A Comparative Discussion

Using Radiance, DAYSIM and Physical Models in Architectural Practice

8th International Radiance Workshop, Harvard GSD
2009_10_22

Presented by: Kevin Van Den Wymelenberg, University of Idaho, Integrated Design Lab - Boise

Thanks to: Northwest Energy Efficiency Alliance
IDL Staff Ery Djunaedy PhD, Gunnar Gladics, Nick Hubof and Tim Hedrick
Special thanks: Mehlika Inanici, PhD
Integrated Design Lab Network

Seattle – University of Washington
Portland – University of Oregon
Boise – University of Idaho
Bozeman – Montana State University
Spokane – Washington State University
DAYLIGHTING TOOLS
No Shading - 12 PM

With Shading - 12 PM

June

September

December

PHYSICAL MODELING HELIODON
OVERCAST SKYBOX Design Analysis

Li-Cor 210 sa

Easy HDRs
PHYSICAL MODELING OVERCAST SKYBOX

Baseline: No skylights
RAINIER VISTA BOYS & GIRLS CLUB- Seattle, WA (IDL- Puget Sound)

PHYSICAL MODELING OVERCAST SKYBOX

Modification 1: Two skylights- One in stairwell
Modification 2: Two skylights- Both in Learning Center
Rainier Vista Boys & Girls Club - Seattle, WA (IDL - Puget Sound)

**Physical Modeling: Overcast Skybox**

Modification 3: Three skylights - Two in Learning Center and one in stairwell
RAINIER VISTA BOYS & GIRLS CLUB- Seattle, WA (IDL- Puget Sound)

PHYSICAL MODELING OVERCAST SKYBOX

Modification 4: One skylight- Elongated rectangle
RAINIER VISTA BOYS & GIRLS CLUB - Seattle, WA (IDL- Puget Sound)

PHYSICAL MODELING OVERCAST SKYBOX

Modification 5: Two skylights - Large squares
RAINIER VISTA BOYS & GIRLS CLUB - Seattle, WA (IDL - Puget Sound)

**PHYSICAL MODELING**

**OVERCAST SKYBOX**

Modification 6: Two skylights - Large 6' x 16' rectangle and skylight at stairwell
North Mall Office Building – Salem, OR
YGH, Portland, Boise

PHYSICAL MODELING ~ Confidence
Garden City Head Start – Boise, ID
McKibben & Cooper Architects, Boise 2002 TESTS

PHYSICAL MODELING ~ Confidence
Federal Way Youth Development Center
Weinstein ALU
2003 TESTS

PHYSICAL MODELING ~ Confidence
Federal Way Youth Development Center

Weinstein AΙU

2003 TESTS

PHYSICAL MODELING ~ Confidence
Tumble Time Gymnasium – Boise, ID
Cole + Poe Architects, Boise

PHYSICAL MODELING ~ Confidence
DIGITAL SUITE ANALYSIS

Baseline: Banner Bank configuration
DIGITAL MODELING

Improved Glazing (SB70xSP/SP)
HDR Rendering

Luminance False Color: 50 - 2200 cd/m²

3" Inverted Louver Blinds
DIGITAL MODELING

Triple Pane Glazing (SP/70xI/SP)
DIGITAL MODELING

Light Brown Modular Walls
Baseline- Perimeter Hard Wall Offices

Luminance False Color: 50 - 2200 cd/m²

Daylight Autonomy- % of time above 300 lux

DA 300 lx

HDR Rendering
DIGITAL MODELING

Perimeter Open Office Plan

Luminance False Color: 50 - 2200 cd/m²

HDR Rendering

Daylight Autonomy: % of time above 300 lux

DA 300 lx
INTEGRATED DESIGN LAB
DIGITAL MODELING

Seventh Floor Skylights

HDR Rendering
Luminance False Color: 50 - 2200 cd/m²
Daylight Autonomy: % of time above 300 lux

DA 300 lx
INTEGRATED DESIGN LAB

HYBRID DIGITAL/PHYSICAL ANALYSIS
VOCATIONAL EDUCATION BUILDING

DAYLIGHTING STUDIES FOR:
CTA Group - Boise, ID
This project includes analysis of two large open spaces for vocational education. The space to the North has an approximately 35’ ceiling height allowing for specialty equipment. Dissecting the two spaces is a hallway leading from the classroom portion on the West end with access to the large spaces along its length and terminating at the East entrance. The south space is composed of an open auto shop through the center and a spray shop at the East end. The roof is articulated in a cascading fashion from high in the north to low in the south to allow for clerestory lighting.
VOCATIONAL EDUCATION BUILDING

V. 1 DIGITAL MODEL ANALYSIS
   6.05.09
V. 2 DIGITAL MODEL ANALYSIS
   6.19.09
V. 3 DIGITAL MODEL ANALYSIS
   7.15.09
V. 1 PHYSICAL MODEL ANALYSIS
   9.08.09
V. 4 DIGITAL MODEL ANALYSIS
   9.09.09
V. 2 PHYSICAL MODEL ANALYSIS
   9.22.09
VOCATIONAL EDUCATION BUILDING

V. 1 DIGITAL MODEL ANALYSIS
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   9.08.09
V. 4 DIGITAL MODEL ANALYSIS
   9.09.09
V. 2 PHYSICAL MODEL ANALYSIS
   9.22.09
JUNE 21
Overcast - 12:00

The above floor plan graphically shows the amount of daylight hitting a work plane at 30 inches. The values for the daylight are in the units of Lux (a measure of the apparent intensity of light hitting or passing through a surface). One footcandle is equivalent to 10.67 Lux. Values along the 30 foot high North facade are relatively high due to the large amount of glazing.
ANALYSIS DATA

SEPTEMBER 21
Overcast - 12:00

Values along the 30 foot high North facade are relatively high due to the large amount of glazing.
ANALYSIS DATA

DECEMBER 21
Overcast - 12:00

Even in the worst case scenario light levels are never below 200 Lux during this time and are appropriate for the tasks that will be conducted within these spaces. However light levels are still relatively high along the North facade.
ANALYSIS DATA

SEPTEMBER 21
Clear Sky No Sun - 09:00 - Meets LEED V3.0 Requirements for these two spaces.

LEED V3.0 - Demonstrate 75% or more of all regularly occupied spaces areas achieve daylight illuminance levels of a minimum of 25 footcandles (fc) and a maximum of 500 fc in a clear sky condition on September 21 at 9 a.m. and 3 p.m.
ANALYSIS DATA

SEPTEMBER 21
Clear Sky No Sun - 15:00 - Meets LEED V3.0 Requirements for these two spaces.

LEED V3.0 - Demonstrate 75% or more of all regularly occupied spaces areas achieve daylight illuminance levels of a minimum of 25 footcandles (fc) and a maximum of 500 fc in a clear sky condition on September 21 at 9 a.m. and 3 p.m.
Daylight Autonomy is defined as the percentage of the year that a certain location exceeds a certain minimum daylight threshold during a given set of hours. Therefore 80% of the year 300 lux was achieved from 09:00 till 20:00.

Useful Daylight Illuminances (UDI) determines when daylight levels are "useful" for the occupant, i.e., neither too dark (<100 lux) nor too bright (>2000 lux). Therefore <10-20% of the year light was "useful". This low percentage is due to the late occupancy times as well as the high values in the northern space and the lower levels in the southern space.
VOCATIONAL EDUCATION BUILDING

V. 1 DIGITAL MODEL ANALYSIS
   6.05.09

V. 2 DIGITAL MODEL ANALYSIS
   6.19.09

V. 3 DIGITAL MODEL ANALYSIS
   7.15.09

V. 1 PHYSICAL MODEL ANALYSIS
   9.08.09

V. 4 DIGITAL MODEL ANALYSIS
   9.09.09

V. 2 PHYSICAL MODEL ANALYSIS
   9.22.09
BASELINE

SEPTEMBER 21 - 12PM - OVERCAST SKY

GEOMETRY:
Model built from scratch in Ecotect using provided sketchup model and CAD building dimensions.

APERTURES:
N. Windows & 2 Clerestorys:
VLT-70% PPG Solarban 60 Clear
All other Glazing:
VLT- 55% PPG Solarban 60 Clear

MATERIALITY:
Floor:
IRC- 40% Slab Concrete
Walls:
IRC- 80% Concrete
MODIFICATION 1

SEPTEMBER 21 - 12PM - OVERCAST SKY

GEOMETRY:
Moved the Autobody clerestory North 20' to wash the back wall with DL and added 5 (4x6) skylights 25' from S. wall.

APERTURES:
- N. Windows & 2 Clerestorys: VLT-70% PPG Solarban 60 Clr
- All other Glazing: VLT-55% PPG Solarban 60 Clr
- Skylights: VLT-50% Translucent Panel

MATERIALITY:
- Floor: IRC-40% Slab Concrete
- Walls: IRC-80% Concrete
MODIFICATION 2

SEPTEMBER 21 - 12PM - OVERCAST SKY

GEOMETRY:
Using the original autobody clerestory plan and reduced the glazing on the North facade: from approx. 3000sf glazing to 975sf.

APERTURES:
- N. Windows & 2 Clerestories:
  - VLT-70% PPG Solarban 60 Clr
- All other Glazing:
  - VLT-55% PPG Solarban 60 Clr

MATERIALITY:
- Floor: IRC-40% Slab Concrete
- Walls: IRC-80% Concrete
MODIFICATION 3

SEPTEMBER 21 - 12PM - OVERCAST SKY

GEOMETRY:
Used the original autobody clerestory plan and removed the view windows in the N shop to analyze the daylight windows.

APERTURES:
N. Windows & 2 Clerestorys:
VLT-70% PPG Solarban 60 Clr
All other Glazing:
VLT- 55% PPG Solarban 60 Clr

MATERIALITY:
Floor:
IRC- 40% Slab Concrete
Walls:
IRC- 80% Concrete
**MODIFICATION 4**

SEPTEMBER 21 - 12PM - OVERCAST SKY

**GEOMETRY:**
Removed the workshop N. Facade windows to test the addition of 6 (4x8) skylights.

**APERTURES:**
N. Windows & 2 Clerestorys:
- VLT-70% PPG Solarban 60 Clr

All other Glazing:
- VLT- 55% PPG Solarban 60 Clr

Skylights:
- VLT- 50% Translucent Panel

**MATERIALITY:**
- Floor: IRC- 40% Slab Concrete
- Walls: IRC- 80% Concrete

Note - This mod uses the modified clerestory plan in the autobody shop. This has little to no effect in the Windshop.
MODIFICATION 5

SEPTEMBER 21 - 12PM - OVERCAST SKY

GEOMETRY:
Added the windshop N. Facade view windows to test with the 6 (4x8) skylights.

APERTURES:
N. Windows & 2 Clerestories:
VLT-70% PPG Solarban 60 Clr
All other Glazing:
VLT- 55% PPG Solarban 60 Clr
Skylights:
VLT- 50% Translucent Panel

MATERIALITY:
Floor:
IRC- 40% Slab Concrete
Walls:
IRC- 80% Concrete
MODIFICATION 6

SEPTEMBER 21 - 12PM - OVERCAST SKY

GEOMETRY:
Moved the 6 (4x8) skylights near the middle of the ceiling/roof.

APERTURES:
N. Windows & 2 Clerestories:
VLT-70% PPG Solarban 60 Clr
All other Glazing:
VLT-55% PPG Solarban 60 Clr
Skylights:
VLT-50% Translucent Panel

MATERIALITY:
Floor:
IRC-40% Slab Concrete
Walls:
IRC-80% Concrete

Note - This mod uses the modified clearestory plan in the autobody shop. This has little to no effect in the Windshop.
MODIFICATION 7

SEPTEMBER 21 - 12PM - OVERCAST SKY

GEOMETRY:
Using mod 2 N. facade window layout. Added light diffusion devices above the corridor to bounce light into autobody shop. See section.

APERTURES:
N. Windows & 2 Clerestorys:
VLT-70% PPG Solarban 60 Ctr
All other Glazing:
VLT- 55% PPG Solarban 60 Ctr

MATERIALITY:
Floor:
IRC- 40% Slab Concrete
Walls:
IRC- 80% Concrete
Light Diffusion Device:
VLT- 24% Translucent Panel
MODIFICATION 8

SEPTEMBER 21 - 12PM - OVERCAST SKY

GEOMETRY:
Changed materiality of light diffusion device.

APERTURES:
N. Windows & 2 Clerestories:
VLT-70% PPG Solarban 60 Clr
All other Glazing:
VLT-55% PPG Solarban 60 Clr

MATERIALITY:
Floor:
IRC-40% Slab Concrete
Walls:
IRC-80% Concrete
Light Diffusion Device:
IRC-70% Opaque Plaster Panel
MODIFICATION 9

SEPTEMBER 21 - 12PM - OVERCAST SKY

GEOMETRY:
Siding of daylight (DL) and view (VW) windows on N. and E. Facade: (North = 11 DL & 11 VW (3’4” x 7’8”) = 560sf of glazing) & (East = 3 DL and 3 VW = 154sf of glazing)

APERTURES:
N. Windows & 2 Clerestories:
VLT-70% PPG Solarban 60 Ctr
All other Glazing:
VLT-55% PPG Solarban 60 Ctr

MATERIALITY:
Floor: IRC-40% Slab Concrete
Bottom Walls:
IRC-70% Concrete
Upper Walls & Ceiling:
IRC-60% Concrete
Light Diffusion Device:
IRC-70% Opaque Plaster Panel
CALIBRATING EXPECTATIONS
CAES – Idaho Falls, ID

GSBS Architects, Salt Lake
VOCATIONAL EDUCATION BUILDING

V.1 DIGITAL MODEL ANALYSIS
6.05.09

V.2 DIGITAL MODEL ANALYSIS
6.19.09

V.3 DIGITAL MODEL ANALYSIS
7.15.09

V.1 PHYSICAL MODEL ANALYSIS
9.08.09

V.4 DIGITAL MODEL ANALYSIS
9.09.09

V.2 PHYSICAL MODEL ANALYSIS
9.22.09
DAYLIGHT ANALYSIS: WINDSHOP

The Windshop space would be used to teach installation and repair of wind turbines. From a daylighting standpoint, we are investigating design options that would provide adequate illumination for the critical visual tasks occurring in the space. Another issue that must be taken into account is the glare that a south-facing clerestory could create.

Wind shop: added skylights, modified north facade glazing.
Analysis of light diffuser above corridor.
BASELINE

WINDSHOP BASELINE

Knowing that full glazing on the north wall was too much, measurements on the best glazing ratio were tested with a physical model in the skybox. The baseline case for the glazing has 10 window bays each 9’ wide. Openings start at 4’ high for lower view windows and 3’ high for top windows. There is no re-light battle in the baseline case. The above floor plan graphically shows the amount of daylight hitting the work plane at 32 inches above the floor.
MODIFICATION 1

WINDSHOP MODIFICATION 1
Modification 1 tests the effects of a 6’ high flat baffle hanging from the bottom cord of the trusses. It is positioned approximately 10’ back from clerestory glazing.

Daylight factor readings stay above 2 but light is a little less even against the southern side of the room.
MODIFICATION 2

WINDSHOP MODIFICATION 2
Modification 2 tests the effects of a 6’ high curved baffle hanging from the bottom cord of the trusses. It is positioned approximately 10’ back from clerestory glazing.

Very little change occurs between the straight baffle to the curved.
MODIFICATION 3

WINDSHOP MODIFICATION 3
Modification 3 changes the north wall glazing. The lower view window stays at 4’ tall and the upper glazing changes from 3’ tall to 5’ tall. The 6’ high curved baffle is used. It is positioned approximately 10’ back from clerestory glazing.

Very little changes at the north wall but large changes in the center of the space. The central readings jump from 2.0-2.5 up to 2.5-3.5.
MODIFICATION 4

WINDSHOP MODIFICATION 4

Modification 4 keeps the lower view window at 4' tall and the upper glazing at 5' tall. The 6' high straight baffle is used. It is positioned approximately 10' back from clerestory glazing.

Very little changes between modification 3 and 4.
MODIFICATION 5

WINDSHOP MODIFICATION 5
Modification 5 changes the north wall glazing. The lower view window changes from 4' tall to 5' tall, and the upper glazing changes from 5' tall to 7' tall. The 6' high straight baffle is used. It is positioned approximately 10' back from clerestory glazing.

Lighting levels rise dramatically. Against the north glazing wall they jump above 6 and fall off to 3 at the back of the room.
MODIFICATION 6

WINDSHOP MODIFICATION 6
Modification 6 keeps the lower view window at 5' tall, and the upper glazing changes at 7' tall. The 6' high curved baffle is used. It is positioned approximately 10' back from clerestory glazing.

Little change between modification 5 and 6. Some changes in lighting against the north wall.
Modification 4 is the preferred modification. Regarding visual comfort in the photographs, modification 4 was comfortably illuminated without any areas of concern for glare. The straight baffle blocks direct southern sun while deflecting light into the relight at the northern side of the autobody shop. The horizontal illumination graphs illustrate a similar story to the photograph. Overall, the room is within the adequate daylight factor percentage and relatively evenly daylighted. One addition that could be made is to use a translucent material on the baffle to reflect light as well as illuminate that surface adjacent to the clerestory.
ANALYSIS DATA: AUTOBODY

For the autobody shop we investigated: a) how modifications in the windshop affect the daylight coming through the relight into the autobody, and b) how iterations within the autobody shop can improve illuminance levels and daylight uniformity.

Autobody shop: Analysis of clerestory baffle type, clerestory position, daylighting window above garage door
Wind shop: Analysis of clerestory baffle type
BASELINE

AUTobody SHOP BASELINE

Because the modifications in the windshop have an effect on the daylight in the autobody shop, we observed how a battle in the windshop would change the quality of daylight in the autobody. The dimensions of the glazing on the north facade of the windshop will be fixed. The baseline case for the glazing has 10 window bays each 9’ wide. Openings start at 4’ high for lower view windows and 3’ high for top windows. There is no re-light battle in the baseline case. The above floor plan graphically shows the amount of daylight hitting the work plane at 32 inches above the floor.
MOD 1

AUTobody shop modification 1

Modification 1 will use the selected window dimensions for the north facade of the windshop as well as the straight baffle to deflect light into the autobody. In the autobody, mod1 will have no baffle on the clerestory, and no glazing above the garage doors.
MOD 2

AUTobody SHOP MODIFICATION 2

Modification 2 will use the selected window dimensions for the north facade of the windshop with a curved baffle to deflect light into the autobody. In the autobody, mod 2 will have no baffle on the clerestory, and no glazing above the garage doors.
**MOD 3**

**AUTOBODY SHOP MODIFICATION 3**

Modification 3 will use the selected window dimensions for the north facade of the windshop with a straight baffle to deflect light into the autobody. In the autobody, mod 3 will have a curved baffle on the clerestory, and no glazing above the garage doors.
MOD 4

AUTobody shop modification 4

Modification 4 will use the selected window dimensions for the north facade of the windshop with a straight baffle to deflect light into the autobody. In the autobody, mod 4 will have a straight baffle on the clerestory, and no glazing above the garage doors.
MOD 5

AUTobody SHOP MODIFICATION 5

Modification 5 will use the selected window dimensions for the north facade of the windshop with a straight baffle to deflect light into the autocad. In the autocad, mod 5 will have a curved baffle on the clerestory, a shift of the clerestory five feet north, and no glazing above the garage doors.
MOD 6

AUTobody SHOP MODIFICATION 6

Modification 6 will use the selected window dimensions for the north facade of the windshop with a straight baffle to deflect light into the autobody. In the autobody, mod 6 will have a curved baffle on the clerestory, a shift of the clerestory ten feet north, and no glazing above the garage doors.
MOD 7

AUTobody SHOP MODIFICATION 7

Modification 7 will use the selected window dimensions for the north facade of the windshop with a straight battle to deflect light into the autobody. In the autobody, mod 7 will have a curved battle on the clerestory, a shift of the clerestory ten feet north, and clear glazing above the garage doors.
MOD 8

AUTobody shop modification 8
Modification 8 will use the selected window dimensions for the north facade of the windshop with a straight baffle to deflect light into the autobody. In the autobody, mod 8 will have no baffle on the clerestory, original clerestory location, and clear glazing above the garage doors.
AUTobody shop modification 8

Although the daylight uniformity is not as even as other options, modification 8 is the preferred option because of the illumination levels within the desired range. Visually, the space is comfortable and well lit. An area of concern would be potential glare caused by the south facing clerestory. Careful design of overhangs or multiple exterior louvres would satisfy the issue.
COMBINED

Shown above are the HDR images of the chosen modification of the three studied spaces.
Comparisons from Architects' Perspective

- general appearance of images
- type of data available
- usefulness of data to inform design decisions
- closing the loop
- time investment

* Not a validation exercise
MODELING COMPARISONS

- Detailed – Single Case
- Detailed - Iterative
- Simple – Single Case
- Simple – Iterative

(Vocational Education Building – CTA Group)
(Airport Terminal – HDR Inc.)
INTEGRATED DESIGN LAB

MODELING COMPARISONS

- Detailed – Single Case
- Detailed - Iterative
- Simple – Single Case
- Simple – Iterative

(Vocational Education Building – CTA Group)
(Airport Terminal – HDR Inc.)
Several key factors are to be considered when comparing these two models. Only half of the physical model was actually constructed with the rest being represented by a mirror placed at midpoint, this mirroring is helpful in keeping the model to a manageable size, but reduced accuracy somewhat. The physical model also has no glass built in and must account for the specific VLT of the glass with a universal reduction factor in Excel after data collection.
WINDSHOP September 21st Sunny 12:00pm
VINCENT PAPERTH DESIGN LAB

AUTOSHOP  September 21st Overcast
AUTOSHOP  September 21st Sunny 12:00pm
Simple Tone Mapping Exercise
Most designers do not understand luminance...
...and depending...drastically different conclusions.
PHYSICAL MODEL

CONSTRUCTION – Building a complex physical model may take several days to a week to complete. Modeling construction may need to account for iterative testing and the ability to modify the model for different analysis. This model had adjustable clerestory positions, window sizing and baffle location and type.
75.5 Hr.

DATA COLLECTION / ANALYSIS – Time in this process is driven by the amount and difficulty of modification being tested. In this project 14 physical iterations were tested during analysis.
48 Hr.

DOCUMENTATION/REPORTING – Displaying data in a meaningful and simple manner is essential.
19.75 Hr.

143.25 Hr. Total for 14 iterations ~ 10.23 hours each

DIGITAL MODEL

CONSTRUCTION – A complex digital model may be imported from other software platforms into Ecotect or directly to Radiance, however more this often requires significant remodeling. Extreme detail is possible but increased vertices results in increased processing time.
86.5 Hr.

DATA COLLECTION / ANALYSIS – This analysis included Daysim and Radiance runs but excludes computer processing time entirely. 18 digital iterations were tested during analysis.
56 Hr.

DOCUMENTATION/REPORTING – Displaying data in a meaningful and simple manner is essential.
58 Hr.

200.5 Hr. Total for 18 iterations ~ 11.11 hours each (Plus computer processing time)
Depending on the project and level of design resolution a highly detailed model can be created and simulated with both digital and physical tools.
MODELING COMPARISONS

- Detailed – Single Case
- Detailed - Iterative
- Simple – Single Case
- Simple – Iterative

(Vocational Education Building – CTA Group)
(Airport Terminal – HDR Inc.)
AIRPORT TERMINAL  Simple Iterative

HDR Inc. Boise Office
TERMINAL

September 21st Overcast – 12PM
9 skylights
Physical Model

Digital Model

September 21st Overcast – 12PM
9 skylights
TERMINAL

September 21st Overcast – 12PM
6 skylights
September 21st Overcast – 12PM
6 skylights
**Simple Iterative Physical Model**

**Construction** – Simple physical models can be constructed in a single day and be modified on the fly during data collection and analysis phases. These models need only represent a scaled space and the requisite surfaces at a reflectance similar to those planned for the building.

38 Hr.

**Data Collection / Analysis** – Time in this process is driven by the amount and difficulty of modification being tested. In this project 4 physical iterations were tested during analysis.

17.5 Hr.

**Documentation / Reporting** – Displaying data in a meaningful and simple manner is essential.

18.5 Hr.

74 Hr. Total for 4 iterations ~ 18.5 hours each

**Simple Iterative Digital Model**

**Construction** – Creation of simple digital models from geometry inputs from other software can sometimes mean re-modeling. However, if speed is more concerning than quality and accuracy, i.e., at the initial design phase, it is possible to work directly from an imported model or even to work directly out of a modeling program such as SketchUp.

12.5 Hr.

**Data Collection / Analysis** – This value excludes computer processing time entirely. 4 digital iterations were tested during analysis.

35.5 Hr.

**Documentation / Reporting** – Displaying data in a meaningful and simple manner is essential.

23.5 Hr.

71.5 Hr. Total for 4 iterations ~ 17.85 hours each

**MODELING** Simple Iterative

Depending on the project and level of design resolution, a highly detailed model can be created and simulated with both the digital and physical tools.
Depending on the project and level of design resolution, a highly detailed model can be created and simulated with both the digital and physical tools.
Overall Time Investment Comparison

![Bar chart comparing time investment for different tasks and stages in physical and digital environments. The chart includes categories for Documentation/Reporting, Data Collection/Analysis, and Model Construction. The bars are color-coded for clarity.]
Conclusions

### Physical vs Digital

- **Real time** ↔ **Processing time**
- **Eye adaptation** ↔ **Tone Mapping**
- **Approximate sky** ↔ **More accurate sky files**
- **Real sky** ↔ **Real sky (potential)**
- **Slower to build** ↔ **Quicker to build**
- **Quicker to test** ↔ **Slower to test**
- **Intuitive** ↔ **High expertise**
- **Expensive equipment** ↔ **Freeware**
- **Physical materials** ↔ **Complex material specs**

### For Designer’s

- Commit to test daylight design ideas
- Iterative analysis, not compliance
- Interpret data systematically & critically
- Follow up, close the loop
A Comparative Discussion

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