How Designers Can Curb Risk with Performance-Based Modeling

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Principal
February 20, 2019
Learning Objectives

Today We Will Discuss:

- Energy & Building Design
- Value Proposition
- Managing Risk through Modeling
- Case Studies
“Design is not just what it looks like and feels like. Design is how it works.”

Steve Jobs
Energy & Buildings – Big Picture

Data Source: CBECS 2003 Dataset
Energy & Buildings – Big Picture

Modeled Projects are showing 40% better energy performance than non-modeled

Source: Charts from 2017 AIA 2017 2030 Report
Energy & Buildings – Big Picture

Source: Chart from 2017 AIA 2017 2030 Report
Low-Energy Pathway
Navigating the Model-verse
Tools – Interoperability

Design Tools

Simulation Tools
Energy & Design

- Develop a game plan for reducing loads
- Load Reduction = Design Opportunities
- Load reduction is the lowest cost strategy
- Efficient systems can be complex & $$$
- Onsite generation is a utility concept most expensive
HVAC System Strategies

Load Ranges for New Offices

Conventional
- Fan Coils
- Variable Air Volume

Advanced
- Chilled Beams/Ceilings
- Chilled Beams + DOAS Cooling

Passive
- Natural Ventilation
- Natural Ventilation + Thermal Mass

Cooling Loads

2 w/sf (6.8 Btu/sf)
4 w/sf (13.6 Btu/sf)
6 w/sf (20.4 Btu/sf)
8 w/sf (27.4 Btu/sf)
10 w/sf (34.1 Btu/sf)


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Value Proposition

Making the Case:

- Energy cost is < 1% of overall cost.
- Concentrate on building and occupant savings.
- Apply societal cost to help inform decisions, e.g. cost of carbon
  - Oregon is implementing cap and trade policy
  - Cost of carbon may exceed energy cost

Source: 2016 OEER BOMA
Value Proposition

Assigning Value

- Construction Cost
- Energy Use
- Embodied Energy
- Carbon Emissions
- Occupant Comfort
- Public Trust

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What is Risk?
What is Risk?
Identifying Risk

Surprise!
January 29, 2019
Risk of Climate Change

- 1st company to cite Climate Change as reason for bankruptcy filing
- $30 billion in liability and damages
- Company value plunged by 50%
- Up to 16 million customers affected
- Cost get passed on to customers/shareholders

Image Credit: New York Times
Risk of Climate Change

This is America’s estimated current emissions trajectory.

Here’s what America pledged under the Paris agreement.

But here’s roughly what’s needed to stay below 2°C of warming.

Source: NYT Article “The World Still Isn’t Meeting Its Climate Goals”
Risk of Climate Change

Impacts of Climate Change

- 2°C ceiling is woefully short of what is needed.
- U.N. study predicts we have less than 13yrs to curb irreversible impacts
- Need to strive for 1.5°C difference (already at 1°C)
- **Difference of 0.5°C could mean:**
  - Marine life diminished by 50%.
  - 50% less fresh water supply.
  - 40-70% insect & pollinator loss.
  - Extinction of 25% of plants & animals.
  - 99% coral destruction
  - 60% of World’s coffee supply vanishes
  - Economic losses ranging from 700B-1.3T/yr.

Source: NYT Article “The World Still Isn’t Meeting Its Climate Goals”
Understanding Risk

Upstream Impacts

- Need significant more rare metals than currently supplied/available.
- Need 12 times indium by 2050.
- More mining needed to come on-line.

Downstream Impacts

- Need significant efforts to recycle electronic devices.
- Geo-economic implications from sourcing.
- Supply shortage to meet demands for rare metals. Cost uncertainty.

Source: Popular Mechanics Article "We Might Not Have Enough materials for All the Solar Panels and Wind Turbines We Need"
Designing for Loads

30% WWR – South Facade

40% WWR – South Facade

50% WWR – South Facade

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Designing for Loads

70% WWR – South Façade No Shade

Cooling Load Profile: South Office No Shade

DESIGN DAY COOLING LOAD
(Including Thermal Lag)

70% WWR – South Façade With Shade

Cooling Load Profile: South Office with Shade

DESIGN DAY COOLING LOAD
(Including Thermal Lag)
Occupant Comfort

Winter Design Condition
Spatial Mapping – Percentage Persons Dissatisfied

ASHRAE 90.1 Code Envelope
• Reff 15.6 Opaque Walls
• Reff 2.5 Fenestration

Enhanced Envelope
• Reff 19.3 Opaque Walls
• Reff 3.0 Fenestration

Passivhaus Envelope
• Reff 39 Opaque Walls
• Reff 5 Fenestration
Visual Comfort

Daylight Autonomy – At Skylights

Daylight Autonomy – Between Skylights

Daylight Autonomy
Visual Comfort

3/21 9:00 AM Imperceptible Glare (33% DGP)
Instructor's field of view includes window. Brightness ratio exceeds 7:1 at this time and could cause visual discomfort.

+ 178 cd/m²
+ 59 cd/m²
+ 66 cd/m²
+ 39 cd/m²
+ 178 cd/m²

3/21 9:00 AM Imperceptible Glare (27% DGP)
Students field of view has minimal direct exposure to high illuminance areas. Minimal risk of visual discomfort.

+ 178 cd/m²
+ 58 cd/m²
+ 33 cd/m²
+ 58 cd/m²

3/21 9:00 AM Imperceptible Glare (33% DGP)

3/21 9:00 AM Imperceptible Glare (27% DGP)

3/21 9:00 AM Imperceptible Glare (33% DGP)

3/21 9:00 AM Imperceptible Glare (27% DGP)

Hours of Sun Light > 4,000 Lux
Dashed area denotes space that has highest risk for direct sun. Anticipate potential visual discomfort for occupants within this area.

Plan – Window Shades Up

Heat map plot that highlights the percentage of space that receives direct sun during time of day and by month.

Largest direct sun occurs in the early morning at 7-9am. The space receives relatively consistent sun penetration from Nov through Jan.

Direct Sun Temporal Map - Window Shades Up
Envelope Performance

Estimated Assembly R-Value

39.5

CLT Roof Assembly

1/2" Protection Board (R-0.5)
6" Polyiso Insul. (R-34.2)
3-Ply CLT Deck Insul. (R-5.6)

10.5" (266.7 mm)

Heat Transfer - Temperature

Heat Transfer - Flux

Outdoor Temp.
0°F

Dewpoint @ 50.5 °F

Interior Temp.
70°F

Thermal Bridging thru Fasteners

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Envelope Performance

Adjusted Assembly R-Value

20.4

Homogeneous Tributary Area
21.5%

Thermal Bridging Tributary Area
78.5%

Eff R-Value of Region: 15.2

Eff R-Value of Region: 39.5

Roof Assembly Axon

Heat Flux Overlay

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Envelop Performance

Window Jamb Detail

As Designed - Detail

Heat transfer converges at window frame thermal break. Allows heat to bypass exterior insulation.

Consider moving frame 1 to 1.5 inches to align thermal break with exterior insulation.

Isotherms

Window thermal break aligns with sheathing to provide a thermal short-circuiting.

Aluminum trim piece provides thermal bridging that circumvents exterior insulation.

Heat Flow

Thermal bridging and higher heat transfer through metal studs but controlled by exterior insulation.

Heat Flux

Outdoor Temp. 0°F

Interior Temp. 70°F

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Case Study 1
View of West Facade

Project: N Beech Office Building
Building Type: Speculative Office
Size: 4 Stories, 20,036 sf (Gross)
Client: Willamette Stone

Image Credit: FWD Architecture

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Solar Analysis – South Facade

Summer Solstice

9am

View from SE

12pm

3pm

Fall Equinox

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February 20, 2019
Solar Analysis – South Façade

No Panel Scenario

Approx. 94% of south façade are windows. Reducing window area is recommended.

This area of the façade receives the highest amount of solar heat gain due to the limited overhang projections at roof & balcony level. Using vertical screen panel or strategically eliminating windows need to be considered.

Setback of façade for balcony provides adequate shading of solar radiation in summer. Approx. 70% of solar radiation is controlled at this location.

Cantilevered floor above acts as a shading device and reduces approximately 60% solar radiation on this region of façade from June-Sept.

Annual Solar Radiation: 9am-6pm

Summer Solar Radiation: 9am-6pm

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Annual Solar Radiation: 9am-6pm

Summer Solar Radiation: 9am-6pm
Solar Analysis – West Façade

No Panel Scenario

Annual Solar Radiation: 9am-6pm
Approx. 97% of west façade are windows. Reducing window area is recommended.

Summer Solar Radiation: 9am-6pm
Modest shading is being provided where the skewing upper floor plate provides more overhang depth.

West façade receives approximately 30% more solar radiation on a unit basis (SHG/Area) than the south façade. Since the west façade has the most surface area it also has the largest solar heat gain. Strategic reduction of window area with high performance glazing and shading will be key in reducing space overheating and glare along the perimeter.
Solar Analysis – Panels

Annual Solar Radiation: 9am-6pm

Control Case

Avg. 19.3% Reduction in SH from Perforated panels

Panels have limited capability to shade global radiation

Hourly Solar Reduction of Perforated Metal Panels

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**Solar Analysis – West Facade**

**No Shade Scenario**

**Figure 1 – Component Cooling Load Profile**

- Significant solar load in baseline

**Design Alt 4**

**Figure 2 – Component Cooling Load Profile**

- Outline of baseline cooling loads
- Solar load reduced significantly

**DESIGN DAY COOLING LOAD**

- (Including Thermal Lag)
- Peak Reduction of 39%
Facade Analysis

West Facade

**Figure 9** – HVAC Load Profiles with OEESC Code Glazing

Cooling use is approx. 3 times higher on west façade vs. south façade.

**Figure 10** – HVAC Load Profiles with Solarban 60 Glazing

Slight reduction in HVAC heating due to the increased thermal performance from the argon gas in IGU air gap.

**Figure 11** – HVAC Load Profiles with Solarban 70XL Glazing

Approx. 25% reduction in peak HVAC cooling use (Jul), as compared to baseline.

**Figure 12** – HVAC Load Profiles with Solarban 90 Glazing

Approx. 25% reduction in peak HVAC cooling use (Jul), as compared to baseline. Approx. 20% increase in heating load due to the glazing’s lower SHGC.
Facade Analysis

**Figure 3** – South Façade Design Alternate Heat Gain Comparison

**Figure 4** – West Façade Design Alternate Heat Gain Comparison

- Baseline (#1)
- Architectural Shading/Overhangs (#5)
- 17% Window Area Reduction (#8)
- Solarban 70XL Glazing (#10)
# Façade Analysis

## West Façade

**Table 1 – West Façade Cooling Load Performance Comparison**

<table>
<thead>
<tr>
<th>ID</th>
<th>Option Description</th>
<th>Peak Cooling Load</th>
<th>Peak Cooling Load</th>
<th>Cooling Load Reduction</th>
<th>Cooling Load Savings</th>
<th>EUI</th>
<th>Estimated Energy Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Watts</td>
<td>Btu</td>
<td>Btu</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alt 1</td>
<td>Baseline - No-Shade</td>
<td>27,181</td>
<td>92,742</td>
<td>24,372</td>
<td>26.3%</td>
<td>69.01</td>
<td></td>
</tr>
<tr>
<td>Alt 2</td>
<td>SB 70 XL + Perforated Panels w/ 50% Open Factor</td>
<td>20,038</td>
<td>68,370</td>
<td>24,372</td>
<td>26.3%</td>
<td>59.40</td>
<td>13.9%</td>
</tr>
<tr>
<td>Alt 3</td>
<td>SB 70 XL + Perforated Panels w/ 60% Open Factor</td>
<td>16,492</td>
<td>56,271</td>
<td>36,471</td>
<td>39.3%</td>
<td>54.90</td>
<td>20.4%</td>
</tr>
</tbody>
</table>

**Notes:**
1) Sensible cooling load values are based on a west facing perimeter zone with a depth of 15'-0".
2) Peak cooling load includes a 15% safety sizing factor per ASHRAE 90.1.
3) Baseline includes glazing that conforms to Oregon Energy Code 2014 version.

## South Façade

**Table 2 – South Façade Cooling Load Performance Comparison**

<table>
<thead>
<tr>
<th>ID</th>
<th>Option Description</th>
<th>Peak Cooling Load</th>
<th>Peak Cooling Load</th>
<th>Cooling Load Reduction</th>
<th>Cooling Load Savings</th>
<th>EUI</th>
<th>Estimated Energy Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Watts</td>
<td>Btu</td>
<td>Btu</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alt 1</td>
<td>Baseline - No-Shade or Overhangs</td>
<td>10,065</td>
<td>34,342</td>
<td>--</td>
<td>--</td>
<td>64.40</td>
<td></td>
</tr>
<tr>
<td>Alt 2</td>
<td>Current Design w/ Overhangs + Balconies</td>
<td>8,078</td>
<td>27,562</td>
<td>6,780</td>
<td>19.7%</td>
<td>57.77</td>
<td>16.3%</td>
</tr>
<tr>
<td>Alt 3</td>
<td>SB 60 + Perforated Panels w/ 50% Open Factor</td>
<td>7,218</td>
<td>24,628</td>
<td>9,714</td>
<td>28.3%</td>
<td>53.90</td>
<td>21.9%</td>
</tr>
<tr>
<td>Alt 4</td>
<td>SB 70 XL + Perforated Panels w/ 60% Open Factor</td>
<td>6,190</td>
<td>21,120</td>
<td>13,222</td>
<td>38.5%</td>
<td>49.32</td>
<td>26.5%</td>
</tr>
</tbody>
</table>

**Notes:**
1) Sensible cooling load values are based on a south facing perimeter zone with a depth of 15'-0".
2) Peak cooling load includes a 15% safety sizing factor per ASHRAE 90.1.
## Table 4 – Design Alternate Capital Cost Savings Summary

<table>
<thead>
<tr>
<th>ID</th>
<th>Option Description</th>
<th>Initial Investment Cost</th>
<th>Operational Cost</th>
<th>Total Cost</th>
<th>Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>Baseline - Code Glazing + No-Shade Devices</td>
<td>$148,456</td>
<td>$56,747</td>
<td>$205,204</td>
<td>--</td>
</tr>
<tr>
<td>Alt 1</td>
<td>SB 60 + Perforated Panels w/ 50% Open Factor</td>
<td>$182,888</td>
<td>$48,385</td>
<td>$231,273</td>
<td>$-26,069</td>
</tr>
<tr>
<td>Alt 2</td>
<td>SB 70 XL + Perforated Panels w/ 50% Open Factor</td>
<td>$178,387</td>
<td>$44,424</td>
<td>$222,811</td>
<td>$-17,607</td>
</tr>
<tr>
<td>Alt 3</td>
<td>SB 70 XL + Perforated Panels w/ 60% Open Factor</td>
<td>$178,945</td>
<td>$44,636</td>
<td>$223,581</td>
<td>$-18,377</td>
</tr>
</tbody>
</table>

**Notes:**
1) Initial capital construction cost accounts for estimated HVAC system, glazing and exterior metal screens.
2) Operational cost includes electricity energy cost of $0.08/kWh over 15 years. No adjustments for cost inflation are included in the calculations.
3) Construction cost used were derived from cost estimates developed by Seabold Construction Co., dated April 17, 2018.

## Table 5 – Design Alternate Capital Cost Savings Summary

<table>
<thead>
<tr>
<th>ID</th>
<th>Option Description</th>
<th>Initial Investment Cost</th>
<th>Operational Cost</th>
<th>Total Cost</th>
<th>Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>Baseline - Code Glazing + No-Shade Devices</td>
<td>$136,129</td>
<td>$226,266</td>
<td>$362,395</td>
<td>--</td>
</tr>
<tr>
<td>Alt 1</td>
<td>SB 60 Argon</td>
<td>$141,950</td>
<td>$218,865</td>
<td>$360,814</td>
<td>$1,581</td>
</tr>
<tr>
<td>Alt 2</td>
<td>SB 60 Argon + 30% Frit</td>
<td>$144,210</td>
<td>$214,974</td>
<td>$359,184</td>
<td>$3,212</td>
</tr>
<tr>
<td>Alt 3</td>
<td>SB 60 Argon + 40% Frit</td>
<td>$145,232</td>
<td>$213,692</td>
<td>$358,924</td>
<td>$3,471</td>
</tr>
<tr>
<td>Alt 4</td>
<td>SB 70 XL Argon</td>
<td>$130,211</td>
<td>$198,471</td>
<td>$328,682</td>
<td>$34,714</td>
</tr>
<tr>
<td>Alt 5</td>
<td>SB 70 XL Argon + 30% Frit</td>
<td>$142,259</td>
<td>$197,032</td>
<td>$339,291</td>
<td>$23,105</td>
</tr>
<tr>
<td>Alt 6</td>
<td>SB 70 XL Argon + 40% Frit</td>
<td>$143,559</td>
<td>$196,852</td>
<td>$340,411</td>
<td>$21,985</td>
</tr>
<tr>
<td>Alt 7</td>
<td>SB 90 Argon</td>
<td>$144,246</td>
<td>$194,333</td>
<td>$338,579</td>
<td>$23,816</td>
</tr>
<tr>
<td>Alt 8</td>
<td>SB 90 Argon + 30% Frit</td>
<td>$147,270</td>
<td>$192,354</td>
<td>$339,625</td>
<td>$22,771</td>
</tr>
<tr>
<td>Alt 9</td>
<td>SB 90 Argon + 40% Frit</td>
<td>$148,548</td>
<td>$191,725</td>
<td>$340,273</td>
<td>$22,122</td>
</tr>
</tbody>
</table>

**Notes:**
1) Initial capital construction cost accounts for estimated HVAC system, glazing and exterior metal screens.
2) Operational cost includes electricity energy cost of $0.08/kWh over 15 years. No adjustments for cost inflation are included in the calculations.
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Case Study 2
Project: RCC Office Building – Portland International Airport
Building Type: Mixed Use
Size: 4 Stories, 91,000 sf (Gross)
Client: Port of Portland

View of Southwest Facade

Image Credit: YGH Architecture

Partial Section – SW Facade
Shading Benefit of Shadow Frame – Summer Solstice

No direct sun hits the façade at this time of day.

9 AM

12 PM

3 PM

6 PM
Shading Benefit of Shadow Frame – Summer Solstice

No direct sun hits the façade at this time of day

9 AM

12 PM

3 PM

6 PM

Shading Benefit of Shadow Frame – Fall Equinox

No direct sun hits the façade at this time of day

9 AM

12 PM

3 PM

6 PM

South Façade Shadow Frame Performance - Summer Solstice

Potential Heating Penalty.

Peak Solar Load

Average 37% solar heat gain reduction from shading devices after 3pm

South Façade Shadow Frame Performance - Fall Equinox

Potential Heating Penalty.

Potential Cooling Benefit.

Est. Peak Solar Load

Missing direct solar data. Cloudy condition.

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February 20, 2019
West Elevation – Solar Radiation (Jun-Sep)

Daylight Autonomy  sDA 29.7%

DA 87.4%

ASE 10.2%

February 20, 2019
Vertical Fin Option Comparison – Jun-Sep

Shroud provides relatively consistent shading of this region of façade.

**Daylight Performance**

<table>
<thead>
<tr>
<th>Scenario</th>
<th># Vert Fins</th>
<th>Rotation Angle</th>
<th>Solar Load Reduction %</th>
<th>DA -300</th>
<th>ASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline*</td>
<td>0</td>
<td>0</td>
<td></td>
<td>29.6</td>
<td>10.4</td>
</tr>
<tr>
<td>Option A</td>
<td>5</td>
<td>0</td>
<td>20.1%</td>
<td>29.4</td>
<td>10.3</td>
</tr>
<tr>
<td>Option B</td>
<td>5</td>
<td>22.5</td>
<td>27.4%</td>
<td>29.7</td>
<td>10.2</td>
</tr>
<tr>
<td>Option C</td>
<td>5</td>
<td>30</td>
<td>29.1%</td>
<td>30.6</td>
<td>10.2</td>
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<tr>
<td>Option D</td>
<td>7</td>
<td>30</td>
<td>37.0%</td>
<td>31.9</td>
<td>10.0</td>
</tr>
<tr>
<td>Option E</td>
<td>9</td>
<td>30</td>
<td>44.5%</td>
<td>29.9</td>
<td>9.9</td>
</tr>
</tbody>
</table>

Notes:
1) Baseline scenario includes extended shroud on west façade - no vertical fins.

February 20, 2019
Thank You