

4.430 Daylighting

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4.430 Daylight Availability Metrics



Scale Models

- Build a 1/2" to the foot model of your course project. Maximum model dimensions are 20' x 30' with a maximum height of 20'.
- You may for example choose one specific element of the design for which your group would like to test various options. This could be exterior variants such as louvers or window sizes and locations, or interior variants such as light shelves, material properties or ceiling profiles.
- It is advisable to develop your design in sketch form before constructing the model.
- Please submit a few photos of your model(s).
- To build your models, you will need the following list of items:
 - o Xacto or matte knife and blades
 - o Straight edge for cutting
 - o Architect's scale
 - o Triangle(s)
 - o Tracing Paper
 - o Pens or pencils for sketching
 - o FoamCor (enough)
 - o Glue and/or pins to hold model together
 - o Tape (black if available) to prevent light leaks
 - o Any other favorite model building tools and materials.

Which group has never built a model?



Daylight Availability Metrics



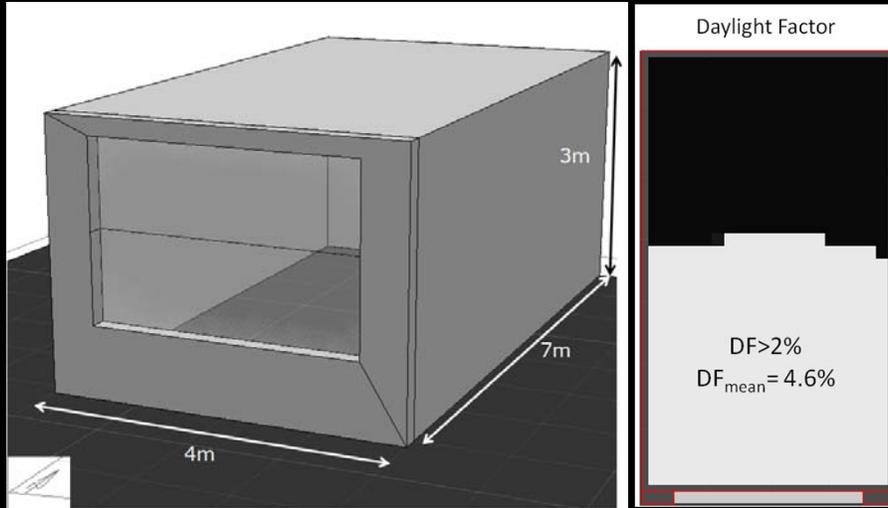
Historical Background: “Right of Light”

UK Prescription Act (1832): If one has benefited from daylight access across some else's property for over 20 years, an absolute and indefeasible 'rights to light' is granted to the building.

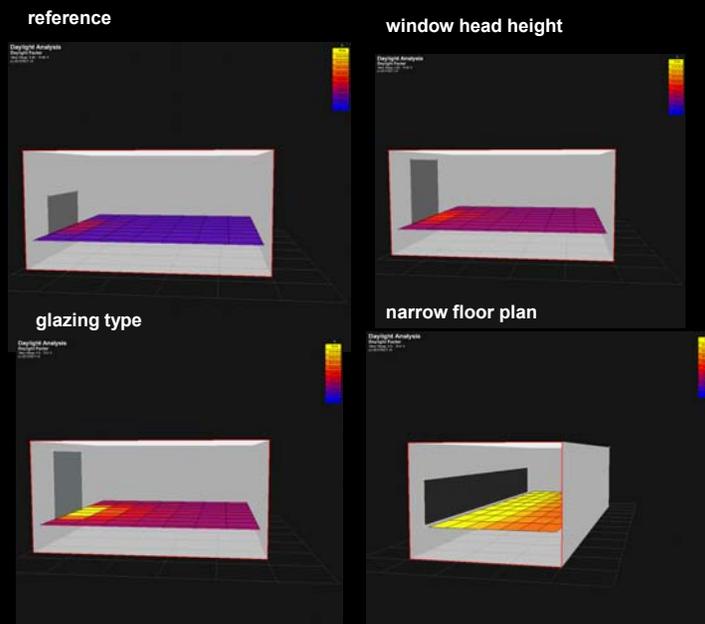
"Before WWII, legal rights of light constituted practically the only profitable field for daylight experts."



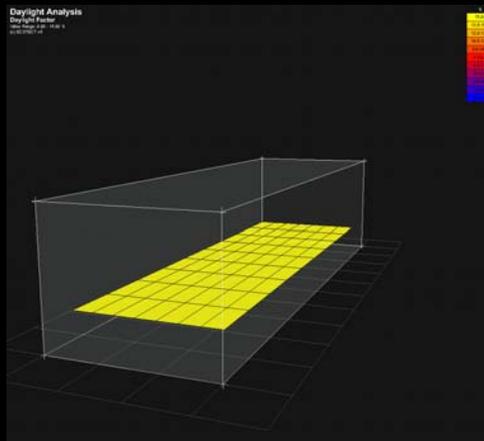
Daylight Factor Analysis - Example



Daylight Factor – Design Implications



Daylight Factor – Design Implications



Note, there are LEED certified buildings that are fully glazed!

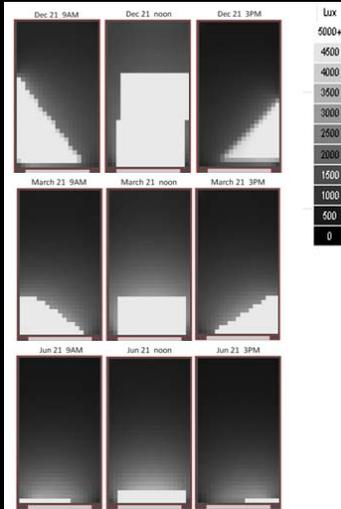


Daylight Factor Use in Design

- Argument:
 - overcast sky as a worst case scenario
 - venetian blinds (even if closed) still admit sufficient DL



Combine Daylight Factor Analysis with Shading Studies



Resulting building design good from an energy standpoint. Could it be better?



D/S emo: Daylight Factor and Clear Sky Calculations



Climate-based Metrics



Limitations of DF & Avoidance of Direct Solar Gains:

- ❑ local climate data (Vancouver vs. Regina)
- ❑ building use (occupancy patterns, lighting requirements)
- ❑ movable shading devices (venetian blinds)



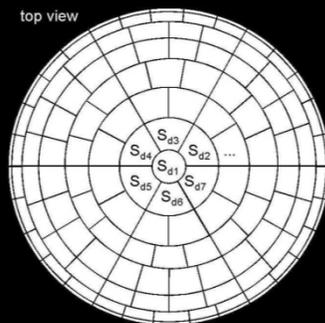
Solution? – Climate-based Metrics

- As opposed to a **static** simulation that only considers one sky condition at a time, **dynamic** daylight simulations generate annual time series of interior illuminances and/or luminances.

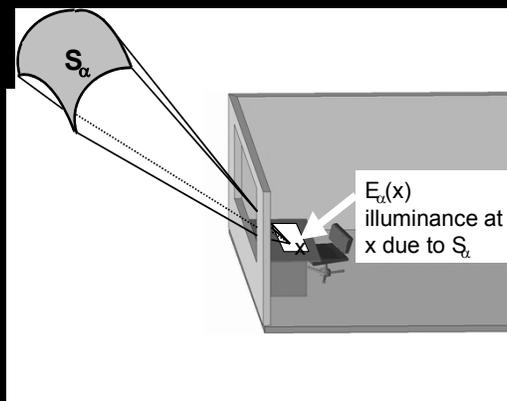


Daylight Coefficients

(1) Division of the Celestial Hemisphere



(2) Calculate Daylight Coefficients



Dynamic Daylight Performance Metrics

- ❑ DDS result in thousands of data points for each sensor.
- ❑ The task at hand is to reduce the data without diminishing its value for building design.
- ❑ Points for discussion:
 - time base
 - lighting requirements
 - movable shading devices



Time Base

- ❑ Daylit Hours of the year:
 - + building form directly related to building site
- ❑ Occupied hours of the year:
 - + daylight needs “witnesses”
 - + sensitive to building use
 - + self scaling: spans the whole range from 0% to 100%
 - + occupancy profiles for different building zones available



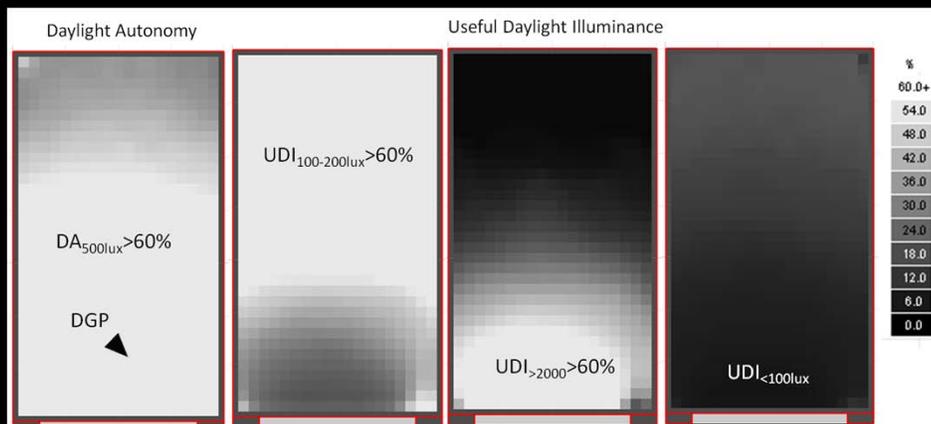
Lighting Requirements – Office Work

- Daylight Autonomy (DA): percentage of working hours when a minimum work plane illuminance is maintained by daylight alone
 - Useful Daylight Illuminances (UDI): divides working hours into three bins:
 - % < 100lux (insufficient daylight)
 - % between 100 lux and 2000 lux (useful daylight)
 - % > 2000 lux (too much DL => visual/thermal discomfort)
 - Continuous DA & DA_{max}:
 - continuous DA >40% 1 credit
 - continuous DA >60% 2 credits
 - continuous DA >80% 3 credits
- } for 60% of work plane and DA_{max}<1%

Paper: Dynamic Daylight Performance Metrics for Sustainable Building Design', Reinhart, Mardaljevic, Rogers (LEUKOS July 2006) <http://www.ies.org/leukos/volume3/number1.cfm>



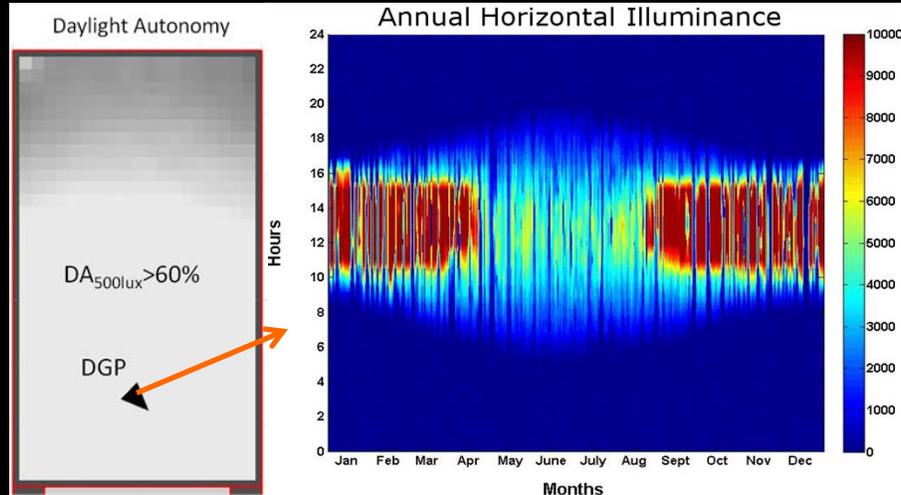
Climate-based Metrics – Spatial Maps



Too much daylight near the facade?



Climate-based Metrics – Temporal Maps



Too much daylight near the façade!



Lighting Requirements - Museums

- Annual Light Exposure: established upper threshold for artwork – already established used for museums (CIE TC3-22 'Museum lighting and protection against radiation damage')



Museum Lighting Requirements

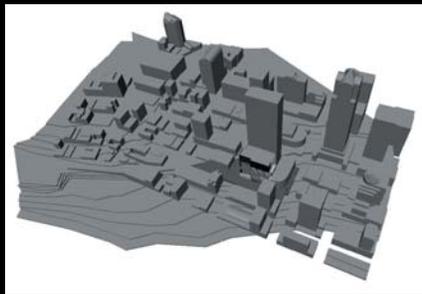
CIE TC3-22 'Museum lighting and protection against radiation damage'

category	material classification	example of materials	lighting illuminance	limiting annual exposure
I	insensitive	metal, stone, glass, ceramic	no limit	no limit
II	low sensitivity	canvases, frescos, wood, leather	200 lux	600 000 lux h /yr
III	medium sensitivity	watercolor, pastel, various paper	50 lux	150 000 lux h/yr
IV	high sensitivity	silk, newspaper, sensitive pigments	50 lux	15 000 lux h/yr

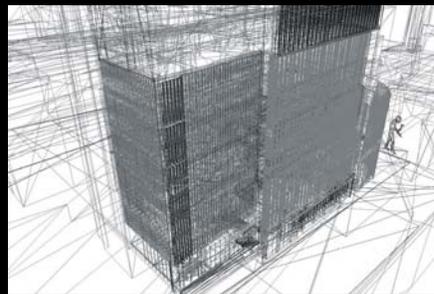


Example: Seattle Art Museum - Arup Lighting using Daysim

3D model of site and building



ARUP Lighting

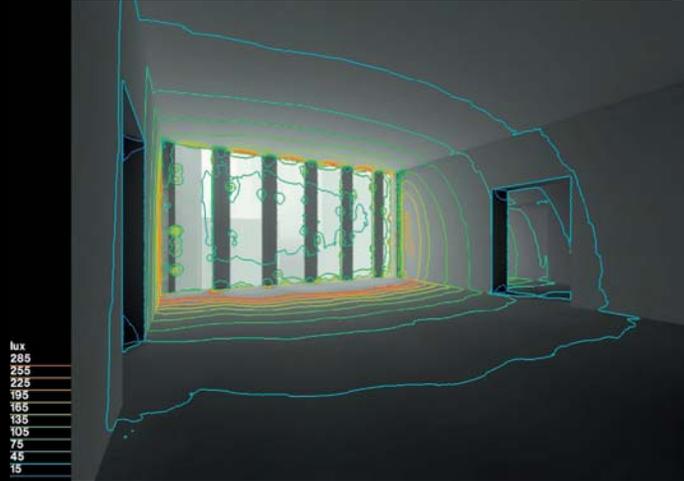


Courtesy of Arup Lighting (Matthew Franks). Used with permission.

source: http://www.radiance-online.org/community/workshops/2005-montreal/PDF/Franks_ArupCaseStudies.pdf



Seattle Art Museum - Arup Lighting



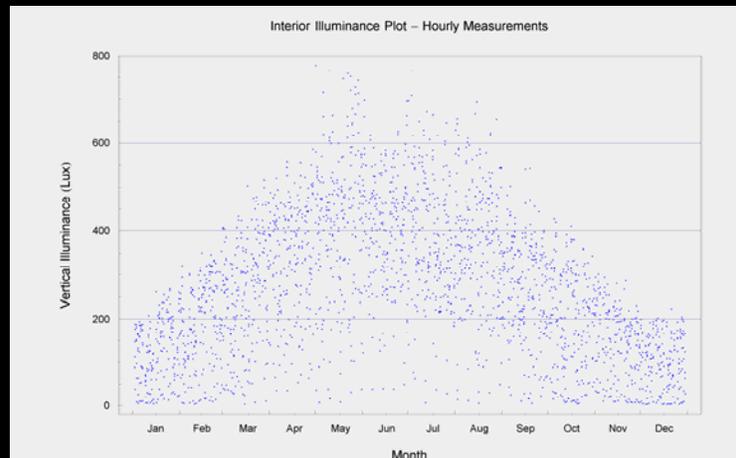
ARUP Lighting

Courtesy of Arup Lighting (Matthew Franks). Used with permission.



Seattle Art Museum - Arup Lighting

Museum Open Hours 1,500,000+ lux-hours



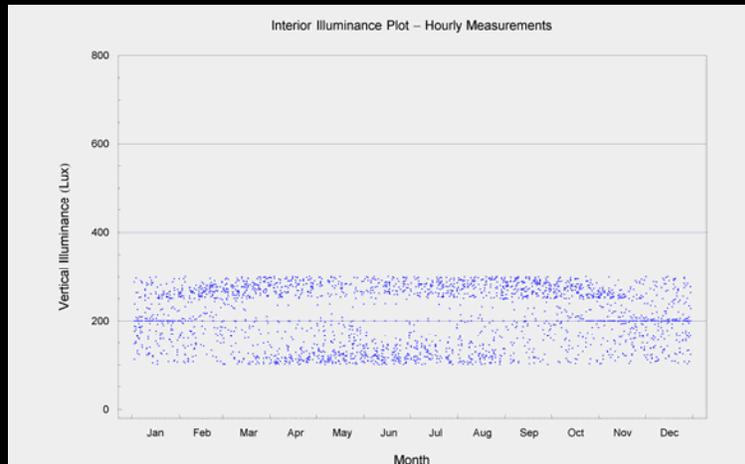
ARUP Lighting

Courtesy of Arup Lighting (Matthew Franks). Used with permission.



Seattle Art Museum - Arup Lighting

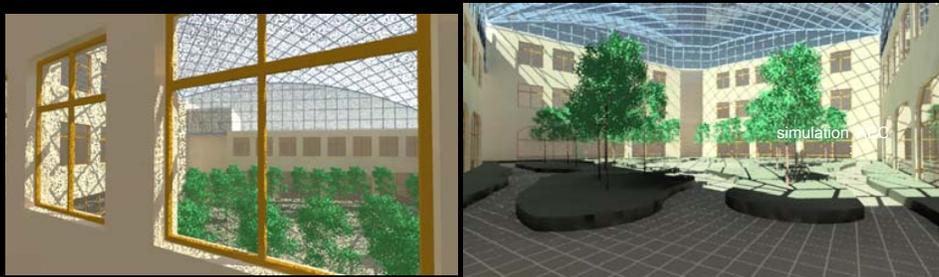
Automatic Shading + Switching 555,000 lh



Courtesy of Arup Lighting (Matthew Franks). Used with permission. ARUP New York

Wrigley Global Innovation Center Chicago, Illinois – AEC

- Winter Garden Atrium break area
- Views from adjacent offices



Courtesy of Zack Rogers, PE, President, Daylighting Innovations. LLC. Used with permission.

Source: <http://www.radiance-online.org/community/workshops/2005-montreal/PDF/AEC.pdf/>



Bldg G Conversion Hartford, CT, USA

architecture: Pratt & Whitney

Perspective drawing of Building G
removed due to copyright restrictions.

Analysis grid of building section
removed due to copyright restrictions.

general office space 130' x 310'

simulation: Kalwall



⌘ Demo: Daylight Autonomy



Daylighting Metrics in Gymnasia

MS Thesis Project -Cynthia Kwan



IESNA RP-6-01 Sports and Recreational Area Lighting

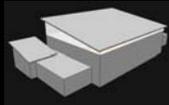
- ❑ Target Illuminance
 - 500 lux for Class III (Some provisions for spectators)
 - 300 lux for Class IV (No provision for spectators)

- ❑ Uniformity ratio (max/min illuminance)
 - ≤ 3.0 for Class III (Some provisions for spectators)
 - ≤ 4.0 for Class IV (No provision for spectators)

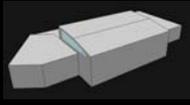
- ❑ Glare avoidance



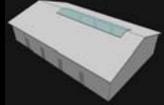
Case Studies



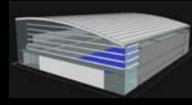
Greensburg, PA
Area 784 m²
Class IV



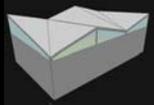
Colbert, WA
Area 534 m²
Class IV



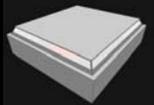
Brownsville, VA
Area 699 m²
Class IV



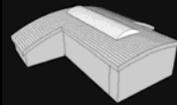
Clouston, WV
Area 1397 m²
Class III



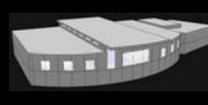
Largo, FL
Area 603 m²
Class IV



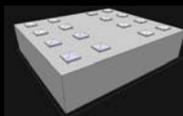
Alameda, CA
Area 1741 m²
Class III



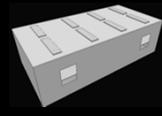
Gloucester, United Kingdom
Area 589 m²
Class IV



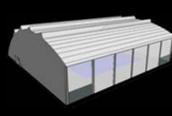
Omaha, NE
Area 2694 m²
Class III



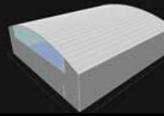
Walton, NY
Area 850 m²
Class III



Berea, OH
Area 502 m²
Class IV



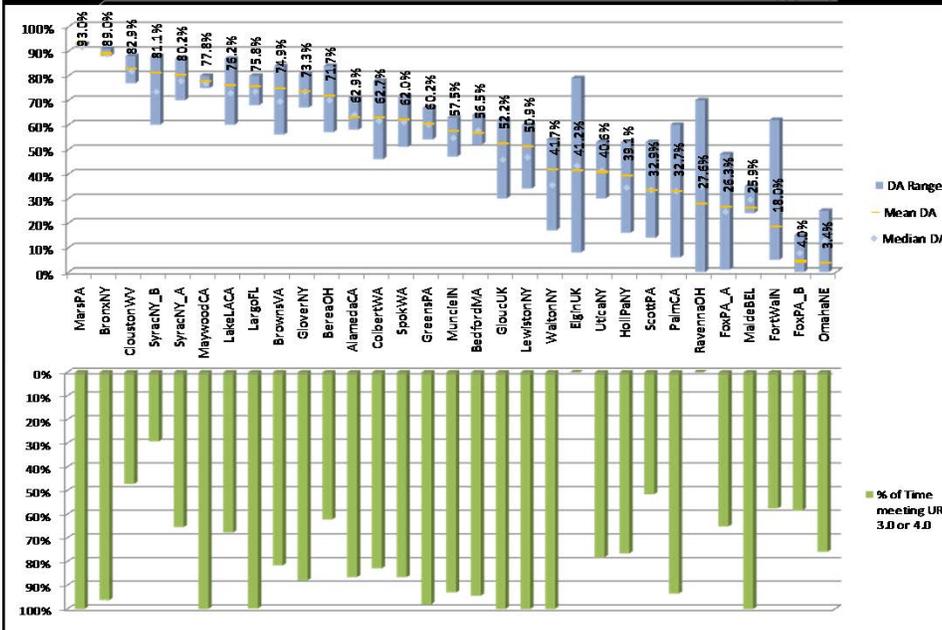
Maldegem, Belgium
Area 2440 m²
Class III



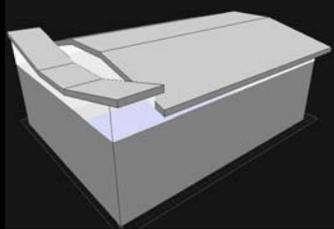
Scottsdale, PA
Area 863 m² Class III



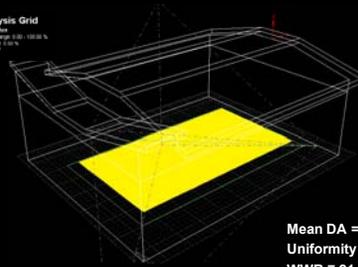
Results DA & Uniformity Ratios



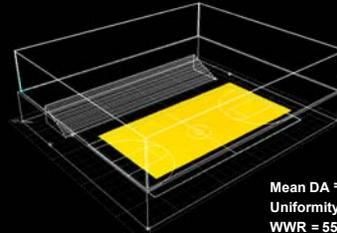
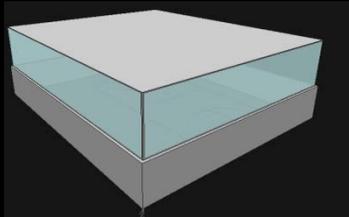
High-scoring Designs



Analysis Grid
Grid Size: 1000 x 1000
Grid Spacing: 1000 x 1000
Grid Type: 2D



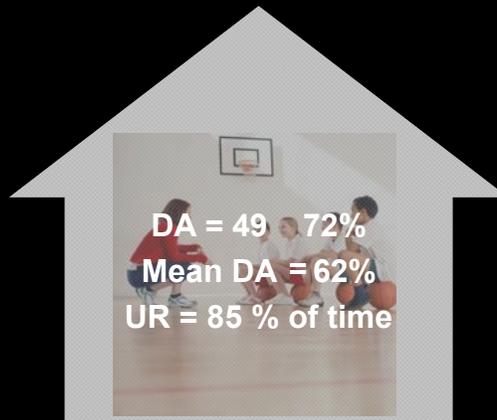
Mean DA = 92.5%
Uniformity met = 100%
WWR = 21.07%



Mean DA = 89.0%
Uniformity met = 96.27%
WWR = 55.33%



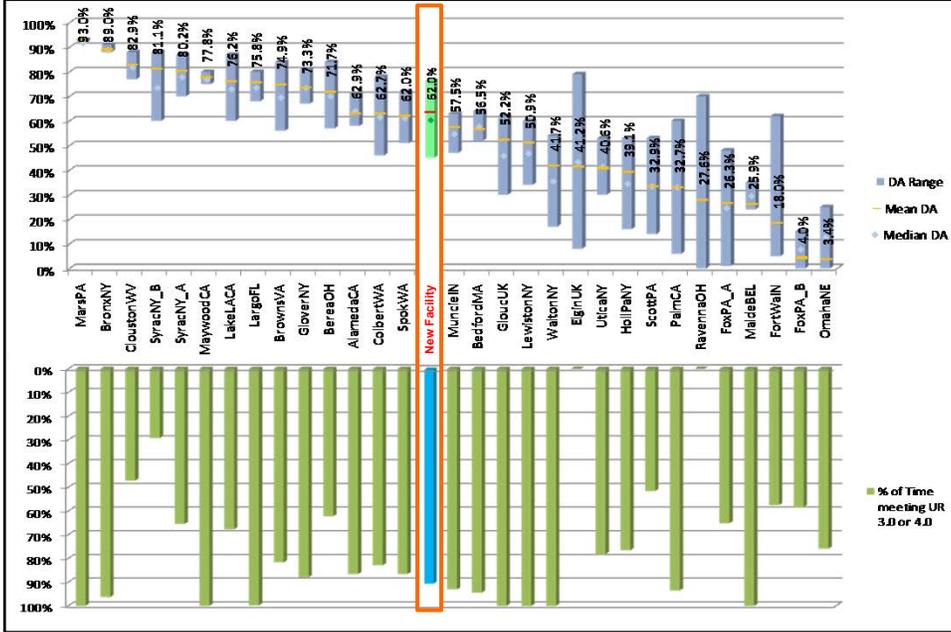
Example Application: New Sports Facility



DA = 49 72%
Mean DA = 62%
UR = 85 % of time



New Sports Facility



MIT OpenCourseWare
<http://ocw.mit.edu>

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Spring 2012

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