.m.	9 a.m.	12 p.m.	3 p.m.	9 a.m.	12 p.m.	3 p.m.
Avg. illuminance (lux)	4337	12 731	11 149	1517	2314	2088	5069	12 968	10 622	7889	20 265	6059
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	87	83	83	100	100	100	87	83	83	50	40	50
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	2

[a]Glazing area: 24%, View: ground and sky, SHG (W/m^2/day): March, 366; June, 303; September, 394; December, 262.

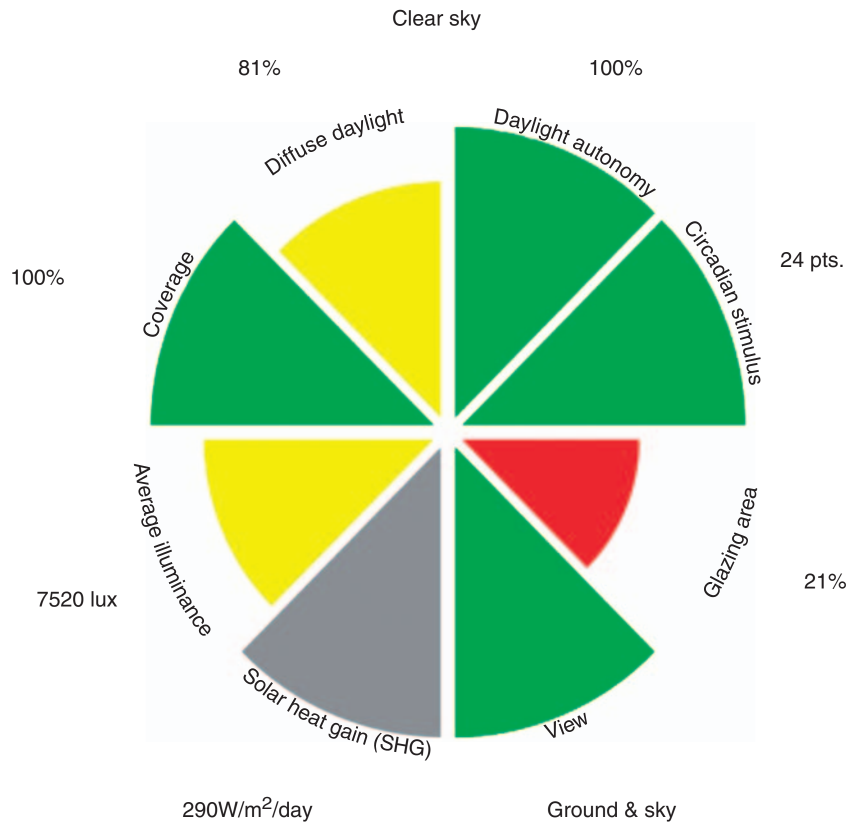

Figure 2 Simplified graphic developed from the data in Table 1 (from Leslie *et al.*[19]).
Note: in the online version of this paper white is denoted by red, grey by yellow, and black by green. The solar heat gain is denoted by hatched gray

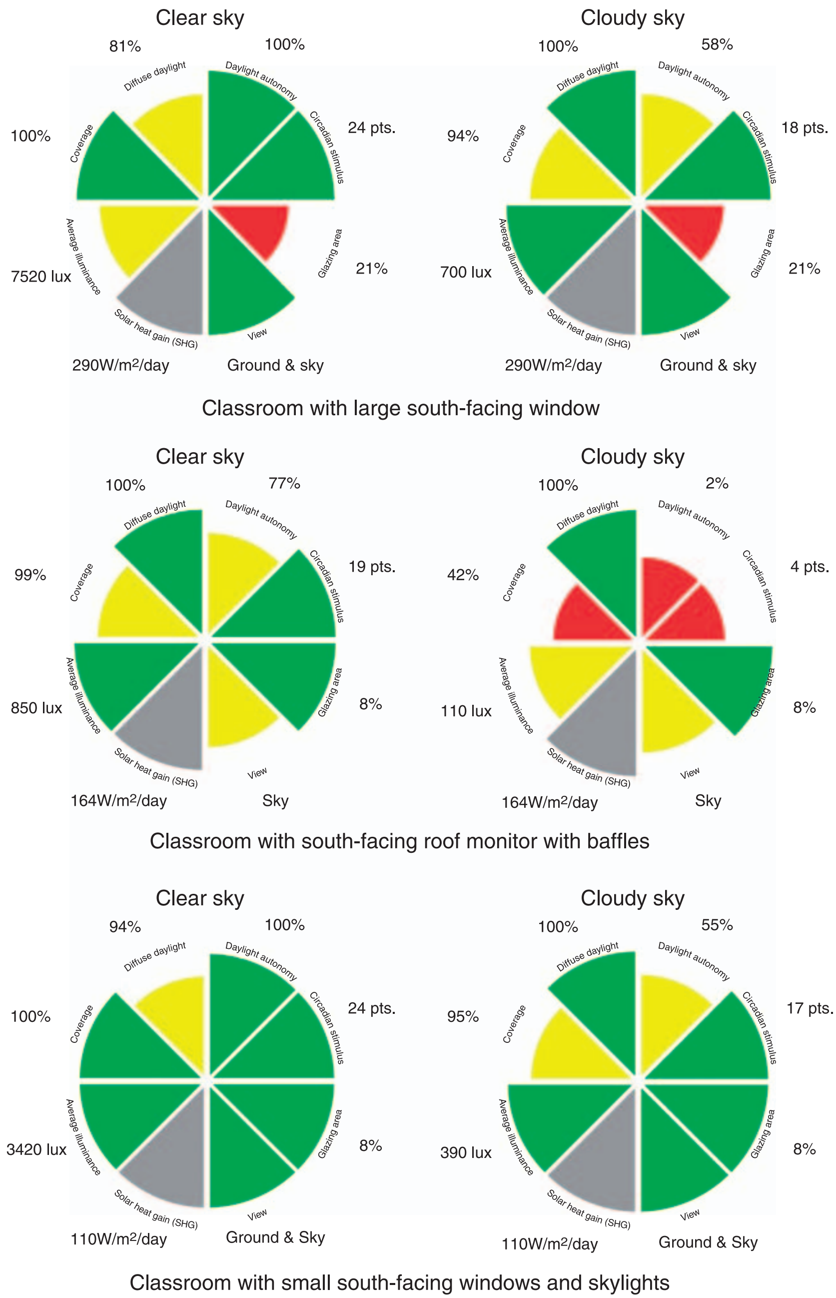

Figure 3 Daylighting dashboards for the three classroom designs considered in the example (from Leslie *et al.*[19]). Note: in the online version of this paper white is denoted by red, grey by yellow, and black by green. The solar heat gain is denoted by hatched gray

require shading devices (such as window blinds) due to direct sun reaching the work plane, indicated by the grey rating for diffuse daylight. With shading devices necessary for both designs, neither design is a clear frontrunner from a daylighting performance point of view, until glazing area is considered. For nearly equal daylighting performance, the small window with skylights requires 2.6 times less glazing. Reducing the amount of glazing material will likely decrease the overall cost of the project. Based on this analysis, the windows with skylights design is chosen as the daylighting strategy for this classroom.

Now that it has been determined that the small window with skylights is the better choice for this project, the daylighting dashboard can be used to find the parts of the design that can be optimized during design development. Under clear sky conditions, the daylighting dashboard indicates caution for the diffuse daylight goal. This implies that direct sunlight is falling on a portion of the work plane, and that the sunlight should be managed with a shading device, such as a window blind. Adding a shading device will improve visual comfort by eliminating glare caused by direct sun falling on the work plane. Next, for cloudy sky conditions, the daylight dashboard shows a grey (caution) rating for both coverage and daylight autonomy. This suggests that there may be room to improve the cloudy sky performance of the design. Possible optimizations for increasing daylight levels include increasing the size of the daylighting elements or better distributing daylight within the space. More daylight can be allowed into the space by increasing the size of the windows or skylights or choosing glazing materials with higher visual transmittance properties. To better distribute daylight in the classroom, the position of windows and skylights could be optimized and/or the diffuse reflectance of interior surfaces could be increased by using more reflective (lighter coloured) materials. As the project moves forward, additional daylighting dashboards could be generated to evaluate the performance of new optimization strategies and help guide design decisions like room finishes, furniture and shade choices.

In the preceding example, three different classroom design alternatives were compared, but many more design alternatives having various window sizes, orientations and shading devices can be generated for comparison. Figure 4 shows 16 different classroom design alternatives that were generated for the publication, 'Patterns to Daylight Schools for People and Sustainability.'[19]

For each classroom design shown in Figure 4, a daylighting dashboard was generated. Figure 5 shows a table of the daylighting dashboard results. Using the table, comparisons of the designs can be easily made for this school to help guide an overall building orientation and fenestration strategy conceptual design. For example, the north small window with skylights performs nearly as well as the south small window with skylights in terms of average illuminance, daylight autonomy, CS and view, but the north small window with skylights provides more diffuse daylight during clear days and less solar heat gain. If the project goal is to maximize daylight autonomy and greater first costs are not an issue, the north large window with skylights provides higher daylight autonomy compared to the small windows with skylights, perhaps suggesting different daylighting strategies for the north-facing versus south-facing classrooms. In another example, the classroom with skylights provides the best overall lighting conditions for the least amount of glazing; however, this strategy provides no view. If view is not a critical design goal, then the skylight design would provide a well-daylit classroom at a lower cost compared to the other designs. Using the daylighting dashboard allows informed decisions to be made early in the conceptual

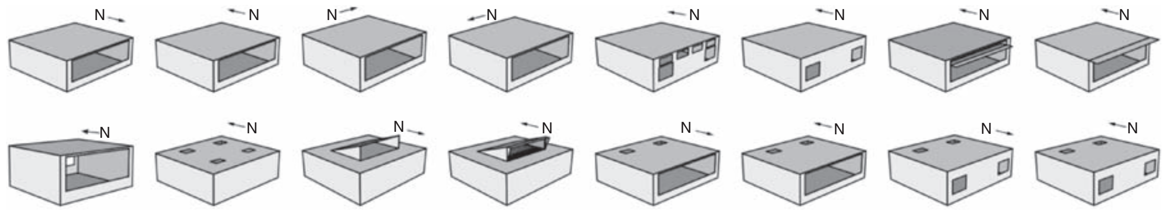

Figure 4 The 16 classroom design alternatives evaluated (from Leslie *et al.*[19])

Classroom Type	Average illuminance (lx) Clear	Average illuminance (lx) Cloudy	Coverage (%) Clear	Coverage (%) Cloudy	Diffuse daylight (%) Clear	Diffuse daylight (%) Cloudy	Daylight autonomy (%) Clear	Daylight autonomy (%) Cloudy	Circadian stimulus (pts.) Clear	Circadian stimulus (pts.) Cloudy	Glazing area (%)	View (G=ground; S=sky; N=none)	Solar heat gain (W/m^2/day)
Classroom													
North Large Window	1130	690	100	93	100	100	96	96	21	18	21	GS	123
South Large Window	7520	700	100	94	81	100	100	58	24	18	21	GS	290
East Large Window	4590	690	100	93	88	100	98	57	22	18	21	GS	224
West Large Window	3850	690	100	93	92	100	98	57	22	18	21	GS	224
South Medium Window	3360	340	100	76	92	100	98	33	23	12	10	GS	145
South Small Window	2240	150	100	35	94	100	73	12	21	7	5	GS	73
South Large Window with Overhang	3320	420	100	90	89	100	100	46	24	16	21	GS	164
South Large Window with Lightshelf	4250	470	100	91	88	100	100	5I	24	16	21	GS	214
Bilateral Large Windows	8480	1350	100	100	78	100	100	97	24	22	41	GS	416
Skylights	2380	470	100	100	100	100	100	73	24	19	6	N	79
North Roof Monitor	470	400	99	89	100	100	71	49	18	16	12	S	69
South Roof Monitor with Baffles	850	110	99	42	100	100	77	2	19	4	8	S	164
North Large Window + Skylights	2360	950	100	100	100	100	100	89	24	21	24	GS	164
South Large Window + Skylights	8680	920	100	100	78	100	100	89	24	21	24	GS	331
North Small Window + Skylights	1470	390	100	95	100	100	98	55	22	17	8	GS	69
South Small Window + Skylights	3420	390	100	95	94	100	100	55	24	17	8	GS	110

Figure 5 Summary of daylighting dashboard results (from Leslie *et al.*[19])

design stage of a project and highlights those aspects of design that may need further development.

5. Discussion

It must be emphasized that the daylighting dashboard is for conceptual design only. The purpose is simply to be able to compare the potential of alternative design solutions to achieve the eight daylighting goals while there is still an opportunity to modify the form, orientation or glazing size. It also identifies areas that receive a grey or white rating where further development should be considered during design development to fully achieve the goal.

The daylighting dashboard is a framework to ensure a more complete design-decision process. The actual values corresponding to the colour ratings can be modified as seen fit by designers, code developers or purveyors of rating systems. For example, one can imagine a rating system requiring that buildings achieve black (or a minimum score) on several specified goals and perhaps grey on a few others.

As with any simplified system, there are limitations to the evaluation. The average illuminance goal considers one average design illuminance for the entire space. Task ambient approaches, often used in daylighting strategies, may require further evaluation. Further, the evaluation uses average illuminance from daylighting throughout the space. A space that has both intense sunlight and dark areas may have an average illuminance that is the same as a space that is uniformly daylit. In this case, looking at the average illuminance rating without also considering the coverage rating can lead to misleading design direction.

The daylighting dashboard introduces circadian stimulation as a quantifiable daylighting design goal for healthy, productive buildings. Research on the impact of light on human health and well-being is new but increasing rapidly. Inclusion of the circadian stimulation goal helps architects begin a dialogue with clients during design development; a dialogue that is likely to support the use of daylighting as an economical and sustainable way to have sufficient light of the right spectrum at the right time. The daylighting dashboard currently relies on the model of human circadian phototransduction by Rea *et al.*[16] and assumes a fixed pupil size of 2.3 mm and a 1-hour exposure duration. This model does not take into account individual differences in response to light, age-related eye changes (i.e., increased light absorption), light history and photopigment regeneration, all of which could affect the light response.[16] Moreover, the calculations assume a relationship between acute melatonin suppression (calculated using the model of human circadian phototransduction)[16] and synchronization between the internal circadian pacemaker and the solar day (known as entrainment). It is not known if acute melatonin suppression at night is a good surrogate for CS sufficient to entrain people to the 24-hour solar day. The CS thresholds for the daylighting dashboard are calculated using the CIE D65 daylight spectrum. In practice, the daylight spectrum, and therefore the CS, may be affected by sky conditions and building materials such as spectrally selective glazing. Finally, the link and quantification between circadian entrainment and health outcomes are only starting to be established. More work is needed to determine the impact of light exposure over the course of the 24-hour day on health and well-being.

Daylighting metrics development to date has been characterized by disagreements on accuracy versus convenience, appropriate calculation times and sky conditions, specific software to be utilized and even what information is necessary to guide performance evaluation. Herein, the authors propose eight minimum components and a simple way to estimate performance at the very beginning of building design. These eight goals are to be prioritized in the context of individual projects, rating systems or code requirements. The software to be used and the absolute rating criteria are open to further discussion. Yet, this early indication of performance and weaknesses of conceptual design alternatives is likely to guide more architects to better daylit buildings. At a minimum, one would surmise that an architect facing one or more red flags during conceptual design would at least give further consideration to these issues or enlist appropriate daylight expertise.

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