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The Science of Daylighting
Session M157

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Summary

Using daylight for task and ambient lighting, or daylighting, is being incorporated into more spaces to save energy and maximize worker productivity. Effective daylighting requires a balance between maximizing daylight into the space while minimizing the negative benefits that can come from uncontrolled daylight.

Designing a space for effective daylighting requires the integration of multiple disciplines including façade design, lighting design and interior design. Interior design elements that were historically selected for aesthetics now have a significant impact on effective daylighting. Shade control strategy, fabric selection, and floor plan design can directly impact how well daylight can be incorporated into a space.

Introduction – The Benefits and Challenges of Daylight

Benefits of Daylight

Daylight was a primary source of light before electric light became accessible and affordable. Today, the need to save electrical energy has daylight being used again for task and ambient lighting. Also, worker productivity is becoming critical as businesses are trying to “do more with less.”

Maintaining worker productivity is critical to maintaining the profitability of a company. According to Scot Horst, senior VP USGBC’s LEED program, “A typical office building’s annual energy costs are \$2.25 per square foot; the human costs are \$318 per square foot.” Understanding how daylight can positively impact worker productivity helps to understand how it should be incorporated into the design of a space.

The human body responds to daylight by maintaining a 24 hour cycle that supports alertness and health¹. The psychological benefits of daylight are just as powerful. Sunlight has an excellent color spectrum so people feel that is it healthier to work under daylight. The same windows used to bring in daylight also provide a view to the outside world which elevates peoples’ mood.²

Energy savings are achieved when the lighting system is designed to respond to daylight. Using sensors, electric lights can be dimmed, or switched, automatically when daylight is present which is called daylight harvesting. A secondary benefit of daylight harvesting is decreasing the cooling load of a building. Electric lights produce both light and heat. Considering that most buildings are cooling dominated, lowering the electric light levels also has a positive benefit on the electrical energy used by the air-conditioning system.³

Challenges of Daylight

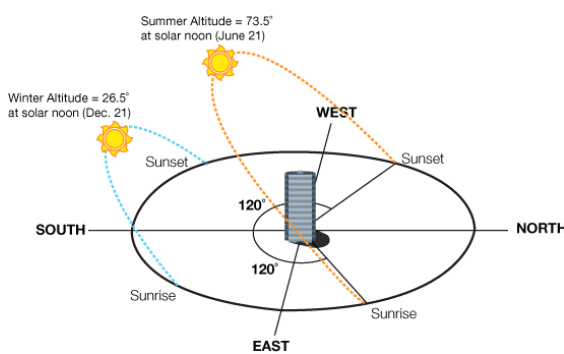
Daylight can positively impact productivity but uncontrolled daylight can just as easily make people less productive. Uncontrolled daylight can cause glare and thermal discomfort which causes people to break from their tasks⁴. Effective interior design will maximize the presence of daylight while minimizing the negative effects from uncontrolled daylight.

Understanding and Managing Daylight

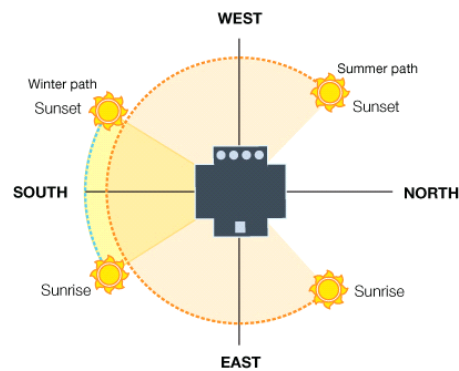
Availability of Daylight

Daylight is a variable source of task and ambient lighting. As seen in Figure 1, the seasonal variation in the sun's position varies how daylight will enter a space.

Figure 1: Variation in Sun position by Season



Isometric view of seasonal sun movements relative to a building



Top down view of seasonal sun movement around building

As seen in Table 1, weather conditions can also have a significant impact the availability daylight for lighting a space.

Table 1: Sunlight availability based on Weather Conditions⁵

Clear Skies, Direct Sunlight	7,000 - 10,000 fc
Clear Skies, Indirect Sunlight	500 fc
Overcast Conditions	1,000 - 5,000 fc

Note: fc = Footcandles

The challenge in using daylight for task and ambient lighting is incorporating proper design elements that can address the heat and glare that can come from direct or overcast direct sunlight but allow diffuse daylight to enter a space.

Managing Daylight

Controlling daylight can be done through static architectural elements like light shelves, louvers, brise soleil or dark tinted glass. Effective daylight control suggests that these static architectural elements be complimented with the inclusion of window treatment options like solar shades or blinds.

Historically, manually controlled window treatments have been selected for interiors but they tend to limit effective daylighting. Studies have shown that manual window treatments are lowered to eliminate glare and they are not raised again⁶. Manual window treatments tend to minimize the ability to daylight harvest with the lighting system.

Motorized window treatments are a means of adding automation to ensure that daylight is automatically brought into a space. Timeclocks can be used to manage raising and lowering the shades. More sophisticated solar tracking systems are being used to schedule window treatment movement to track with the seasonal movements or the sun.

Incorporating Daylight into Interior Design

Effectively designing a space for daylighting requires a space requires coordination of multiple design elements. Many interior design decisions can impact effective daylighting.

Historically, window treatment fabrics were selected for color and style. A “mock up” of the interior space was done to qualitatively understand the impact of the shade fabric on daylight control. Today, there are better tools available to understand how window treatments impact daylighting. To properly select a fabric for daylight control the illumination and luminance must be considered.

Fabric Selection for Illumination of Work surface

Illuminance of the work surface by daylight is controlled by the visible transmittance of the solar shade fabric and the glass type. Proper daylight control requires balancing the fabric selection with the type of glass that has been selected for the space.

The amount of light that can pass through the fabric is measured by the visible transmittance of the fabric (Tv). The visible transmittance of the fabric is controlled by the fabric openness and color. Like fabric, a key property of glass is the visible transmission of light (VT).

Estimating what type of fabric that should be used for a particular glass type can be done using a daylight factor calculation. Daylight factor is useful for estimating how much exterior illumination will reach the interior of a space.⁷ The calculation of daylight factor is impacted by:

- Window to wall ratio of glass
- Visible transmittance of glass
- Visible transmittance of solar shade fabric

Proper daylight control requires selecting a solar shade fabric with a visible transmittance that compliments the glass selection. When the solar shade is down, a properly selected fabric will minimize the impact of direct sunlight on the work surface. As seen in Table 2, the 550 fc of light delivered to the work surface by a fabric with 25% visible transmittance delivers over 10 times the IES recommended 50 fc for work surface illumination. Fabric 1, provides 105 fc of light at the work surface when the shade is down which is a significant improvement in daylight control.

Table 2: Estimating Work Surface Illumination Using Daylight Factor

	Direct Sun Illuminance (fc)	8,000
	Glass Visible Transmission (%)	60%
	Fabric Visible Transmittance (%)	Work Surface Illuminance (fc)
Fabric 1	5%	105
Fabric 2	25%	550

Fabric Selection for Luminance

Luminance measures the directional brightness of a light source in (Cd/m²). When a solar shade is backlit by direct sun, it can become a source of glare. Based on IES guidelines, luminance ratios should never exceed 10:1 for adjacent objects to the work surface. When lighter colored shades are backlit by direct sunlight, their luminance can exceed 2,000 cd/m², which can create luminance ratios well above 10:1. In that case, a window treatment intended to minimize glare from the sun is now a source of glare.

Floor Plan Design

Desk position can have a significant impact on the ability to daylight in a space. Floor plan design is typically determined by workflow and the need to maximize the effective use of an office space. However, most daylight control strategies are based on minimizing direct sunlight on the work surface to minimize heat and glare. When the desks are move too close to the window, the shades tend to be lowered impacting the ability to daylight.

Figure 2 show contrasting floor plans and their ability to daylight. As seen in the space on the left of Figure 2, the position of the desks in this space are 3 ft from the window which keeps the shades closed on the curtain wall glass. In space on the right of Figure 2, desks are 6 ft away from the window using the perimeter of the workspace as a path of egress. The shades are open on the curtain wall glass and the carpet can be effectively used as a lightshelf to reflect daylight deeper into the space.

Figure 2: A Comparison of Floor Plan Designs for Daylighting



Desks are 3 ft from window requiring shades to be down limiting the ability to daylight



Desks are 6 ft from window allowing shades to be open and enabling effective daylighting

Conclusion

Incorporating daylight into a space can be very rewarding but it also has its challenges. Daylight is a variable source of light that need to be addressed during the design stage of every project. Interior design elements have a significant impact on daylighting in ways that impact occupancy comfort and energy savings. In the future, design teams trying to maximize the use of daylight harvesting in spaces will need to effectively integrate interior design elements, like window treatments, solar shade fabric selection and floor plan layout into their design criteria.

¹ Crepeau et al. Lighting as a Circadian Rhythm-Entraining and Alertness Enhancing Stimulus in the Submarine Environment.

² Boyce et al. The Benefits of Daylight Through Windows.

<http://www.lrc.rpi.edu/programs/daylighting/pdf/DaylightBenefits.pdf>

³ Rule of thumb used for HVAC load calculations from US Department of Energy model called DOE-2 and http://www.lightingdesignlab.com/articles/lighting_hvac/lighting_hvac.htm

⁴ Boyce et al. The Benefits of Daylight Through Windows.

<http://www.lrc.rpi.edu/programs/daylighting/pdf/DaylightBenefits.pdf>

⁵ Vogen Horn – Daylighting “...lighting every building using the sky”

⁶ et al. The Benefits of Daylight Through Windows.

<http://www.lrc.rpi.edu/programs/daylighting/pdf/DaylightBenefits.pdf>

⁷ Lighting Research Center, The Daylight Institute: Sustainable Daylighted Building Design