Using Daylighting Performance to Optimise Façade Design

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About IES

• IES was founded over 20 years ago and headquartered in Glasgow is recognised as a world leader in 3D performance analysis software that is used to design tens of thousands of energy efficient buildings across the globe.

• IES produce the market leading IESVE suite of building performance modelling tools

• IES’ technology is supported by integrated consulting services and today its capabilities are expanding from use on individual buildings to helping create sustainable cities.

• IES provides consulting services to Multi-disciplinary, Architectural, Engineering and Manufacturer organisations.

• IES Consulting have worked on over 2,000 projects worldwide, with over 300 years of combined experience and are involved with developing the IES’ technology.

• Our consultants are chartered engineers and accredited professionals across a number of worldwide schemes including LEED, BREEAM, ASHRAE, CIBSE, WELL, etc.
"A room is not a room without natural light"
Louis Kahn
But not all spaces capture daylight effectively

- Some spaces are expected to perform but are too exposed
- The result is visual discomfort with the knock-on of blinds being operated and lights on even when daylight outside is good.
Building Design Issues

What leads to some of these design issues?

• Firstly no daylight modelling is performed
• If it is then modelling occurs late when design flexibility is short
• May be modelled for a specific rating system only – this compliance type approach can offer little value
• Focus is on thermal performance without balancing sunlight needs
• Building types with standardised layouts / repeating spaces use the same façade approach regardless of orientation and seasonal needs
• Cost reduction influences design choices and negatively impacts building performance after design has finished
• The role of occupants is not taken into consideration and their use of blinds
• Innovative design approaches and products are not modelled correctly
Daylight Factor

DF is the ratio of the light level inside a structure to the light level outside the structure, defined as:

\[
DF = \left( \frac{E_i}{E_o} \right) \times 100\%
\]

where, \( E_i \) = illuminance due to daylight at a point on the indoors working plane, \( E_o \) = simultaneous outdoor illuminance on a horizontal plane from an unobstructed hemisphere of overcast sky

Calculating daylight factors requires complex repetition of calculations and thus is generally undertaken using a complex software product such as Radiance.

- Under 2 – Not adequately lit – artificial lighting is required
- Between 2 and 5 – Adequately lit but artificial lighting may be needed part of the time
- Over 5 – Well lit – artificial lighting generally not required, except at dawn and dusk – but glare and solar gain may cause problems
Climate Based Daylight Modelling

- CBDM is the prediction of any luminous quantity (illuminance and/or luminance) using realistic sun and sky conditions derived from standardised climate data.
- CBDM evaluations are usually carried out for a full year at a time-step of an hour or less in order to capture the daily and seasonal dynamics of natural daylight.
- CBDM results are typically focussed on the annual illuminance across nodes determined by a grid size which build up to form a working plane.
- Developed in the late 1990s.
- Can be applied to all buildings anywhere in the world.
Climate Based Daylight Modelling

- 2 phase method, as employed by RadianceIES, uses rtrace to generate the illuminance results at sensor points.
- A ray-tracing simulation to create daylight coefficients for points in the scene, i.e. sensor points or grid points on the WP.
- These coefficients are then used to calculate the illuminance at particular time-steps.
- This approach is much more efficient than running a ray-tracing simulation at each time-step.
- The underlying approach divides the celestial hemisphere into disjoint sky patches and was first proposed by Tregenza who used 145 sub-divisions.
- This approach was taken further by Reinhart with more divisions (minimum 2305) and it is this sky division approach that has been adopted by IES.
- The efficiency is that once the daylight coefficient has been calculated that any sky distribution can be plugged-in to generate the illuminance data.
- With this simple and fast calculation it is possible to simulate a full year to generate annual metrics or time-step by time-step to achieve a true dynamic simulation.
# Climate Based Daylight Modelling

Factors influencing the CBDM simulation:

<table>
<thead>
<tr>
<th>Building</th>
<th>Location</th>
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<tbody>
<tr>
<td>Orientation</td>
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<td>Form</td>
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<td>Window – geometry and transmittance</td>
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<td>Surface reflectance</td>
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<td>Surrounding buildings</td>
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Climate Based Daylight Modelling

- CBDM is sometimes discussed as being too complex

- However it shows now illumination equivalent of thermal lag/inertia and therefore should be an easier prediction than for example a thermal calculation

- CBDM results are typically focussed on the annual illuminance across nodes which build up to form a working plane therefore the number of outputs being assessed remains small
Daylight Issues

- Building industry should consider a move toward the CBDM approach since a space tested under an overcast sky will only ever tell you exactly that, how it performs under an overcast sky.

- DF is a % assessment so it's never going to tell you the captured illuminance the space will perform to.

- A facade designed under DF performance is not going to perform under sunny skies.

- The design needs of DF and CBDM are so different due to the direct component, shading components are not quantified in the same way but need to be accurately considered.

- DF is normally achieved with poor uniformity leading to big disparities in visual comfort across the space and occupant needs become very different leading to operational concerns involving internal blinds.
CBDM Metrics

Annual Illuminance

- The illuminance at a node displayed in lux
- Typically seen as the raw data of the analysis
- Could be taken as the average or cumulative at the node when comparing scenarios
CBDM Metrics

Daylight Autonomy (DA)

• An annual analysis of the fraction of occupied time that the daylight levels exceed a specified target illuminance

Pros:
• Gives an intuitive look at how well daylight will penetrate into the space
• Good for determining which fixtures would benefit from automatic daylight harvesting
• Takes into account the hours of actual operation and real weather conditions at the site

Cons:
• With no upper limit on the allowed illuminance levels then poorly performing spaces with direct sunlight can perform well, for example a greenhouse
Useful Daylight Illuminance (UDI)

- A variant of DA, it is defined as the annual occurrence of illuminances that is within a range considered “useful” by occupants. 3 ranges are applied defined as Supplementary, Autonomous and Exceedance.

- UDI-s (below x lux) where the light would be considered insufficient without electric lighting.
- UDI-a (x to y lux) where daylight is acceptable and electric lighting would not be needed for the majority of the day. Achieving a high UDI-a percentage signifies the space is predominantly daylit throughout and glare is controlled. This can be split into 2 sub-bands defined by the space design illuminance, e.g. 500 lux.
- UDI-e (above y lux) where the amount of daylight would be considered excessive and a source of glare. This creates an expectation blinds would need to be operated.
CBDM Metrics

Pros:
• UDI attempts to penalize for direct sunlight that falls into the space, on the theory that people will find this glary and distracting.
• Good for comparing the performance of two design variations

Cons:
• Since three data points are generated for every spatial point, it is difficult to assess performance at a glance or communicate how well the space performs to the layman
Spatial Daylight Autonomy (sDA)

- A measure of daylight illuminance sufficiency for a given area, reporting a % of floor area that exceeds a specified illuminance level for the specified analysis period.

**Pros:**
- Unlike DA which returns an array of data points for every location in the space, it returns a single number for the space.
- Includes the operational role of shading devices.

**Cons:**
- sDA does not incorporate glare or direct sun exposure – it is intended that ASE would be evaluated separately.
CBDM Metrics

Annual Sunlight Exposure (ASE)

- The % of an analysis area that exceeds a specified direct sunlight illuminance level more than a specified number of hours per year, with operable blinds left open
- Does not include for any sunlight bounces
CBDM Metrics

Pros:
• Fast to calculate
• Useful as a design tool, since it gives a good handle on where the problem areas might be of a design
• Incorporates potential issues of thermal discomfort

Cons:
• Does not address issues of glare due to specular reflections or veiling glare from high luminance ratios
• Strictly speaking not a glare metric at all, it is just a proxy that has been found to predict glare discomfort in many cases.
LM-83

- LM-83 is the Illuminating Engineering Society’s approved method for sDA and ASE
- Driven by the fact an average illuminance is less meaningful due to non-uniform illuminance distributions due to space geometry and other factors discussed
- Set out to be a consistent calculation methodology for multiple design alternatives to be fairly compared
- Defines sDA and ASE
- Defines window groups to allow for blind/shade operation in sDA modelling
- Recommends performance criteria

- \( sDA_{300/50\%} \) – \% of analysis area that achieves 300 lux threshold for 50\% of the analysis period, typically 10 hours per day (1,825 hours per year)
- \( ASE_{1000,250} \) – \% of sensors in the analysis area no more than 1000 lux for more than 250 hours per year considering the same analysis period as sDA
Rating & Compliance Systems

EFA Priority Schools Building Program
• 2013 release included CBDM without option for DF route
• DA should achieve 300 lux for 50% of the time for 50% of the working plane
• UDI minimum target of an average of 80% UDI-a for each learning space for a band of 100-3000 lux
• Aim is to take account of the quality and quantity of sunlight and ensure daylight design becomes a fundamental part of the architectural design
• Specify analysis parameters including 0830-1600h period of operation and 250mm maximum grid size

WELL Building Standard
• Focuses solely on the health and wellness of building occupants
• Includes credit 62 Daylight Modelling
• Uses sDA and ASE metrics
Rating & Compliance Systems

LEED V4

• Includes for Indoor Environmental Quality credit Daylight Option 1. Simulation: Spatial Daylight Autonomy and Annual Sunlight Exposure
• Uses sDA and ASE metrics
• Intent is to more accurately predict daylight access and support the design process for optimising daylight
• Increased access to daylight to the benefit of human behavioural and health effects
• Up to 3 points available
• Approved by IESNA
Daylight Modelling Issues

Common issues include:

• Time
• What approach should be taken - the strategy
• Where in the design stage?
• What tools?
• What method, i.e. massing, sensitivity, detailed, full
Modelling Strategy

• Successful daylight modelling design starts with clearly defined goals

• Design teams should first establish project goals that affect the quality of daylight in a space, setting parameters for direct solar control and uniformity of distribution

• Secondly, quantitative goals such as illuminance and energy targets, and cost considerations should be understood

• Usability and functionality goals and architectural integration are equally important to establish, through a more subjective lens

• Metrics or rating programs should be used as a design guide only if the goals of the project are in line with the daylighting credit/point intent
Modelling Strategy - Suncast

- To analyse the façade exposure map resulting from solar performance
- Review hours and energy
- Identify the most at risk surfaces
- Orientation effects
- Work to determine floor layout and shelter at risk space types
Modelling Strategy - RadianceIES

- To analyse daylight performance captured by the façade
- Review annual illuminance distribution
- Depth of sunlight
- The impact of occupied period’s daylight effectiveness
- Visual comfort / glare
Modelling Strategy - Apache

- To analyse thermal performance from the façade strategy
- Solar gains impacting space conditioning loads and overheating
- Electrical lighting energy consumption
- Total building energy consumption
- Thermal comfort
Future of Daylight Modelling

Architectural design features continue to progress and models need to test performance for:

- Double Facades
- Closed Cavity Facades (CCF)
- Interstitial blinds
- Organically shaped fixed external shades
- Automatic movable external shades
- Transparent architectural forms such as meshes, grilles and fabrics

How to model some of these features?
Future of Daylight Modelling

BSDF - bidirectional scattering distribution function

- Used to name the function which describes the way light is scattered by a surface
- BSDF is to a fenestration system what an IES file is to a luminaire
- File contains output distributions for many incident directions
- Characterises light transmission, reflection and directional distribution of a surface or product
- Essentially a black box to simulate the performance of optically complex fenestration systems
- Represents a transmission element such as a shading device, much easier than drawing
Future of Daylight Modelling

3-phase method
• Includes a BSDF transmission matrix between the daylight and visual matrices

5-phase method
• Employs a high resolution BSDF or actual BSDF geometry to apply the direct solar component as part of the calculation
Future of Daylight Modelling

Parametric modelling

• As standard
• Gaining a foothold in the design process
• Will allow teams to assess a multitude of design options
• Additional modelling time is being supported by increased computation speed and cloud resources
• The key is having a defined strategy to manage the data so not to drown under the sheer volume
• Automatic optimisation is the next step but is not a magic wand
Future of Daylight Modelling

Answer evolving design concerns

• Overheating is a big topic and solar management is at the top of that agenda

• Reducing lighting loads is a substantial help but balancing sunlight and solar gains is crucial

• Wellbeing, which also includes thermal management, is a buzzword and visual comfort management will rise in stature
Thank You + Questions

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