DAYLIGHTING ANALYSIS

www.interactivearchitecture.org/lightmodulator-nick-nch.html

Generic Design/Analysis Methods
(applicable to all sorts of systems)

• Rules/patterns/precedents
  – Simple to use; little input information is required; results have limited accuracy; such methods are typically used to establish best first design moves

• First principles
  – Looking to the laws of physics for analysis procedures; very difficult for complex systems due to multiple interactions between numerous variables

• Correlation methods
  – Can appear complex, but intended to be relatively simple to use; some specific input information is required (namely, the “correlating” parameters); can give fair accuracy; typically used to refine first design moves
Generic Design/Analysis Methods

• **Digital simulation methods**
  – Computer software programs crunching numbers; simulations may use correlations or (more commonly) first principles; lots of specific input information is required; accuracy can be exceptional (or not—remember the "junk in, junk out" rule); historically used as a design refinement tool, but there is a strong trend in practice toward use in the early stages of the design process

• **Analog methods**
  – Object-based using scale models; the extent of required input information varies with the accuracy desired; accuracy can be great (and is a direct function of model accuracy); can be used as both a first-moves and as a design-refinement tool

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**Generic Design/Analysis Methods**

• **Rules/patterns/precedents**

![Image of a room with daylight and a graph](https://www.slideshare.net)

- **Inverse Square Law**
  - Intensity of illumination produced by a point source varies inversely as square of the distance from the source.
  - \[ I \propto \frac{1}{d^2} \]
  - Where, \( I \) is intensity and \( d \) is distance

  ![Graph showing inverse square law](https://www.slideshare.net)

www.slideshare.net

- **First principles**
  - I can solve this equation

www.slideshare.net
Generic Design/Analysis Methods

• Correlation methods

Generic Design/Analysis Methods

• Digital simulation methods

expanding-sketchup.blogspot.com

www.tboake.com

www.lowenergystudio.com
Generic Design/Analysis Methods

• Analog methods

Daylighting Patterns: Getting Started

• The 2.5H “rule”
  – This empirical rule predicts that “useful” daylight will penetrate a space to a distance of 2.5 times the height (H) of a window (above the work plane)—assuming a window width of about 50% of the wall width and an overcast sky (the sky type may not be critical, however, as this is a rough rule)

• The 15/30 “rule”
  – Suggests that a 15-foot-deep zone inward from a window (the wall plane) will receive “adequate” daylight for office work, the next 15 feet (to 30 feet total) will receive “some” daylight (to be supplemented with electric lighting), after 30 feet … there is not much daylighting—assuming no intervening opaque partitions
Daylighting Patterns: Getting Started

- Rough estimations
  - For sidelighting
    - \( DF_{\text{average}} = 0.2 \) (window area/floor area)
    - \( DF_{\text{minimum}} = 0.1 \) (window area/floor area)
  - For toplighting
    - Clerestory
      - \( DF_{\text{average}} = 0.2 \) (glazing area/floor area)
    - Horizontal skylight
      - \( DF_{\text{average}} = 0.5 \) (skylight area/floor area)

As with all such estimates, a reasonable design layout is assumed.

More-Refined Daylighting Prediction/Validation Methods

- BRS daylighting protractors (consisting of drawing overlays)
- CIE method (involving many charts)
- IES lumen method (similar to the zonal cavity method used with electric lighting)
- Computer simulations (many programs are available)
- Physical models
BRS Protractors (Correlation)

Building Research Station (UK) for overcast sky conditions
daylighting “units” are read off overlays; rarely used in the US, but the graphic approach can inform design thinking (see next slide)

these are transparent overlays that are used in conjunction with plan and section drawings

BRS Protractors

note that this approach graphically defines the extent of sky “resources” available at any given point within a building — forget the overlay and just do the sketch!
CIE Method (Correlation)

CIE (Europe) for overcast sky conditions
DF is read from chart; rarely used in the US

CIE Method vs. LEED & 2.5H

note that a 60% window area, in a 30 foot wide room, with a room depth of 2.5H yields an initial 2% minimum DF (as required by LEED-NC 2.1)
IES Lumen Method (Correlation)

**THE PROCESS**
1. Determine available daylight.
2. Find transmission through the window.
3. Apply coefficients of utilization for MAX, MID, and MIN.
4. Add illumination from sky and ground for MAX, MID, and MIN.

IESNA (from L-O-F) (USA) -- obsolete overcast sky conditions?
this method is similar to a commonly used electric lighting design method

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Daylighting Software
(may be correlation or first principles)

numerous software packages are readily available for overcast and clear sky conditions
electric light integration usually included

early example of daylighting software
Daylighting Software

Ecotect (and then part of Autodesk; and now ??)

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Daylighting Software

photo-realistic rendering developed in Radiance (from LBL)

image from Arup Lighting
Daylighting Software

- does a program do daylighting analysis or just direct solar?
- what is the learning curve like?
- what is the required input? (too little = inaccurate; too much = time consuming)
- what is the output like?

image from Arup Lighting

www.buildingenergysoftwaretools.com/software-listing

Physical Models (Analog)

as good as the model maker’s skills … what you see can be what you’ll get
Daylighting Models

TVA Building, Chattanooga
model testing showed that atrium louvers would cast too-intense shadows

Using Daylighting Models

^^ architectural daylight meter

^^ mirror sky

what you see (windows behind stage not a good idea)
Daylighting Design Tools vs. Shading Design Tools

artificial sky (LBL): can simulate clear and overcast skies

heliodon (PEC): simulates direct solar radiation

Several Examples of Daylighting

as with the Kimbell Art Museum, a very "architectural" daylighting fixture is a key building feature
compare size of circular skylight
to size of opening on roof
(three slides down)
Mount Angel Library

note electric lamps over bubble skylights—honest / dishonest?

Mount Angel Library

note three different shading treatments on one façade; the interior conditions drive this
surfaces adjacent to apertures are designed to spread daylight and reduce contrast

reading carrels receive and pass on daylight; providing for both privacy and daylight transfer
U.S. Air Force Academy Chapel, Colorado Springs, CO, SOM

www.usafa.af.mil/
Churches, Color, and Daylighting, Portland, OR

stained glass as object

Churches, Color, and Daylighting, Eugene, OR

stained glass as illuminator
under daylight

the lighting “fixtures”

Churches, Color, and Daylighting, Portland, OR

under electric light

daylighting as fallout from a powerful design concept

Thorncrown Chapel, Eureka Springs, AR, Fay Jones
daylighting as a means of expression

MIT Chapel, Cambridge, MA, Eero Saarinen

see following slide for “results”

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daylighting (and electric lighting) as expression

MIT Chapel

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sunlighting/daylighting as connection

circulation spine, earth sheltered bookstore, University of Minnesota
unless blinding, direct solar is often welcomed below ground

Pantheon, Rome, Italy