Ain Shams University
Faculty of Engineering
Department of Architecture

High-Performance Facades: Designing Office Building Facades to Enhance Indoor Daylighting Performance

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M.Sc. Thesis Committee

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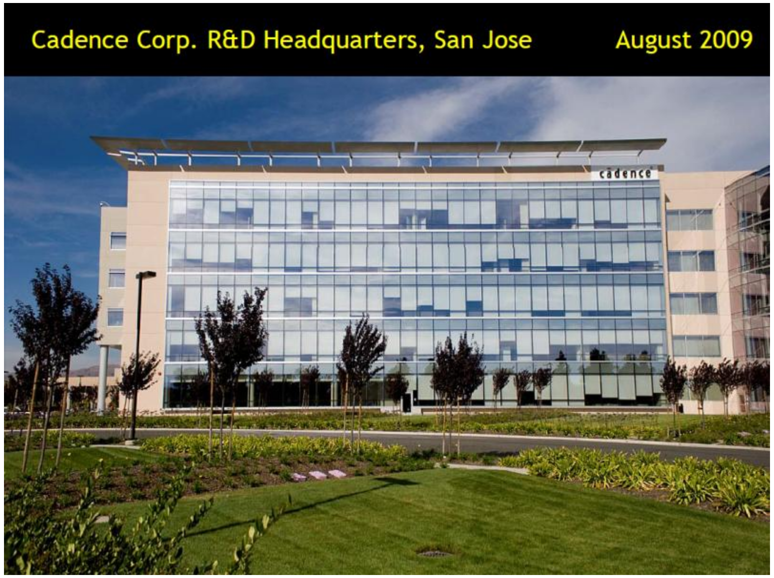
Prof. Dr. Morad Abdelmohsen (Examiner)
Prof. Dr, Ahmed Sherif (Examiner)

"A room is not a room without natural light."

Louis Kahn, 1971

Motivation

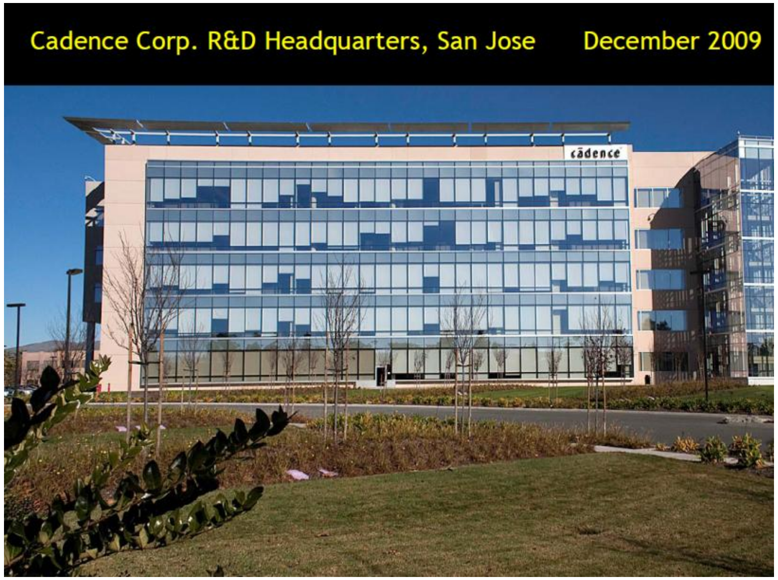
Building skins shouldn't be just designed only for its aesthetics aspects but also as a functioning element in the building.



The research aims to:

-Define guidelines for using daylighting systems to achieve high performance office building facades.

-Explore an integrated framework or methodology for integrating computational and building performance simulation tools.



*Figures copyright: Lecture presentation Prof. G. Z. Brown

1 Shading and Daylight Redirecting Systems: Daylighting Performance Analysis and Guidelines

2 Integrating Daylighting and Energy Consumption Simulations

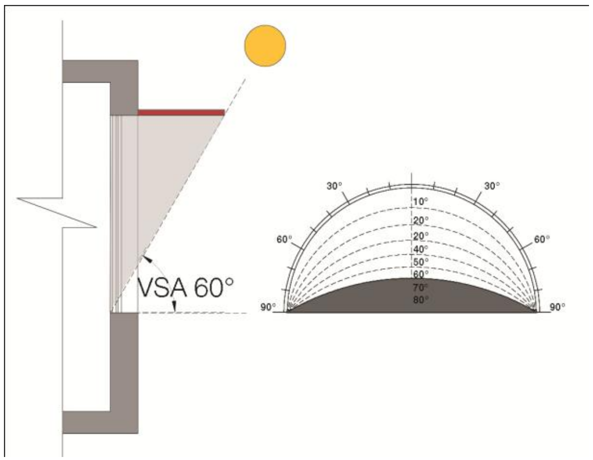
3 Integrating Computational and Building Performance Simulation Techniques for Optimized Facade Designs

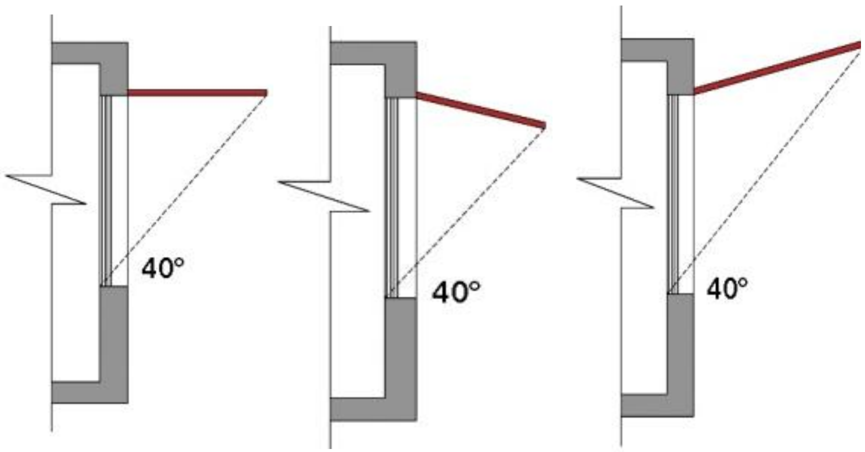
1

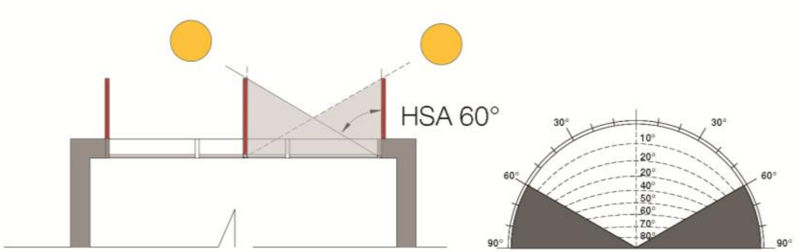
Shading and Daylight Redirecting Systems: Daylighting Performance Analysis and Guidelines

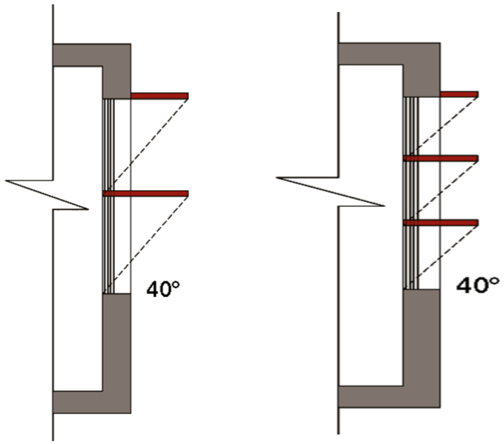
Gadelhak M., (2013) “High-Performance Facades: Designing Office Building Facades to Enhance Indoor Daylighting Performance” M.Sc. Thesis, Ain Shams University.

Shading Devices Design and Parameters





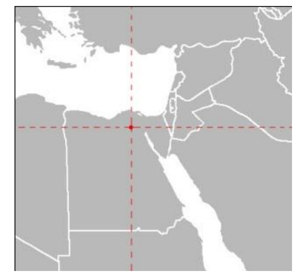


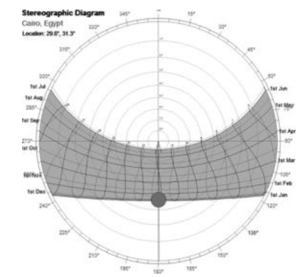


Location and Context

The case study was chosen to be located in the city of Cairo, Egypt (30° N- 31° E).

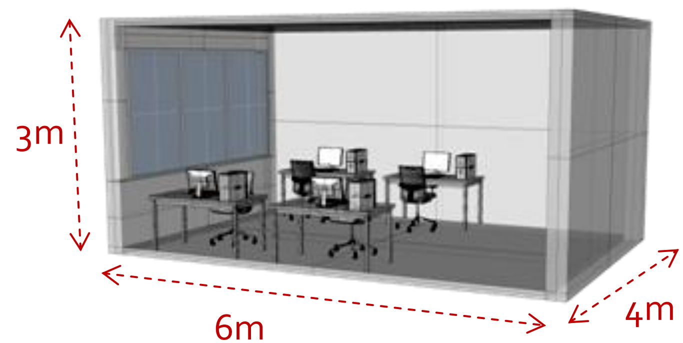
Cairo is endowed with a clear sunny sky for almost all the year round.





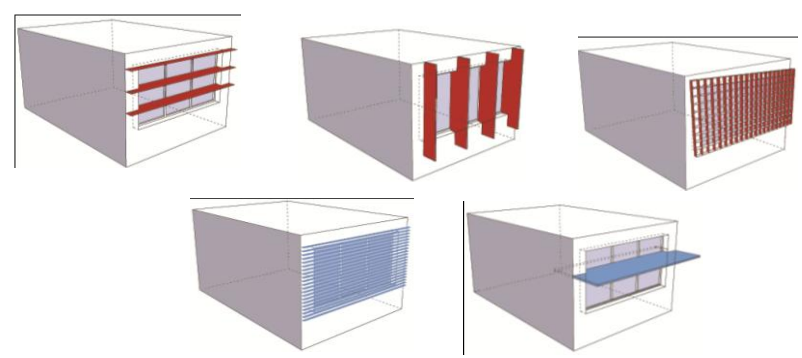
Base Case Parameters

A typical side-lit office room space 4.00 m wide and 6.00 m deep rectangular space, with 3.00 m clear height. The office space was assumed to have 3.60m wide and 1.80 m high window.



Modeled Cases

Different daylighting systems were investigated for the South, and East/West orientations. Three shading systems and two daylight redirecting systems were studied..

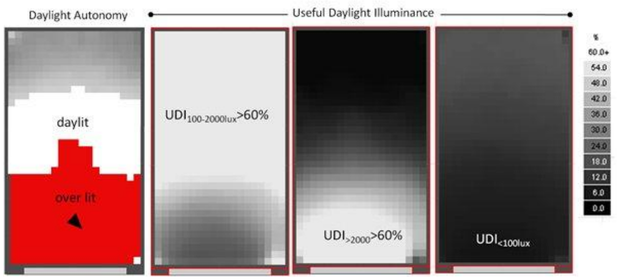


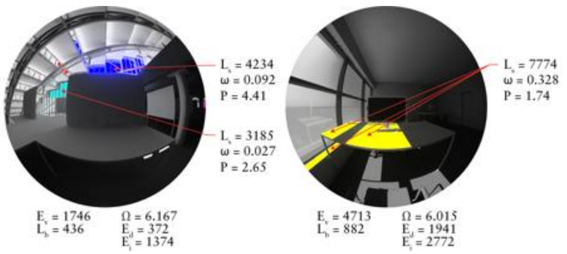
Simulation Parameters and Assumptions

The Daylight Availability metric was chosen as evaluating criteria.
Daylit - Partially daylit - Over lit

"Low Performance": (50%≤ daylit area <65%).
"Medium Performance": (65%≤ daylit area <75%).
"High Performance": (75%≤ daylit area).

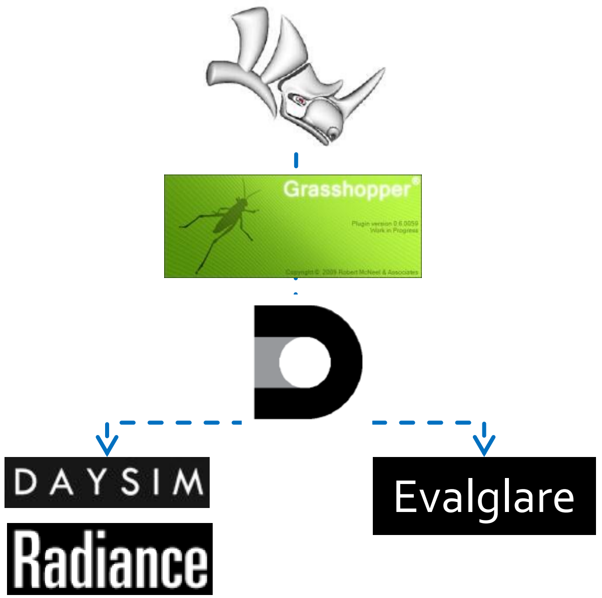
Daylight Glare Probability (DGP)





Simulation Workflow and Modeling Software

Parametric models were created using Grasshopper a plug-in for Rhinoceros modeling software.
Simulations were conducted using Diva-for-Rhino which was used to interface Radiance and Daysim for annual simulation and illuminance computation, and Evalglare for calculating the Daylight Glare Probability (DGP)

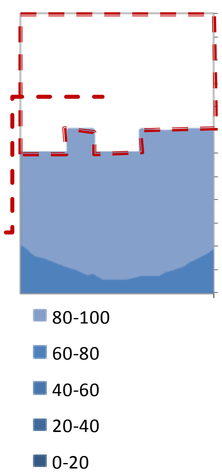


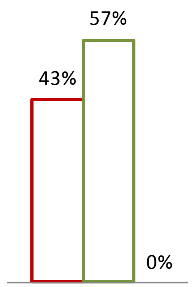
Base Case Simulation Results

South Orientation

57%
Daylit Area

43%
Overlit Area

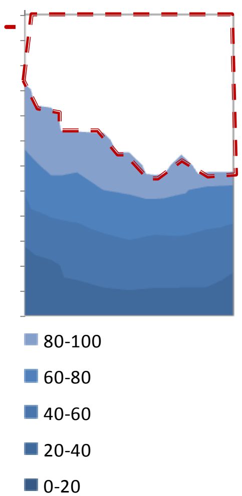


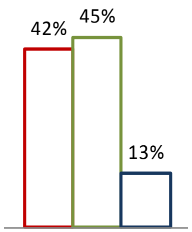


East Orientation

45%
Daylit Area

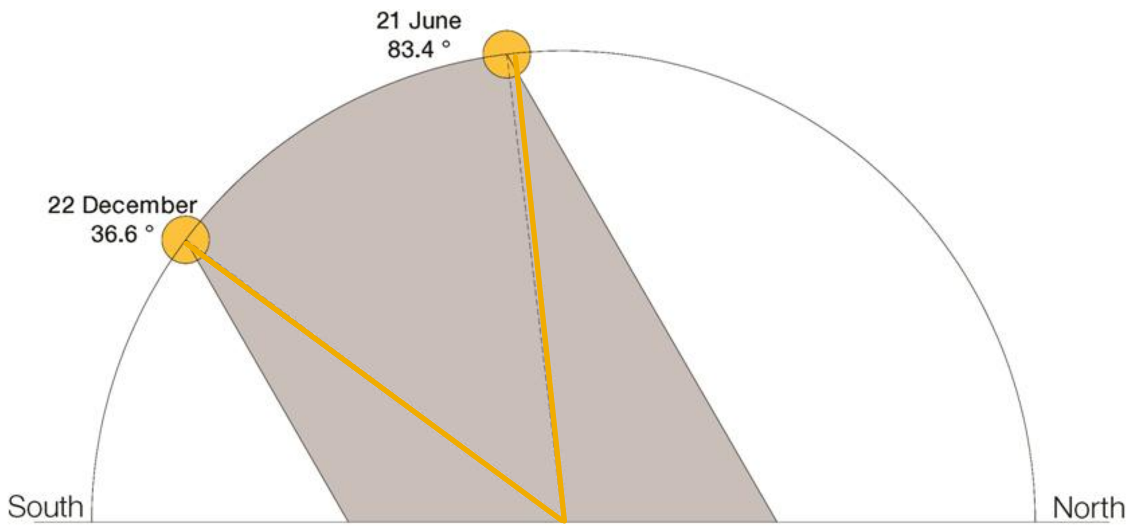
42%
Overlit Area





Sky condition and Sun angles

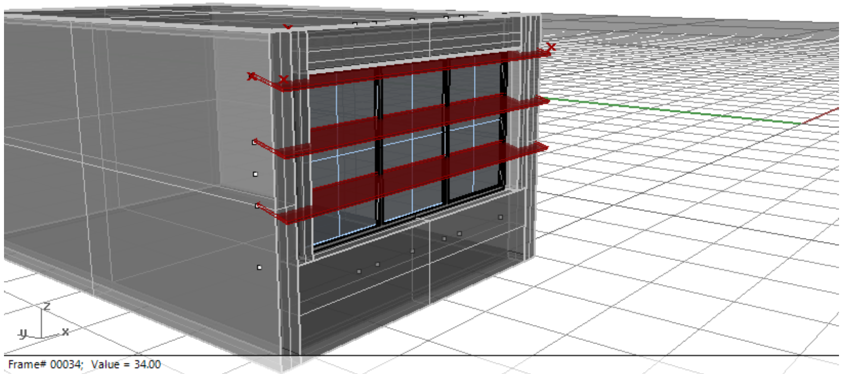
Cairo, Egypt
30 N, 31.2 E



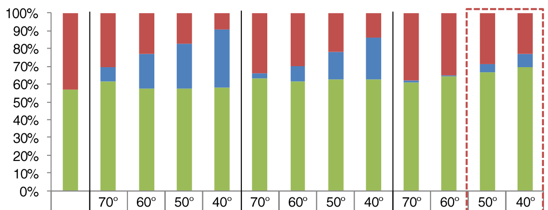
	Winter	Spring	Summer	Autumn	Annual Mean	Percentage
Days with Clear Sky (Monthly Mean)	23	28	31	28	**27**	**90%**
Days with Cloud Sky (Monthly Mean)	7	3	0	2	**3**	**10%**

Horizontal sun breakers

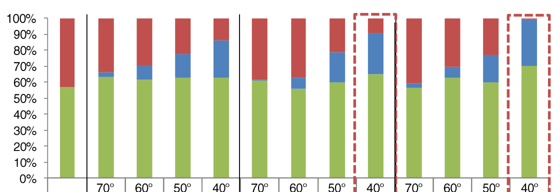
- *Vertical shading angle*: *70°, 60°, 50° and 40°*
- *Rotation angles*: *15° downwards, 0°, and 15° upwards*
- *Number of slats*: *single, double and triple*



South Orientation

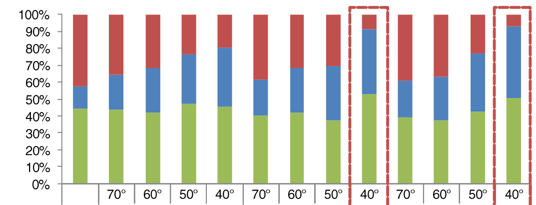


	Base Case	15° Downward 70°	60°	50°	40°	0 70°	60°	50°	40°	15° upward 70°	60°	50°	40°
Overlit	43%	31%	23%	17%	9%	34%	30%	22%	14%	38%	35%	29%	23%
Partially Daylit	0%	8%	20%	26%	32%	3%	9%	15%	24%	1%	1%	4%	8%
Daylit	57%	62%	57%	57%	58%	63%	62%	62%	62%	61%	64%	67%	69%

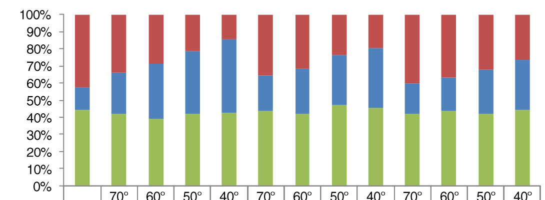


	Base Case	Single Slat 70°	60°	50°	40°	Double Slats 70°	60°	50°	40°	Triple Slats 70°	60°	50°	40°
Overlit	43%	34%	30%	22%	14%	38%	38%	21%	9%	41%	31%	23%	1%
Partially Daylit	0%	3%	9%	15%	24%	1%	7%	19%	26%	3%	7%	17%	29%
Daylit	57%	63%	62%	62%	62%	61%	56%	60%	65%	56%	62%	60%	70%

East Orientation



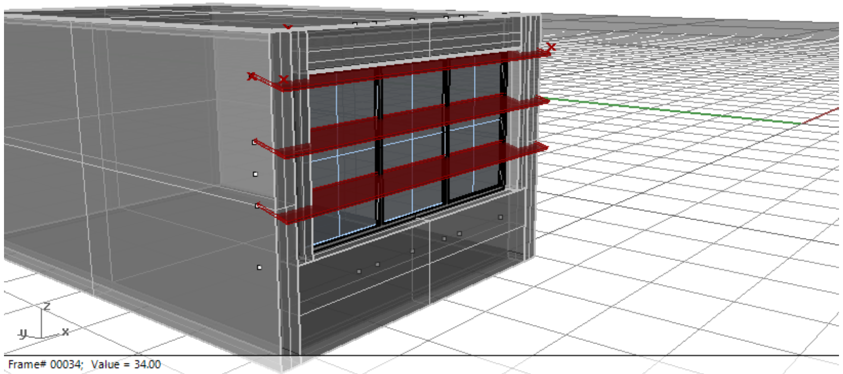
	Base case	Single Slat 70°	60°	50°	40°	Double Slats 70°	60°	50°	40°	Trible Slats 70°	60°	50°	40°
Overlit	43%	36%	32%	24%	20%	38%	32%	31%	9%	39%	37%	23%	7%
Partially Daylit	13%	21%	26%	29%	35%	21%	26%	32%	38%	21%	26%	34%	43%
Daylit	45%	44%	42%	47%	45%	40%	42%	38%	53%	39%	38%	43%	50%



	Base case	15° Downward 70°	60°	50°	40°	0 70°	60°	50°	40°	15° upward 70°	60°	50°	40°
Overlit	43%	34%	29%	21%	15%	36%	32%	24%	20%	40%	37%	32%	26%
Partially Daylit	13%	24%	32%	37%	43%	21%	26%	29%	35%	18%	20%	26%	29%
Daylit	45%	42%	39%	42%	43%	44%	42%	47%	45%	42%	44%	42%	44%

Horizontal sun breakers

- *Vertical shading angle*: *70°, 60°, 50° and 40°*
- *Rotation angles*: *15° downwards, 0°, and 15° upwards*
- *Number of slats*: *single, double and triple*

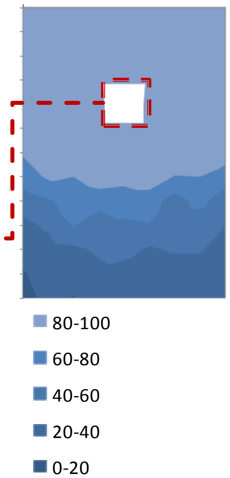


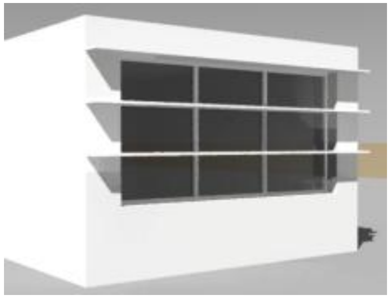
South Orientation

Three slats, horizontal with 50 ° VSA

70%
Daylit Area

1%
Overlit Area



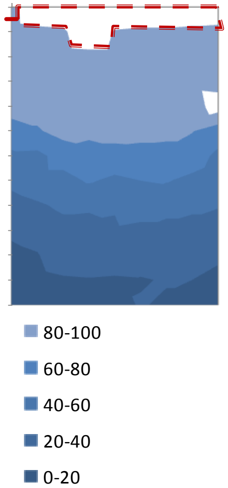


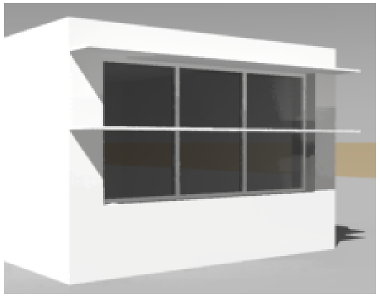
East Orientation

Two slats, horizontal with 50 ° VSA

53%
Daylit Area

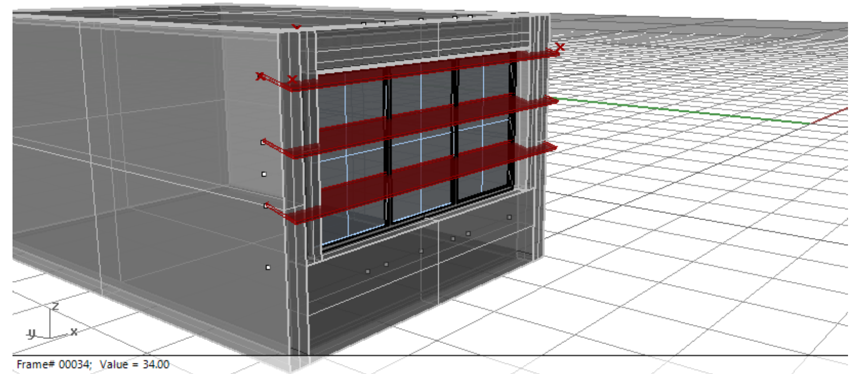
9%
Overlit Area





Horizontal sun breakers

- *Vertical shading angle*: *70°, 60°, 50° and 40°*
- *Rotation angles*: *15° downwards, 0°, and 15° upwards*
- *Number of slats*: *single, double and triple*

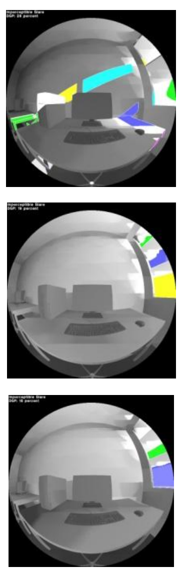


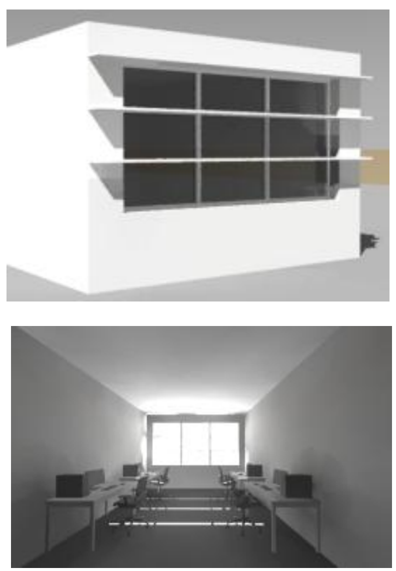
South Orientation

30%

Highest DGP

Imperceptible Glare



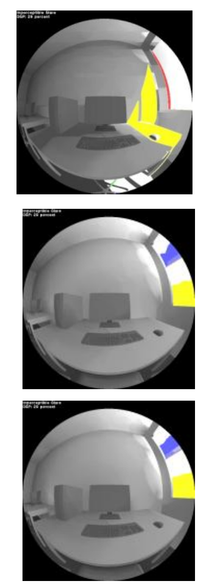


East Orientation

25%

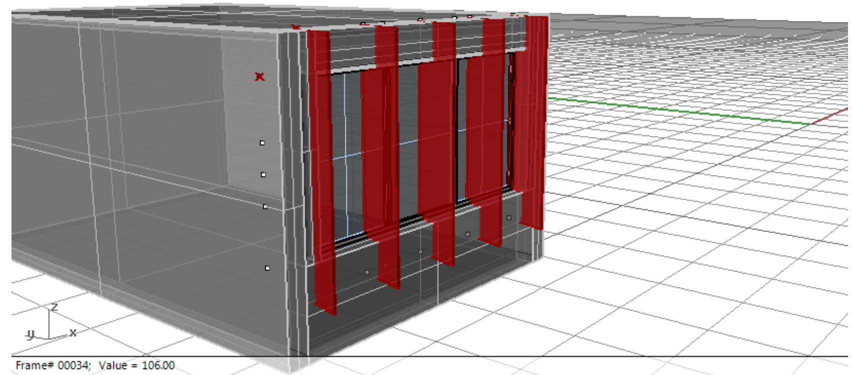
Highest DGP

Imperceptible Glare

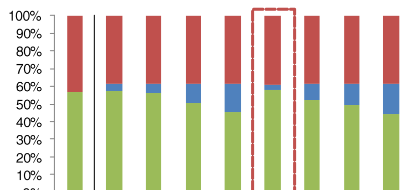


Vertical sun breakers

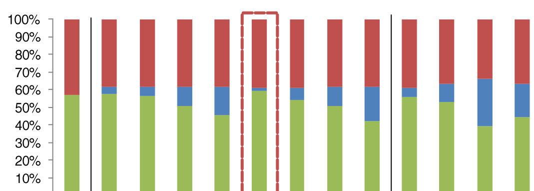
- *Horizontal shading angle*: *70°, 60°, 50° and 40°*
- *Rotation angles*: *15° downwards, 0°, and 15° upwards*
- *Number of slats*: *three, four and five*



South Orientation

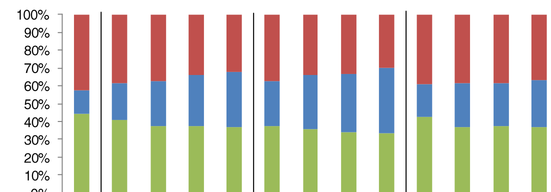


	Base Case	0° 70°	0° 60°	0° 50°	0° 40°	15° 70°	15° 60°	15° 50°	15° 40°
Overlit	43%	38%	38%	38%	38%	39%	38%	38%	38%
Partially Daylit	0%	4%	5%	11%	16%	3%	9%	12%	17%
Daylit	57%	57%	56%	50%	45%	58%	52%	50%	44%

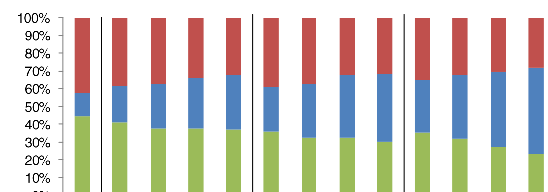


	Base Case	Three Fins 70°	Three Fins 60°	Three Fins 50°	Three Fins 40°	Four Fins 70°	Four Fins 60°	Four Fins 50°	Four Fins 40°	Five Fins 70°	Five Fins 60°	Five Fins 50°	Five Fins 40°
Overlit	43%	38%	38%	38%	38%	39%	39%	38%	38%	39%	37%	34%	37%
Partially Daylit	0%	4%	5%	11%	16%	2%	7%	11%	20%	5%	10%	26%	19%
Daylit	57%	57%	56%	50%	45%	59%	54%	50%	42%	56%	53%	39%	44%

East Orientation

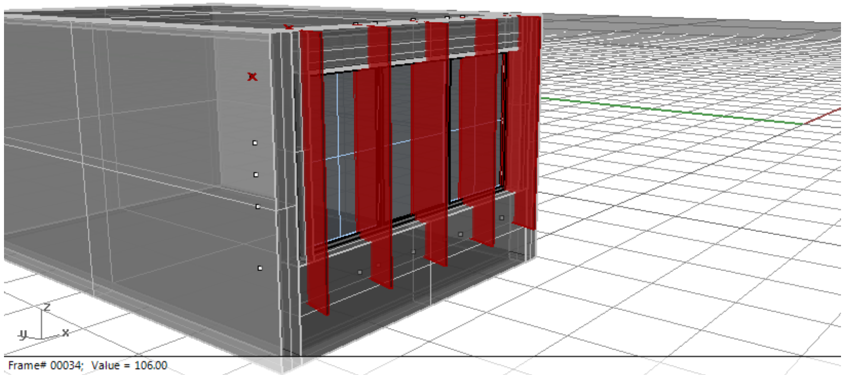


	Base Case	0° 70°	0° 60°	0° 50°	0° 40°	15° Towards North 70°	15° Towards North 60°	15° Towards North 50°	15° Towards North 40°	15° Towards South 70°	15° Towards South 60°	15° Towards South 50°	15° Towards South 40°
Overlit	43%	38%	38%	34%	32%	38%	34%	33%	30%	39%	38%	38%	37%
Partially Daylit	13%	21%	25%	28%	31%	25%	30%	32%	37%	18%	25%	24%	26%
Daylit	45%	41%	38%	38%	37%	38%	36%	34%	33%	43%	37%	38%	37%



	Base Case	Three Fins 70°	Three Fins 60°	Three Fins 50°	Three Fins 40°	Four Fins 70°	Four Fins 60°	Four Fins 50°	Four Fins 40°	Five Fins 70°	Five Fins 60°	Five Fins 50°	Five Fins 40°
Overlit	43%	38%	38%	34%	32%	39%	38%	32%	32%	35%	32%	31%	28%
Partially Daylit	13%	21%	25%	28%	31%	25%	30%	35%	38%	30%	36%	42%	49%
Daylit	45%	41%	38%	38%	37%	36%	32%	32%	30%	35%	32%	27%	23%

Vertical sun breakers



The effect of changing three parameters was studied.

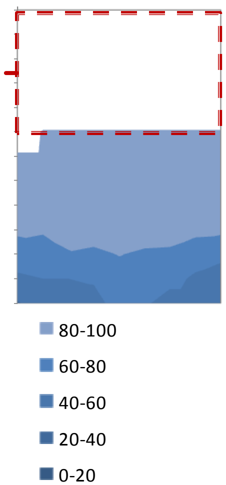
- *Horizontal shading angle: 70°, 60°, 50° and 40°*
- *Rotation angles: 15° North, 0°, and 15° South*
- *Number of slats: three, four and five*

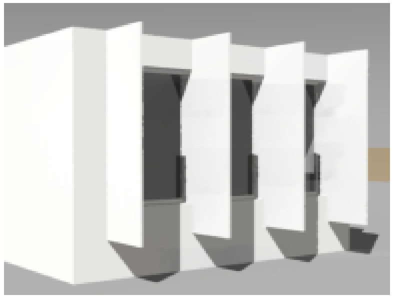
South Orientation

Four slats, 0° rotation, with 70 ° HSA

59%
Daylit Area

39%
Overlit Area



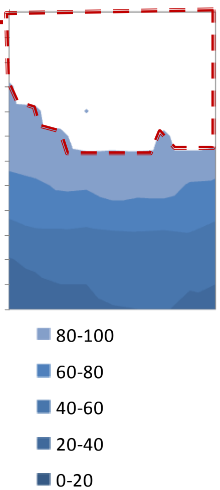


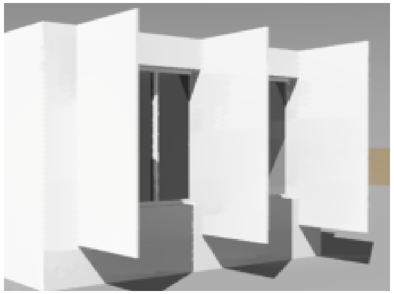
East Orientation

Five slats, *15° South,* with 70 ° HSA

43%
Daylit Area

39%
Overlit Area





Ain Shams University
Faculty of Engineering
Department of Architecture

Solar Screens

The effect of changing three parameters was studied.

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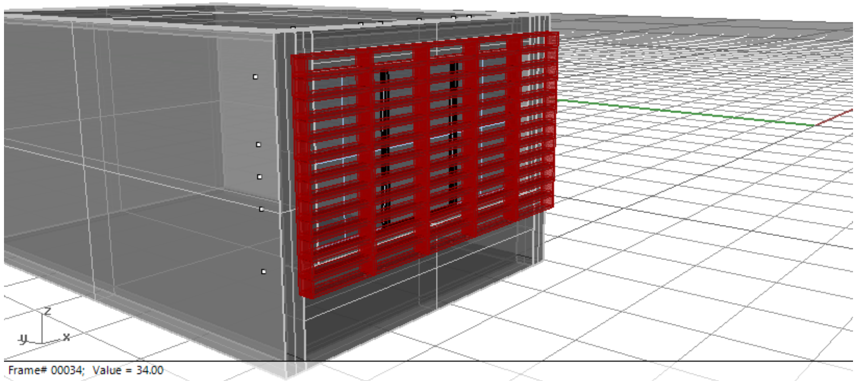
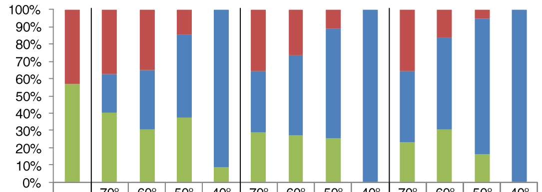
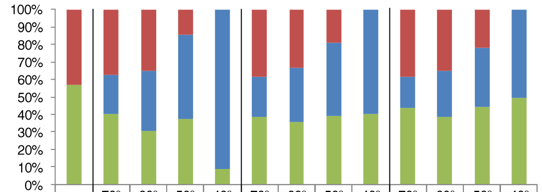
- *Vertical shading angle*: *70°, 60°, 50° and 40°*
- *Perforation ratio*: *90%, 80%, and 70%*
- *Aspect ratio (Horizontal: Vertical)*: *1:1, 2:1 and 4:1*



South Orientation

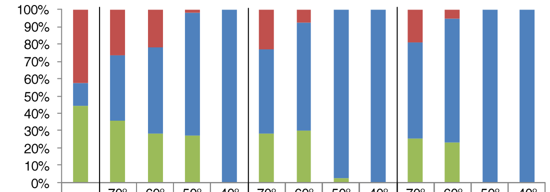


	Base Case	90%				80%				70%			
		70°	60°	50°	40°	70°	60°	50°	40°	70°	60°	50°	40°
Overlit	43%	38%	35%	15%	0%	36%	26%	11%	0%	36%	16%	5%	0%
Partially Daylit	0%	22%	34%	48%	91%	35%	46%	63%	100%	41%	53%	79%	100%
Daylit	57%	40%	31%	38%	9%	29%	27%	26%	0%	23%	31%	16%	0%

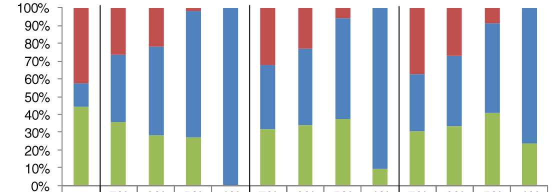


	Base Case	1:1				2:1				4:1			
		70°	60°	50°	40°	70°	60°	50°	40°	70°	60°	50°	40°
Overlit	43%	38%	35%	15%	0%	38%	33%	19%	0%	38%	35%	22%	0%
Partially Daylit	0%	22%	34%	48%	91%	23%	31%	42%	60%	18%	26%	33%	50%
Daylit	57%	40%	31%	38%	9%	38%	36%	39%	40%	44%	38%	44%	50%

East Orientation

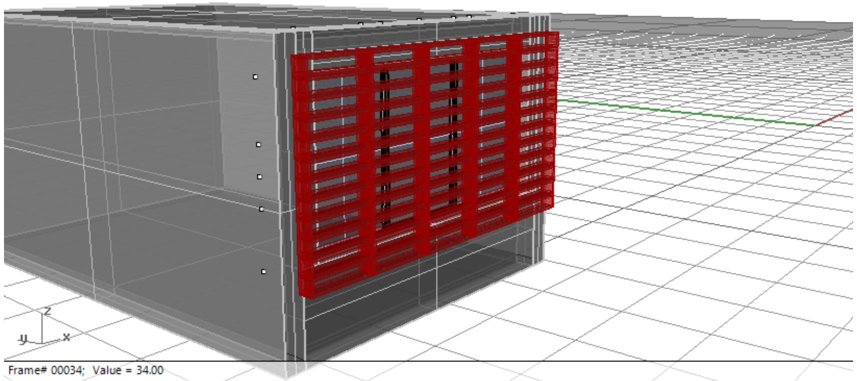


	Base Cade	90%				80%				70%			
		70°	60°	50°	40°	70°	60°	50°	40°	70°	60°	50°	40°
Overlit	43%	26%	22%	2%	0%	23%	8%	0%	0%	19%	5%	0%	0%
Partially Daylit	13%	38%	50%	71%	100%	49%	62%	97%	100%	56%	72%	100%	100%
Daylit	45%	36%	28%	27%	0%	28%	30%	3%	0%	26%	23%	0%	0%



	Base Cade	1:1				2:1				4:1			
		70°	60°	50°	40°	70°	60°	50°	40°	70°	60°	50°	40°
Overlit	43%	26%	22%	2%	0%	32%	23%	6%	0%	38%	27%	9%	0%
Partially Daylit	13%	38%	50%	71%	100%	36%	43%	56%	91%	32%	39%	50%	76%
Daylit	45%	36%	28%	27%	0%	32%	34%	38%	9%	31%	33%	41%	24%

Solar Screens



The effect of changing three parameters was studied.

.

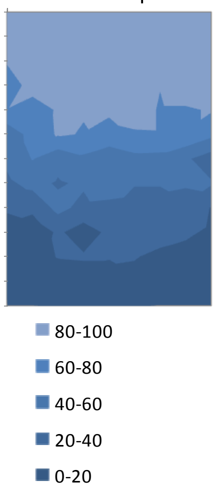
- *Vertical shading angle: 70°, 60°, 50° and 40°*
- *Perforation ratio: 90%, 80%, and 70%*
- *Aspect ratio (Horizontal: Vertical): 1:1, 2:1 and 4:1*

South Orientation

90% perforation, 4:1, with 70 ° VSA

50%
Daylit Area

0%
Overlit Area

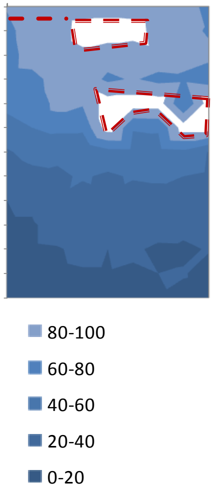


East Orientation

90% perforation, 4:1, with 50 ° VSA

41%
Daylit Area

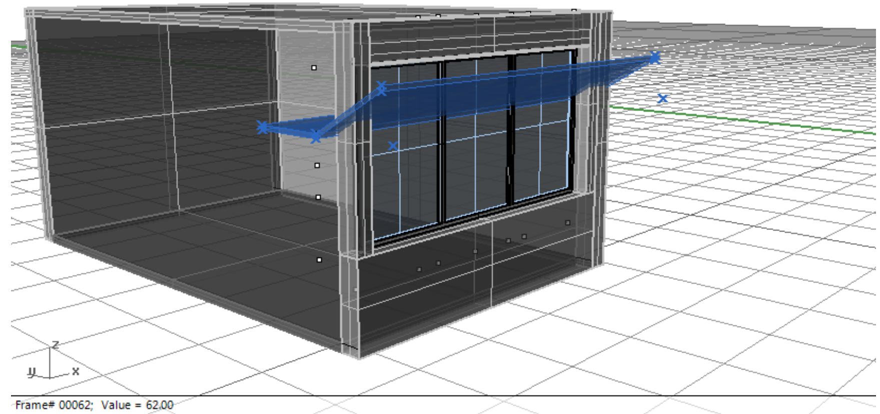
9%
Overlit Area



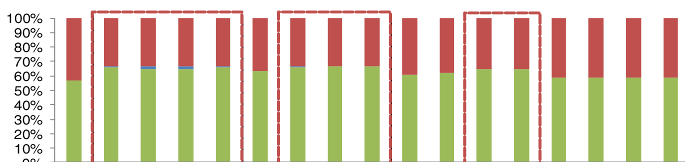
Light Shelves

The effect of changing three parameters was studied.

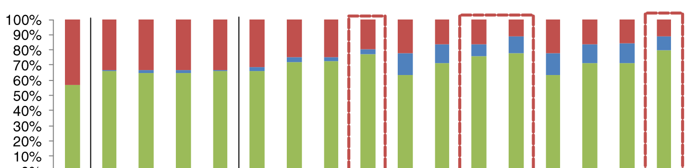
- External light shelf depth:, 60 cm, 80 cm, 100 cm and 120 cm
- Internal light shelf depth: 0 , 30 cm, 60 cm, and 80 cm
- External light shelf rotation angle: 0°, 10°, 20°, and 30°



South Orientation

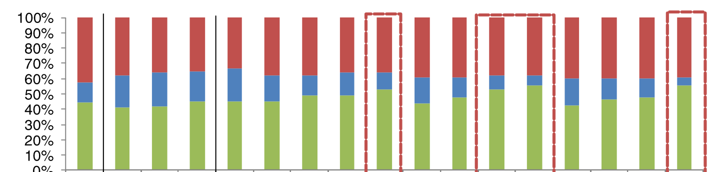


	Base Case	0°				10°				20°				30°			
		60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm
Overlit	43%	33%	33%	33%	33%	37%	33%	33%	33%	39%	38%	35%	35%	41%	41%	41%	41%
Partially Daylit	0%	1%	2%	2%	1%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Daylit	57%	66%	65%	65%	66%	63%	66%	67%	67%	61%	62%	65%	65%	59%	59%	59%	59%

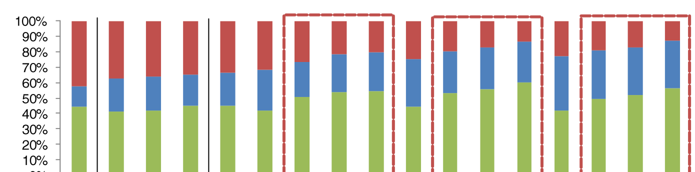


	Base Case	0 cm				30 cm				60 cm				80 cm			
		60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm
Overlit	43%	33%	33%	33%	33%	32%	25%	25%	20%	22%	16%	16%	11%	22%	16%	15%	11%
Partially Daylit	0%	1%	2%	2%	1%	3%	3%	3%	3%	15%	13%	8%	11%	15%	13%	14%	9%
Daylit	57%	66%	65%	65%	66%	66%	72%	73%	77%	63%	71%	76%	78%	63%	71%	71%	79%

East Orientation



	Base case	0°				10°				20°				30°			
		60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm
Overlit	43%	38%	36%	35%	33%	38%	38%	36%	36%	39%	39%	38%	38%	40%	40%	40%	39%
Partially Daylit	13%	21%	22%	20%	21%	17%	14%	15%	11%	17%	13%	9%	7%	17%	14%	12%	5%
Daylit	45%	41%	42%	45%	45%	45%	49%	49%	53%	44%	48%	53%	56%	43%	46%	48%	56%

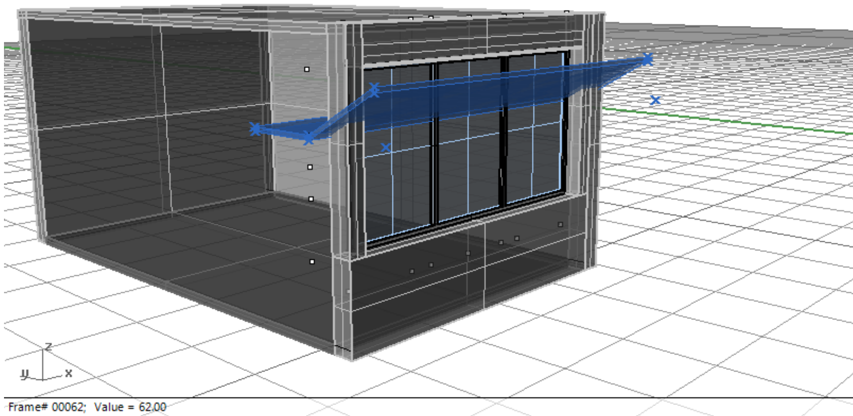


	Base case	30 cm				60 cm				80 cm				120 cm			
		60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm	60 cm	80 cm	100 cm	120 cm
Overlit	43%	38%	36%	35%	33%	32%	26%	21%	21%	25%	20%	17%	14%	23%	19%	17%	13%
Partially Daylit	13%	21%	22%	20%	21%	26%	23%	25%	25%	31%	27%	27%	26%	35%	32%	31%	31%
Daylit	45%	41%	42%	45%	45%	42%	50%	54%	55%	44%	53%	56%	60%	42%	50%	52%	56%

Light Shelves

The effect of changing three parameters was studied.

- External light shelf depth:, 60 cm, 80 cm, 100 cm and 120 cm
- Internal light shelf depth: 0 , 30 cm, 60 cm, and 80 cm
- External light shelf rotation angle: 0°, 10°, 20°, and 30°

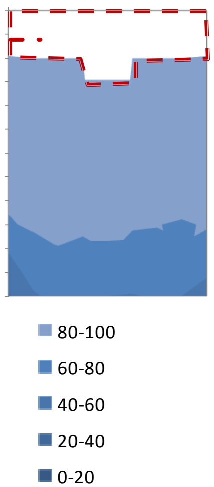


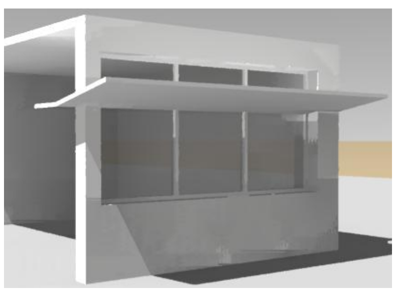
South Orientation

100 cm Ext., 10° rotation, 60 cm Int.

82%
Daylit Area

16%
Overlit Area



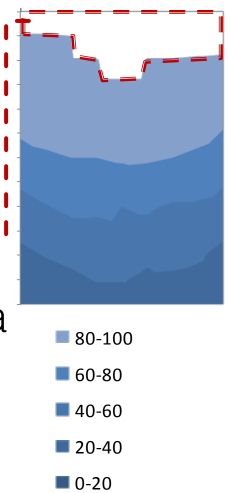


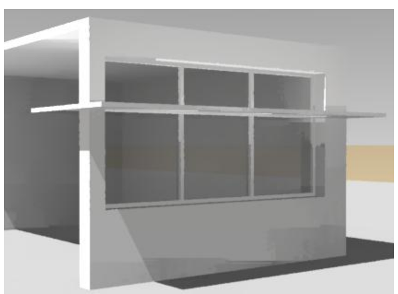
East Orientation

120 cm Ext., 0° rotation, 60 cm Int.

60%
Daylit Area

14%
Overlit Area

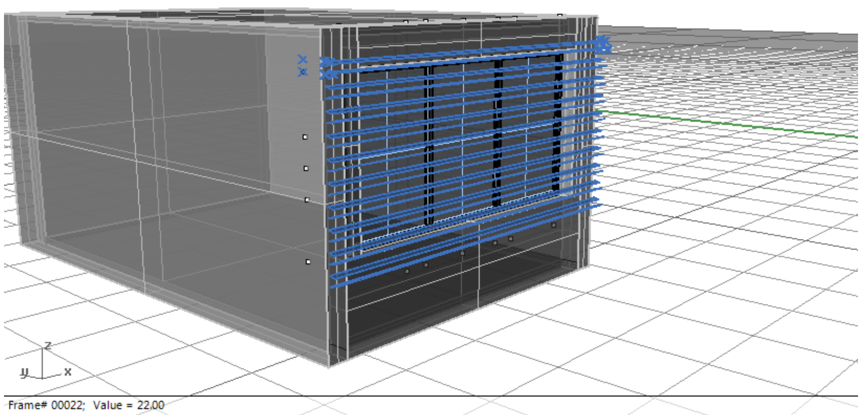




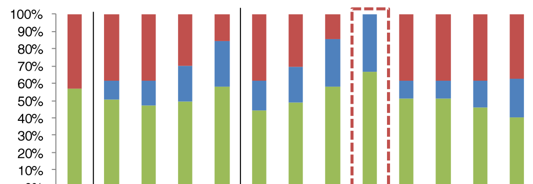
Louvers and Blinds

The louvers were rotated in two different ways:
The conventional way: all louver slats were rotated in the same direction
The combined way: where every other louver have the same rotation angle.

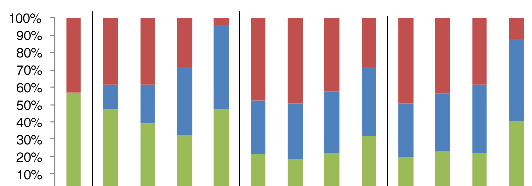
- *Vertical shading angle:* *70°, 60°, 50° and 40°*
- *Rotation angles:* *15° downwards, 0°, and 15° upwards*



South Orientation

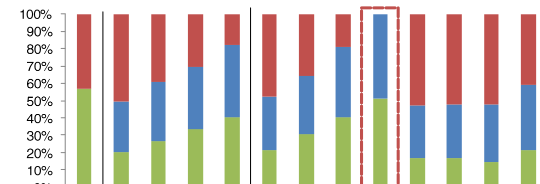


	Base Case	Horizontal				15° Downward				15° Upward			
		70°	60°	50°	40°	70°	60°	50°	40°	70°	60°	50°	40°
Overlit	43%	38%	38%	30%	15%	38%	31%	15%	0%	38%	38%	38%	38%
Partially Daylit	0%	11%	15%	21%	26%	17%	21%	27%	33%	10%	10%	15%	22%
Daylit	57%	50%	47%	50%	58%	44%	49%	58%	67%	51%	51%	46%	40%

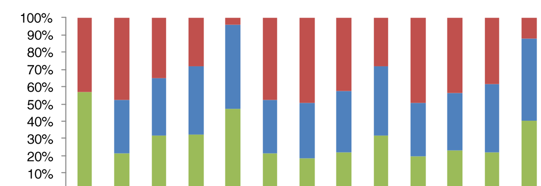


	Base Case	Horizontal / 15° Downward				Horizontal / 15° Upward				15° Downward/ 15° Upward			
		70°	60°	50°	40°	70°	60°	50°	40°	70°	60°	50°	40°
Overlit	43%	38%	38%	28%	4%	48%	50%	43%	28%	50%	44%	38%	12%
Partially Daylit	0%	15%	22%	39%	49%	31%	32%	35%	40%	31%	33%	39%	48%
Daylit	57%	47%	39%	32%	47%	21%	19%	22%	32%	20%	23%	22%	40%

East Orientation

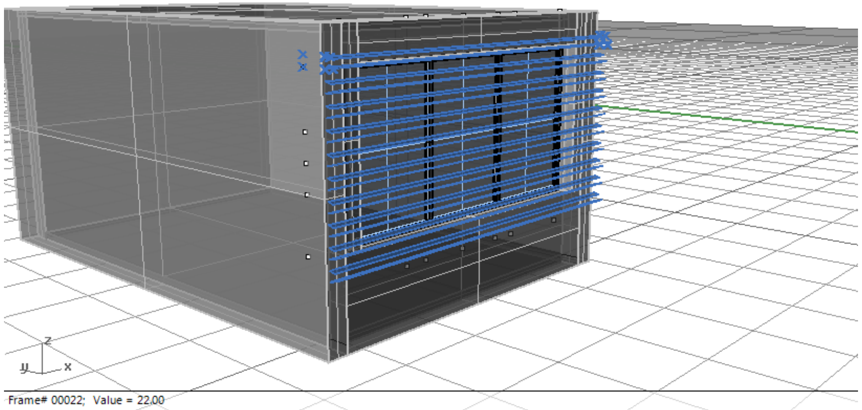


	Base Case	Horizontal				15° Downward				15° Upward			
		70°	60°	50°	40°	70°	60°	50°	40°	70°	60°	50°	40°
Overlit	43%	50%	39%	31%	18%	48%	36%	19%	0%	53%	52%	52%	41%
Partially Daylit	0%	29%	34%	36%	42%	31%	33%	41%	49%	30%	31%	33%	38%
Daylit	57%	21%	26%	33%	40%	21%	31%	40%	51%	17%	17%	15%	21%



	Base Case	Horizontal / 15° Downward				Horizontal / 15° Upward				15° Downward / Upward			
		70°	60°	50°	40°	70°	60°	50°	40°	70°	60°	50°	40°
Overlit	43%	48%	35%	28%	4%	48%	50%	43%	28%	50%	44%	38%	12%
Partially Daylit	0%	31%	33%	39%	49%	31%	32%	35%	40%	31%	33%	39%	48%
Daylit	57%	21%	32%	32%	47%	21%	19%	22%	32%	20%	23%	22%	40%

Louvers and Blinds



The louvers were rotated in two different ways:
The conventional way: all louver slats were rotated in the same direction
The combined way: where every other louver have the same rotation angle.

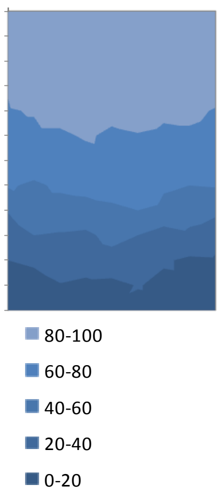
- *Vertical shading angle: 70°, 60°, 50° and 40°*
- *Rotation angles: 15° downwards, 0°, and 15° upwards*

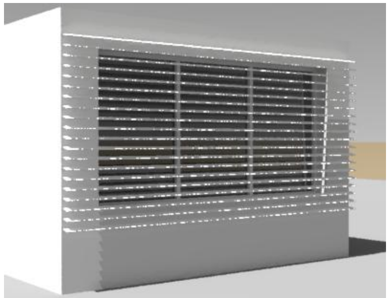
South Orientation

Conventional, 15° downwards, 40 ° VSA

67%
Daylit Area

0%
Overlit Area



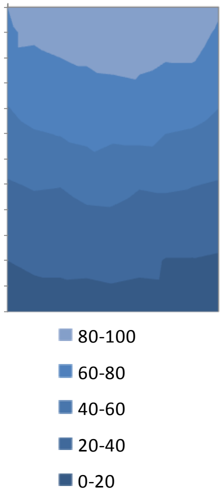


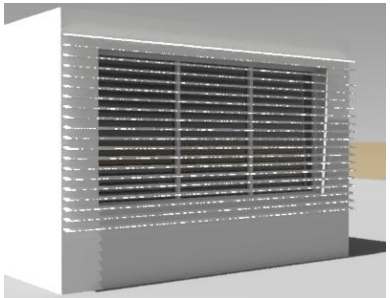
East Orientation

Conventional, 15° downwards, 40 ° VSA

51%
Daylit Area

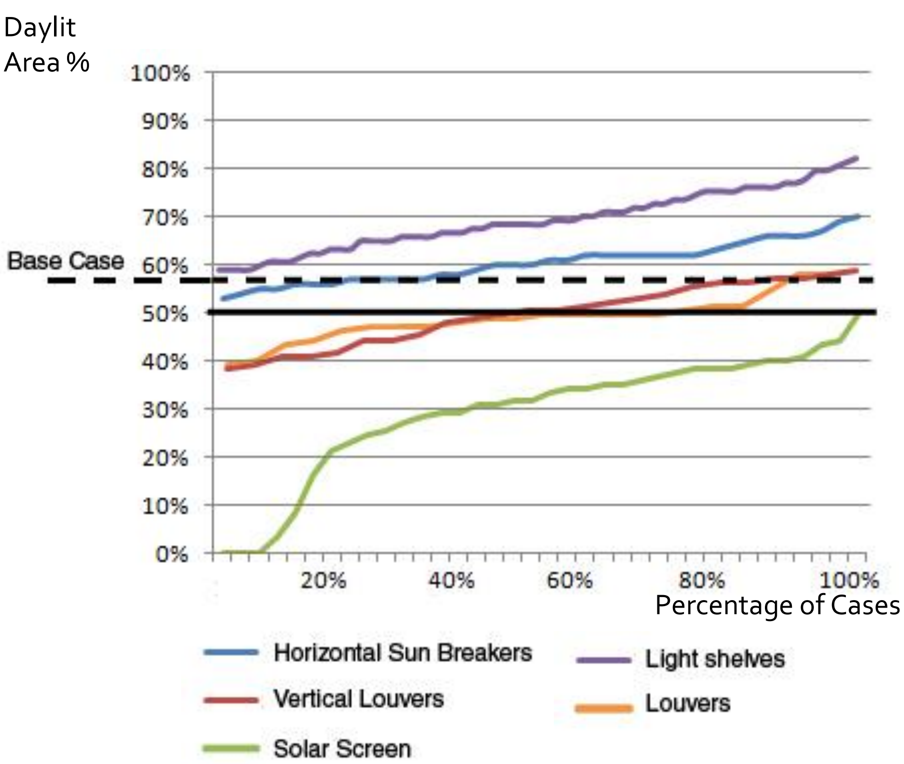
0%
Overlit Area



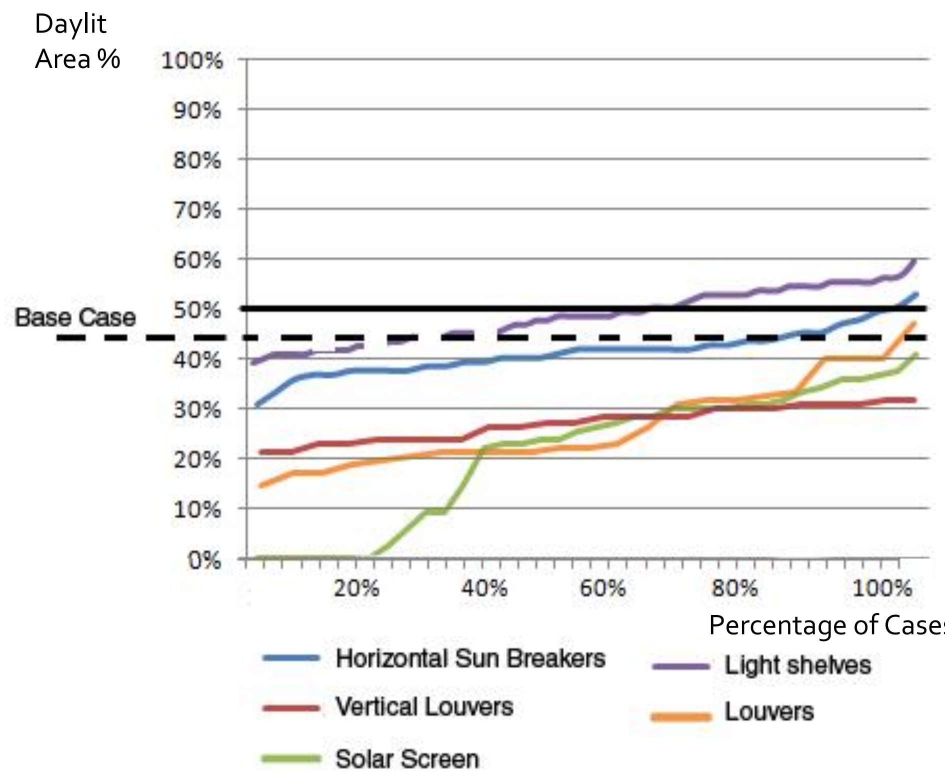


Comparison between the five systems

South Orientation



East Orientation

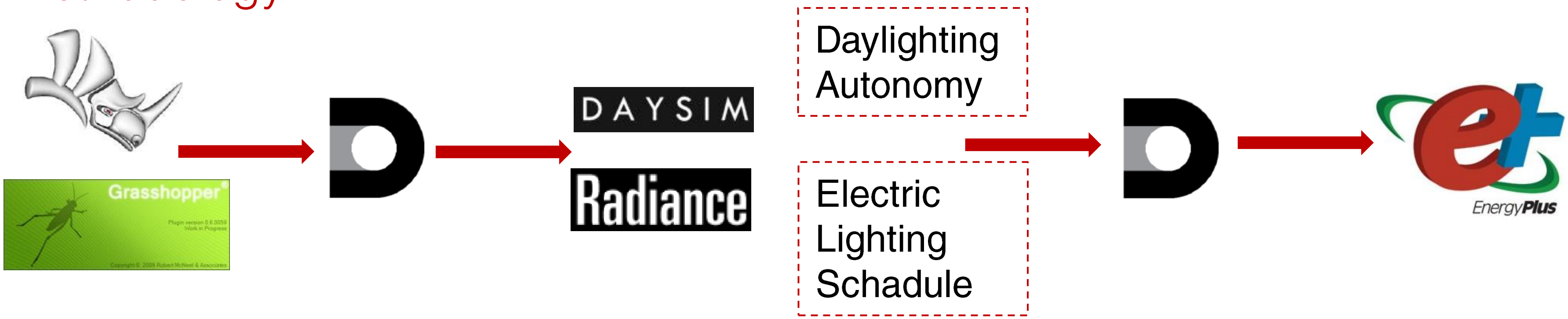


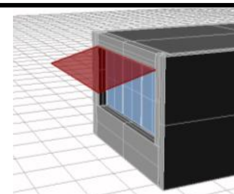
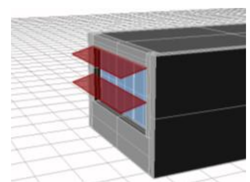
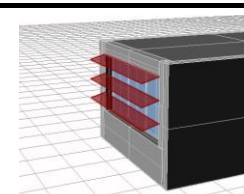
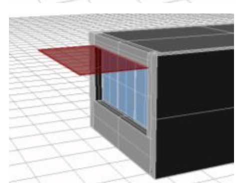
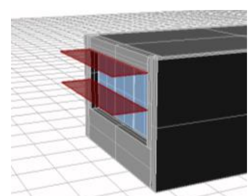
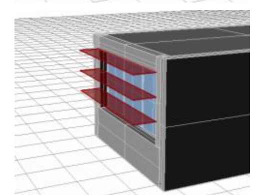
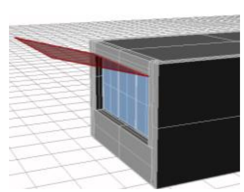
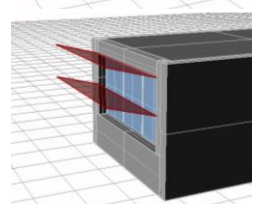
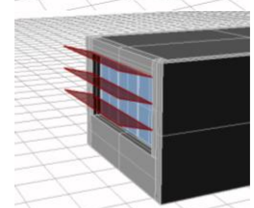
Ain Shams University
Faculty of Engineering
Department of Architecture

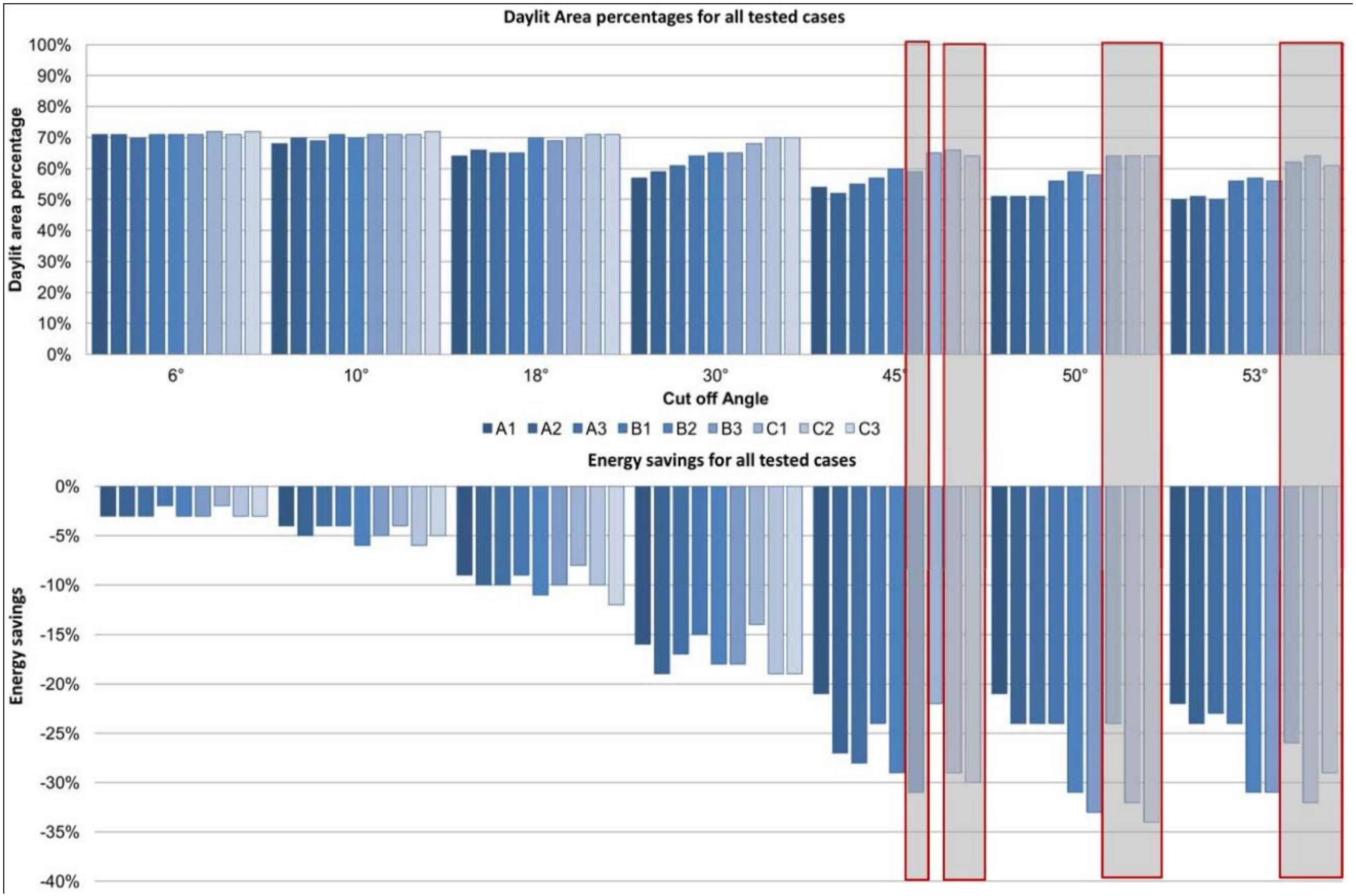
2 Integrating Daylighting and Energy Consumption Simulations

Gadelhak M., Aly M., and Sabry H. “High Performance Facades: The Effect of Sun Breaker on Daylighting Performance and Energy Consumption in South Oriented Office Spaces” 2013 Architectural Engineering Institute (AEI) Conference Penn State College, PA on April 3 - 5th.

Methodology



Studied cases for February\October cut-off angle (40°)				
		Number of slats		
		1	**2**	**3**
15° downwards	**A**			
0°	**B**			
15° upwards	**C**			

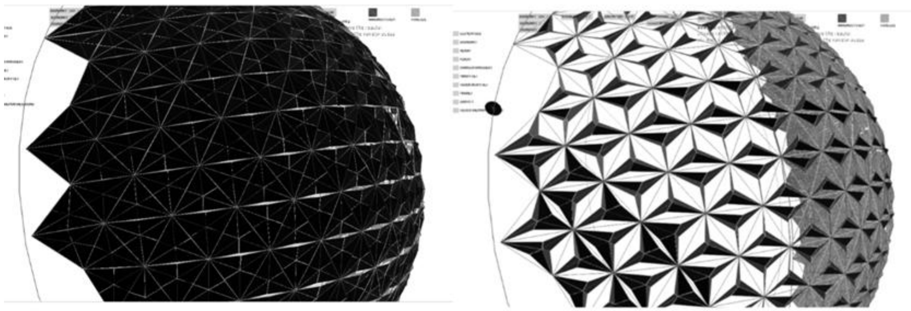

Daylit Area percentages for all tested cases
Daylit area percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
6°
10°
18°
30°
45°
50°
53°
Cut off Angle
A1 A2 A3 B1 B2 B3 C1 C2 C3
Energy savings for all tested cases
Energy savings
0%
-5%
-10%
-15%
-20%
-25%
-30%
-35%
-40%

3 Integrating Computational and Building Performance Simulation Techniques for Optimized Facade Designs

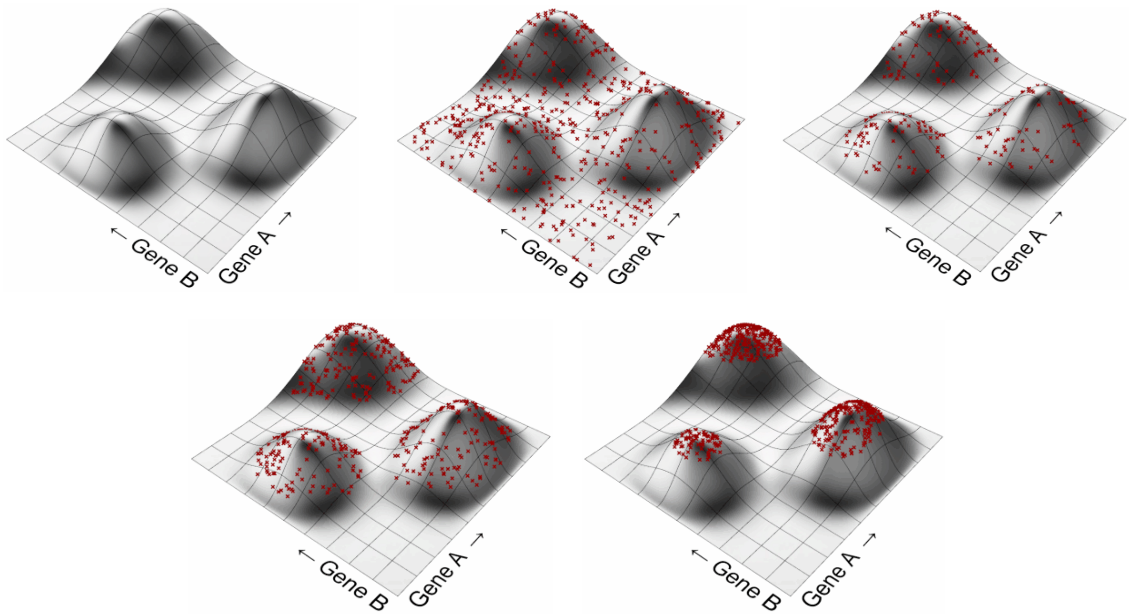
“Integrating Computational and Building Performance Simulation Techniques for Optimized Facade Designs”
eCAADe 2013 conference “Computation and Performance”, TU Delft, Delft, The Netherlands, September 18-20.

Generative Design, Optimization and Form Finding

Generative Design

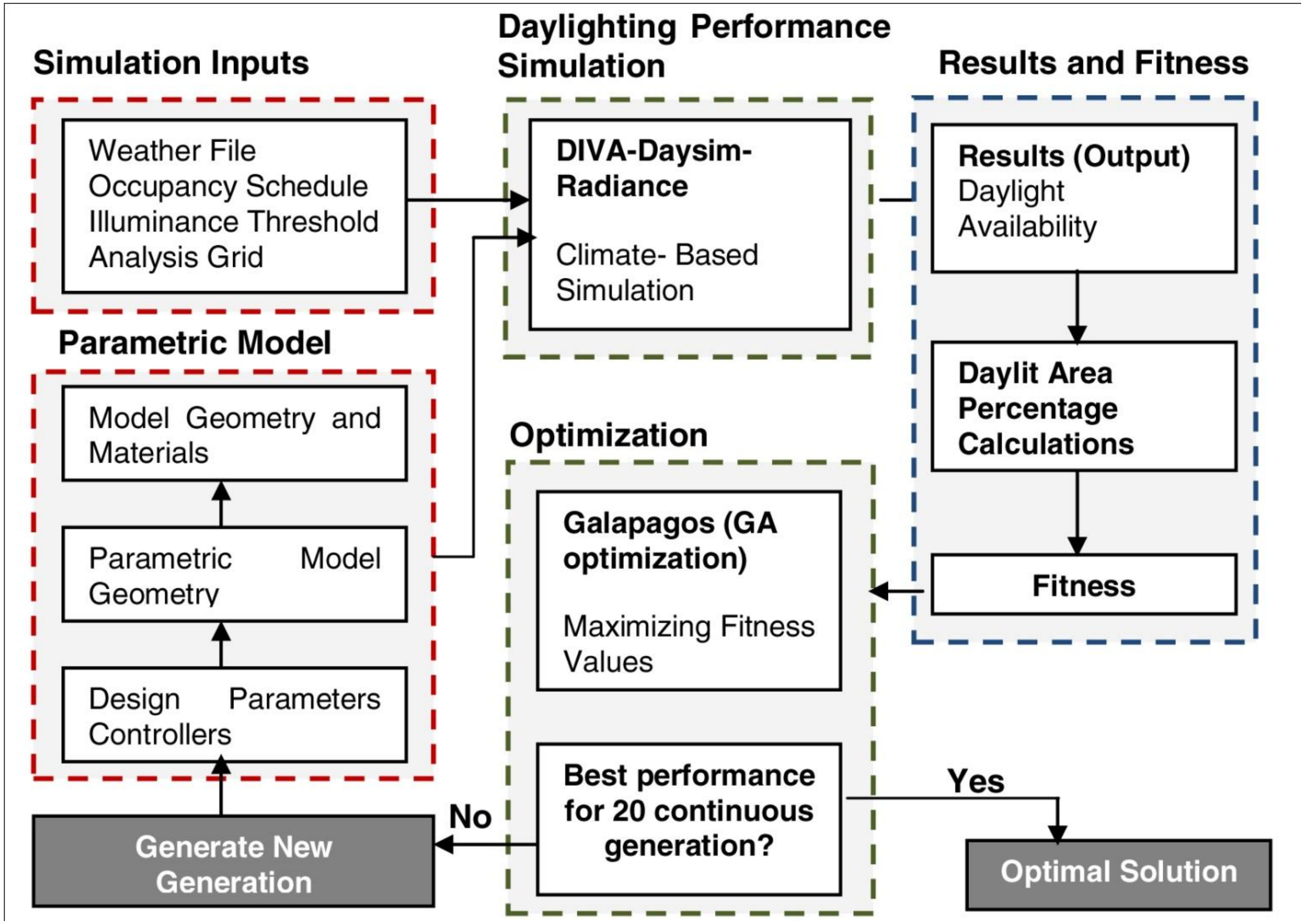


Optimization and Form finding



Generative Design, Optimization and Form Finding

Optimization Methodology



Case 1: Light shelf and Solar screen Combination

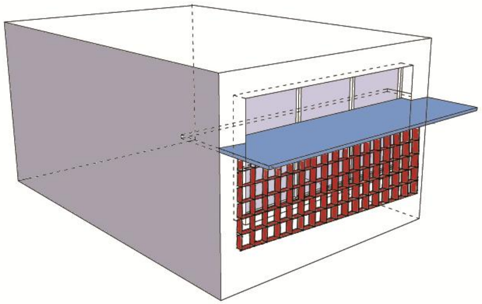
Various combinations of light shelves and solar screens were tested. total number of possible combinations was **2,304 cases** for six different variables.

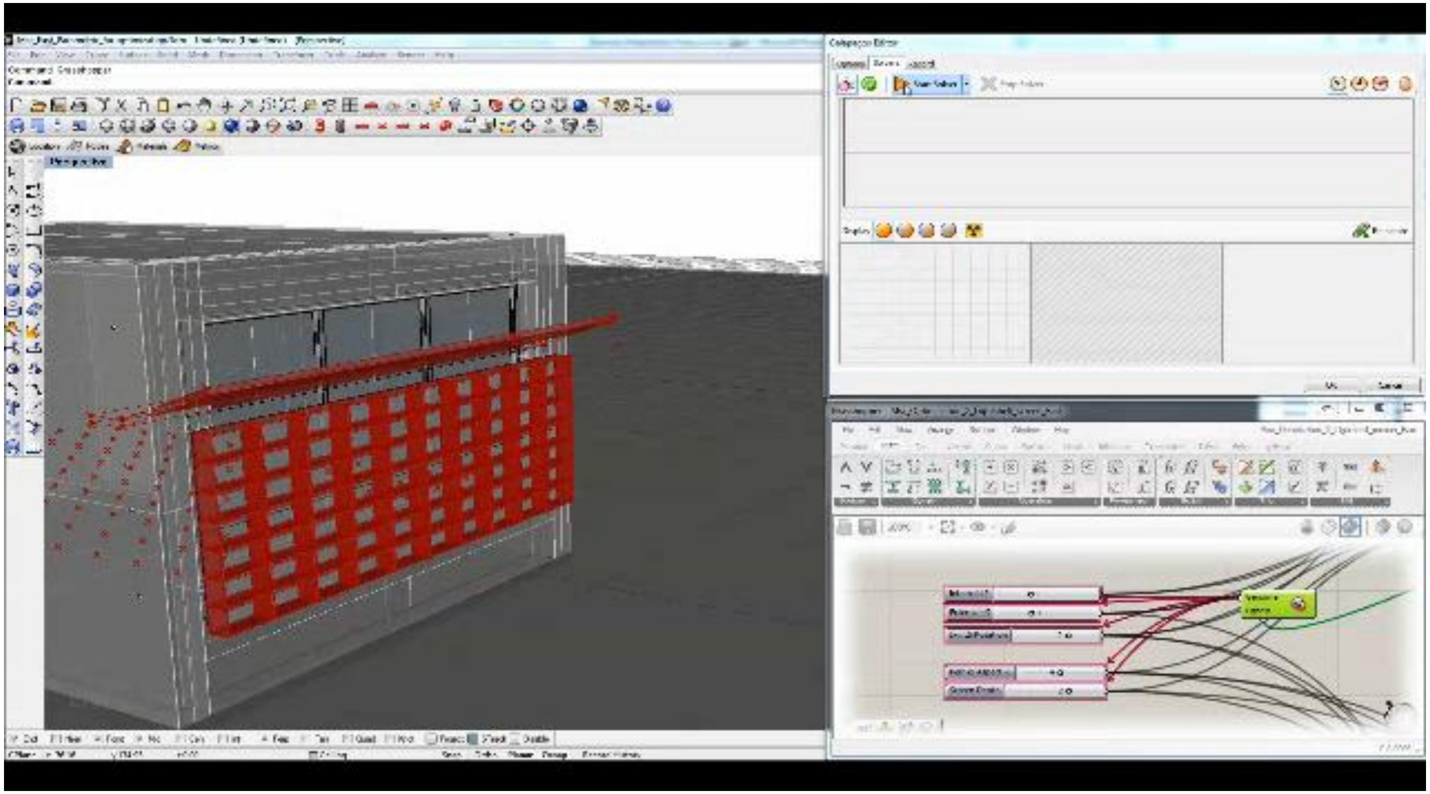
Solar Screen Variables

- *Vertical shading angle*
- *Perforation ratio*
- *Aspect ratio*

Light Shelf Variables

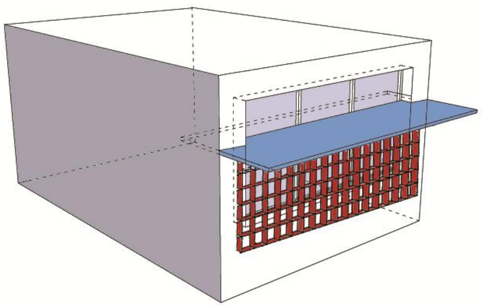
- *External light shelf depth*
- *Internal light shelf depth*
- *External light shelf rotation angle*





Case 1: Light shelf and Solar screen Combination

Various combinations of light shelves and solar screens were tested. total number of possible combinations was **2,304 cases** for six different variables.

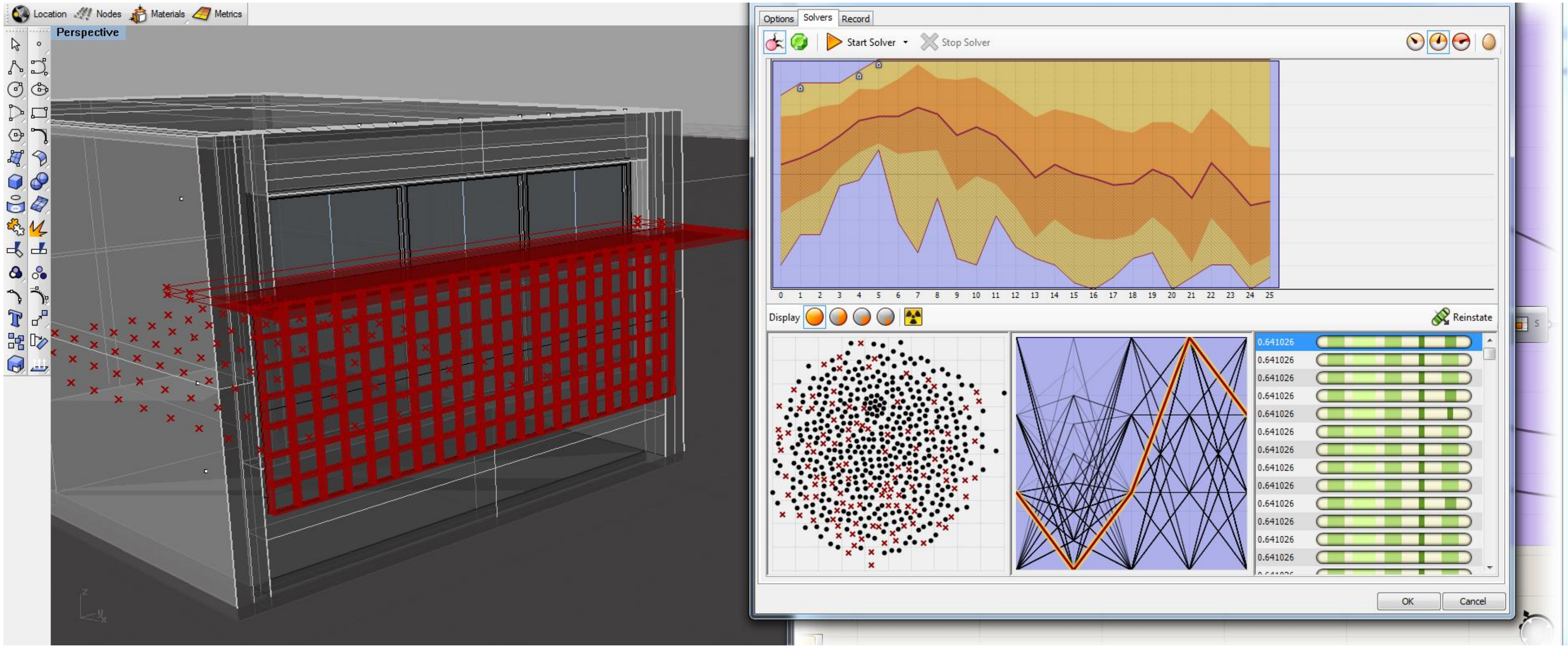


Solar Screen Variables

- *Vertical shading angle*
- *Perforation ratio*
- *Aspect ratio*

Light Shelf Variables

- *External light shelf depth*
- *Internal light shelf depth*
- *External light shelf rotation angle*



Case 1: Light shelf and Solar screen Combination

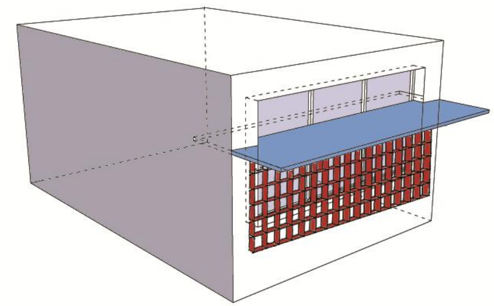
Various combinations of light shelves and solar screens were tested the total number of possible combinations was **2,304 cases** for six different variables. To avoid simulating and analyzing all the cases Galapagos a genetic-algorithm evolutionary solver was used.

Solar Screen Variables

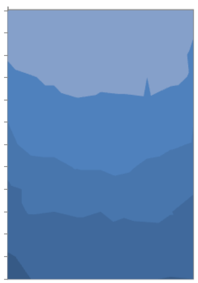
- *Vertical shading angle*
- *Perforation ratio*
- *Aspect ratio*

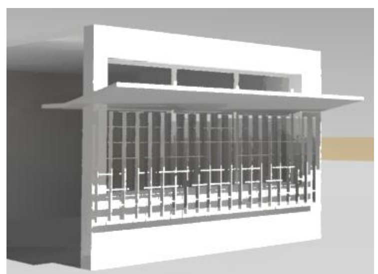
Light Shelf Variables

- *External light shelf depth*
- *Internal light shelf depth*
- *External light shelf rotation angle*

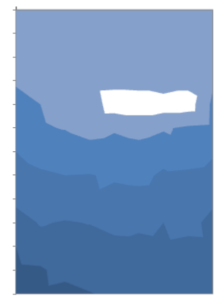


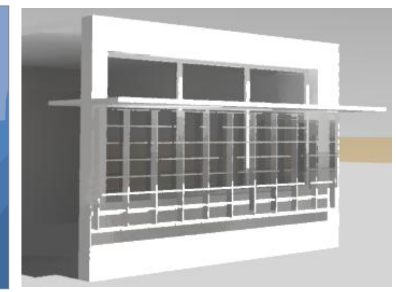
64%
Daylit Area
0%
Overlit Area



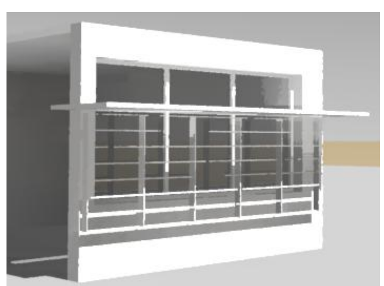


62%
Daylit Area
3%
Overlit Area

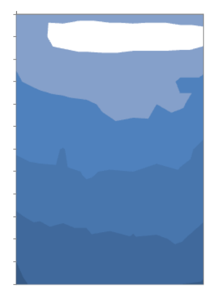


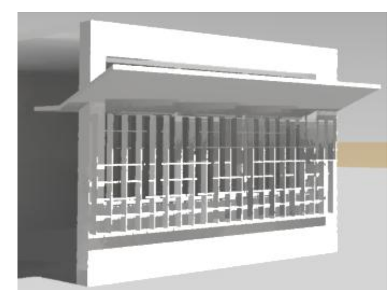


62%
Daylit Area
7%
Overlit Area



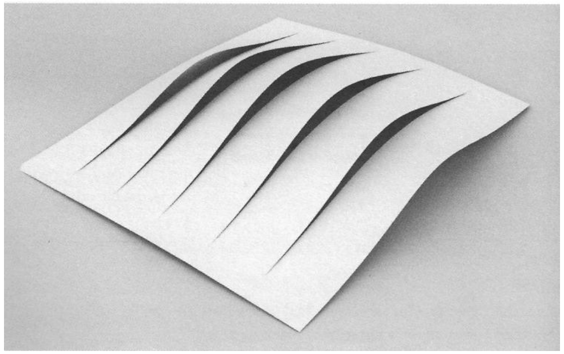
61%
Daylit Area
6%
Overlit Area

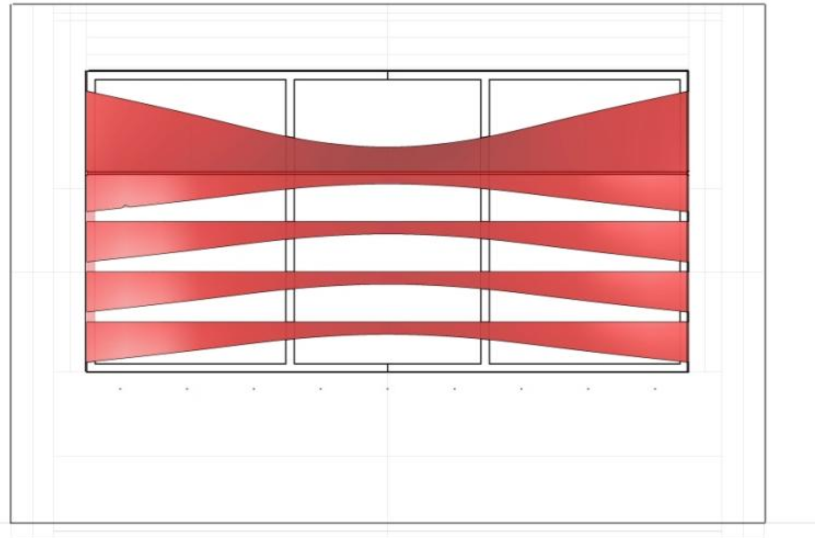


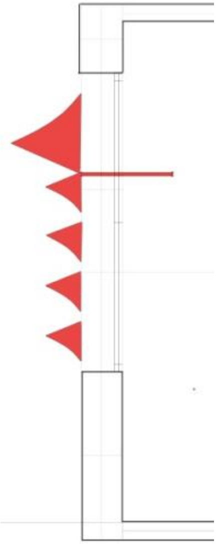


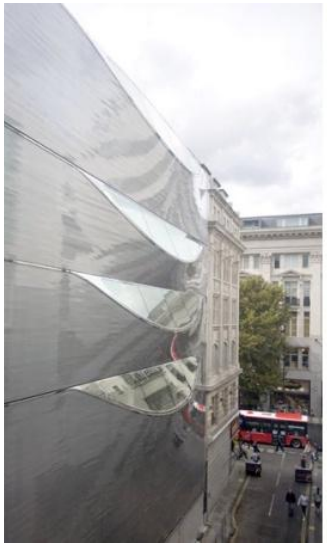
Case 2: Form Finding

Free Form Gills Surface



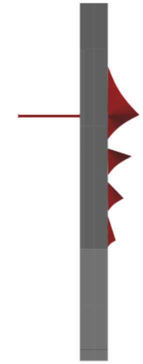






Case 2: Form Finding

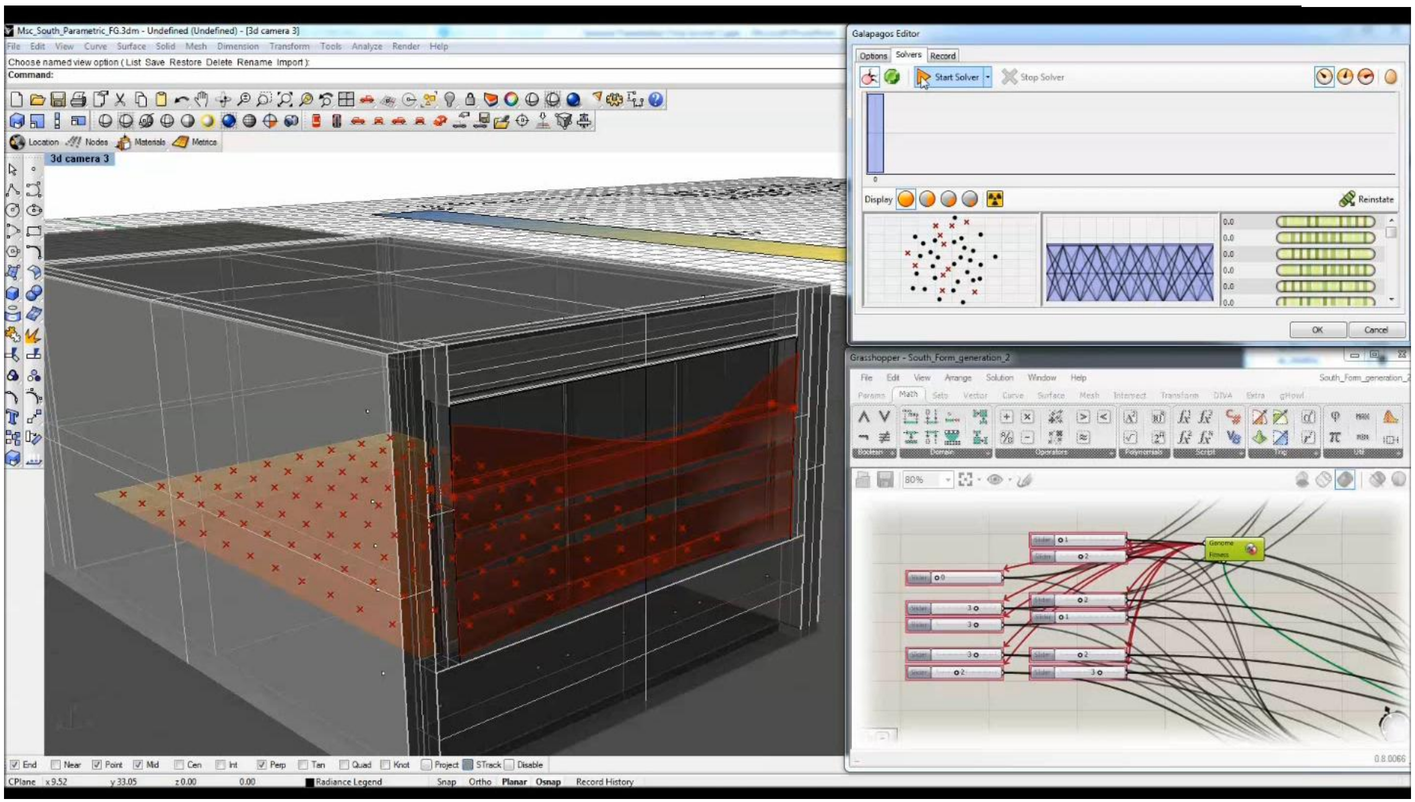
The façade was divided into upper part where a curved light shelf was modeled. In the lower part a free form configuration *"Gills surface"* divided into four curved panels. Total number of possible solutions exceeds 4 millions.



Variables for each curve

- Curve height

-Peak point position



Case 2: Form Finding

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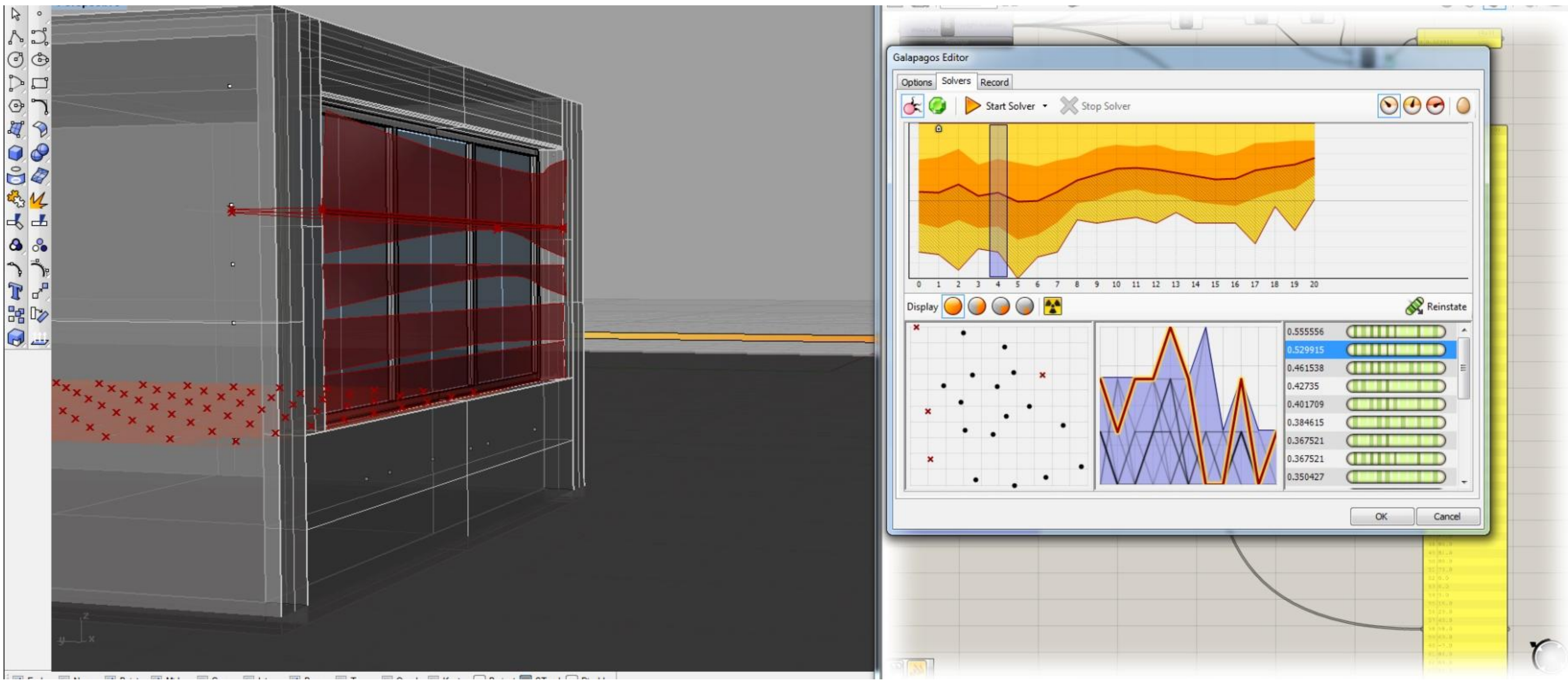
Variables for each curve

- Curve height

-Peak point position

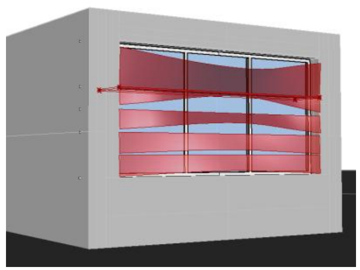


Case 2: Form Finding

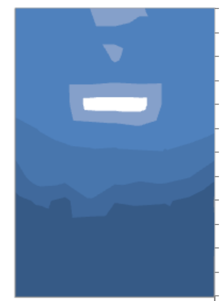
The façade was divided into upper part where a curved light shelf was modeled. In the lower part a free form configuration *"Gills surface"* divided into four curved panels. Total number of possible solutions exceeds 4 millions.

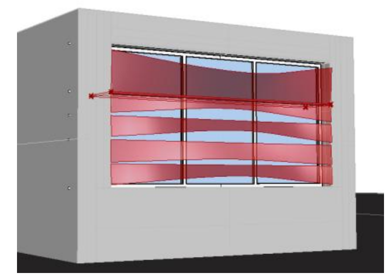
Variables for each curve
- Curve height
-Peak point position

56%
Daylit Area
2%
Overlit Area

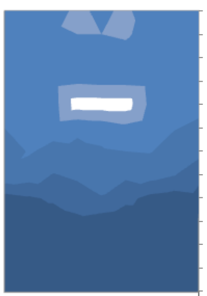


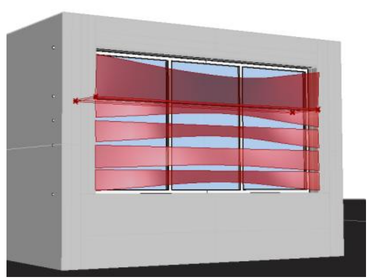
53%
Daylit Area
3%
Overlit Area





51%
Daylit Area
3%
Overlit Area





Future Work

Future Work

Research can extend to cover other environmental aspects to achieve an integrated high performance facades.
- Energy consumption/ Thermal comfort/ Natural ventilation/ Digital fabrication, paneling and structure aspects/ Life cycle cost

Investigating the use of dynamic and kinetic systems for more adaptive solutions and comparing the feasibility of dynamic systems and fixed systems may give a better guide for designing even more dynamic and higher performance facades.

-Finally, verification of the results of this study by real life measurements can strengthen the thesis recommendations.


THANK
YOU!