QODA

Climate Based Daylight Modelling (CBDM) - what is it and how does it improve building design?

Introduction

Most designers would instinctively agree that natural daylight is vital to healthy buildings, but would be less sure how to define 'well daylit' or how to design a building to achieve it. Climate Based Daylight Modelling (CBDM) offers a numerical approach to this design challenge, using modern computational power to evaluate year-round natural light performance of designed spaces in a real climate approximating their intended location. In this respect, CBDM is the equivalent of Dynamic Thermal Simulation for thermal and energy performance, but for natural light.

CBDM has been in development as a performance metric for some years, but became more widely known when it was adopted by the Education Funding Agency (EFA) for all Priority School Building Programme (PSBP) projects in 2014. More recently, it was adopted by the Leadership in Energy and Environmental Design (LEED V4) standard, meaning it will become more commonplace over the next few years.

The science behind CBDM

Traditional assessment of natural daylight in buildings has been done using the Average Daylight Factor (ADF) and related metrics, which are based on a calculated ratio of illuminance outside the building (under a conservative cloudy sky), to the level of illuminance at the working plane inside the building. This approach generates simple and easy-to-understand results, and a single number for a given room in a building. The ADF is therefore a useful tool for quick checks of the intended geometry of a space, but does not have the sophistication to guide detailed glazing and solar design, for example. CBDM provides a highly detailed view of natural light performance by factoring in the following variables:

- Likely climate at building location (specifically including both clear and cloudy skies and their prevalence)
- Solar geometry by latitude and longitude
- Building orientation
- Room and building geometry
- Overshadowing
- User operation of blinds and active solar control measures

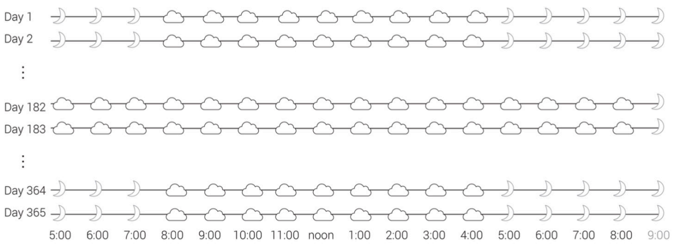


Figure 1

Climate

Traditional point-in-time measurements of natural daylight assume a fixed climate. In the case of the ADF, this is a dull, overcast sky, as shown in figure 1.

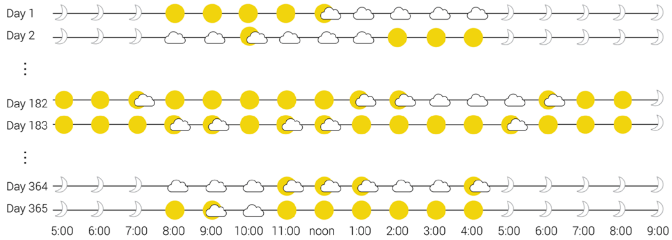


Figure 2

By contrast, climate-based approaches to daylight approximate the real climate of the building location, using the Typical Meteorological Year (TMY). Weather files for global locations are available from the Energy Plus Weather Data service, but are usually built into the specialist software used for daylight modelling.

These weather data are used to generate hourly internal illuminance levels in the designed building, across a fixed grid in the room. This grid is usually at 0.5m or 1m spacing, and 0.75m-0.9m from the floor, and is known as the working plane. Finer or coarser grids are also possible, and floor plane grids, or even walls and ceilings if required.

Figure 3 below shows an illuminance grid, where each point is measured once per hour throughout the daytime year - around 3,600-4,300 data points depending on the daylight metric in use.

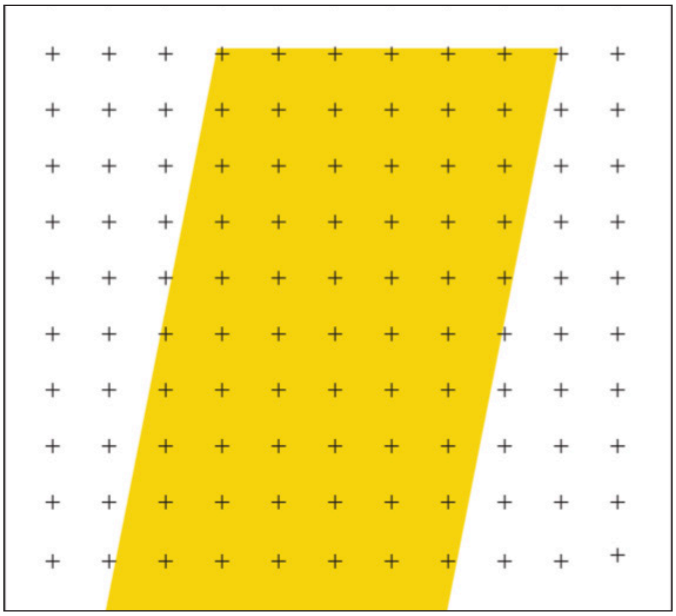


Figure 3

The yellow illuminated area is sunlight arriving at the facade at a specific moment in time.

Ray trace simulations are carried out for each hour of the year, giving rise to an annual average illuminance value for each grid point across the working plane.

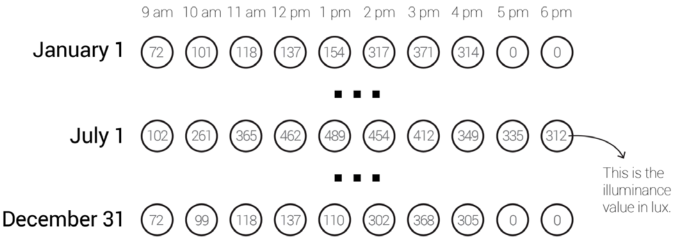
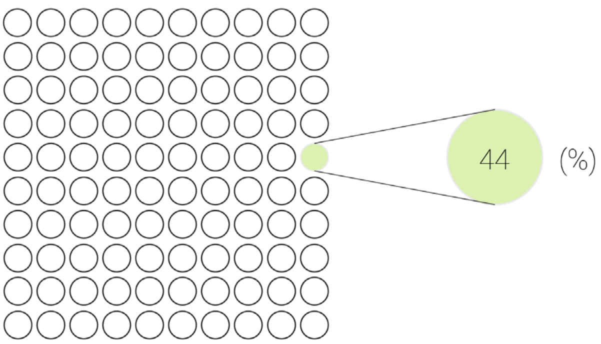


Figure 4

This set of data are the basis on which nearly all CBDM metrics are then calculated. The LEED standard includes a variety of metrics, but the most commonly used in the UK are the Useful Daylight Illuminance (UDI) and Daylight Autonomy (DA). These are specified by the EFA for school design, and values given that all teaching spaces must meet. UDI is unique in specifying both a minimum and maximum daylight level, which allows this single metric to guide designers on both sufficient daylight, and avoiding both glare and excessive solar gains. The use of UDI in school designs has resulted in a significant reduction in total glazed area to a typical school classroom when referenced against designs based on the daylight factor. This should result in lower levels of summer overheating, all other factors being equal.

Figure 5

The UDI uses the average illuminance per grid point, and measures it against the minimum and maximum illuminance permitted, generating a 'pass' or 'fail' result. In the case of an EFA school classroom, for example, minimum illuminance is typically 100 lux, and maximum 3000 lux. Where the grid falls between these values, the illuminance is deemed acceptable. Over a year, these individual values are aggregated, to give an area percentage that complies with the requirements.



This point is within the useful range of daylight for 44% of one year. The rest of the time it is either too bright or too dark.

Figure 6

In the example shown in figure 6, the point identified has acceptable illuminance values for 44% of the possible daylit year. Having values that are both spatial, and time-based, allow designers a fuller picture of the daylight performance of a designed space.

CBDM in use

Using CBDM, comparisons are possible between complex alternative designs, where more basic metrics like the daylight factor could not determine differences in performance. Not only that, but because the UDI identifies areas of excessive light, the design can be optimised to reduce glare and unwanted sunlight.

To illustrate this benefit, two window arrangements are compared on a typical school classroom, one with conventional windows, the other with a light shelf.

The area of excessive light near the window (shown in light blue), is completely removed by the use of the light shelf, and at the same time, the desirable area of useful light has moved from the rear of the classroom to the centre. These subtitles of design decision making would not be possible using a method like the daylight factor. The CBDM approach therefore allows a step-change in the design of spaces that are well naturally daylit.

The technical briefing is an introductory summary of the complex subject of CBDM, and has necessarily excluded some topics. Further reading is available from a number of online sources. Some of the imagery is provided courtesy of LightStanza (www.lightstanza.com), a leading provider of specialist CBDM software, with whom QODA work closely.

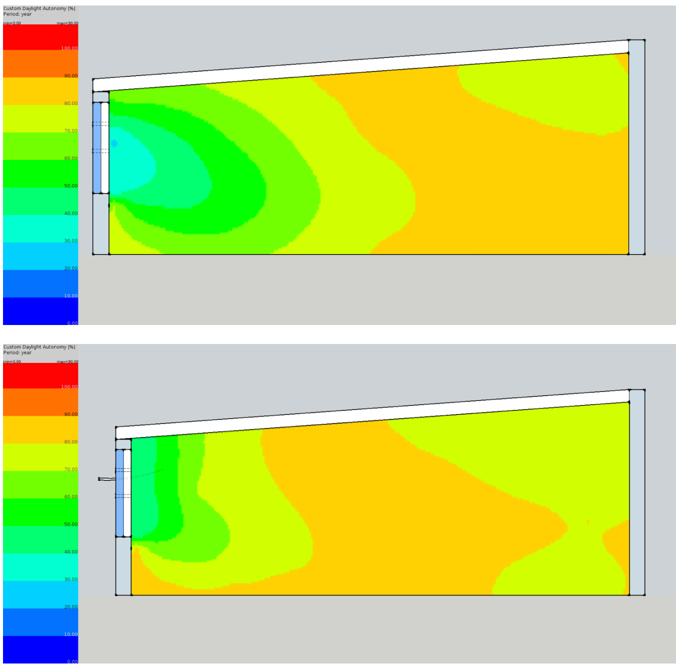


Figure 7