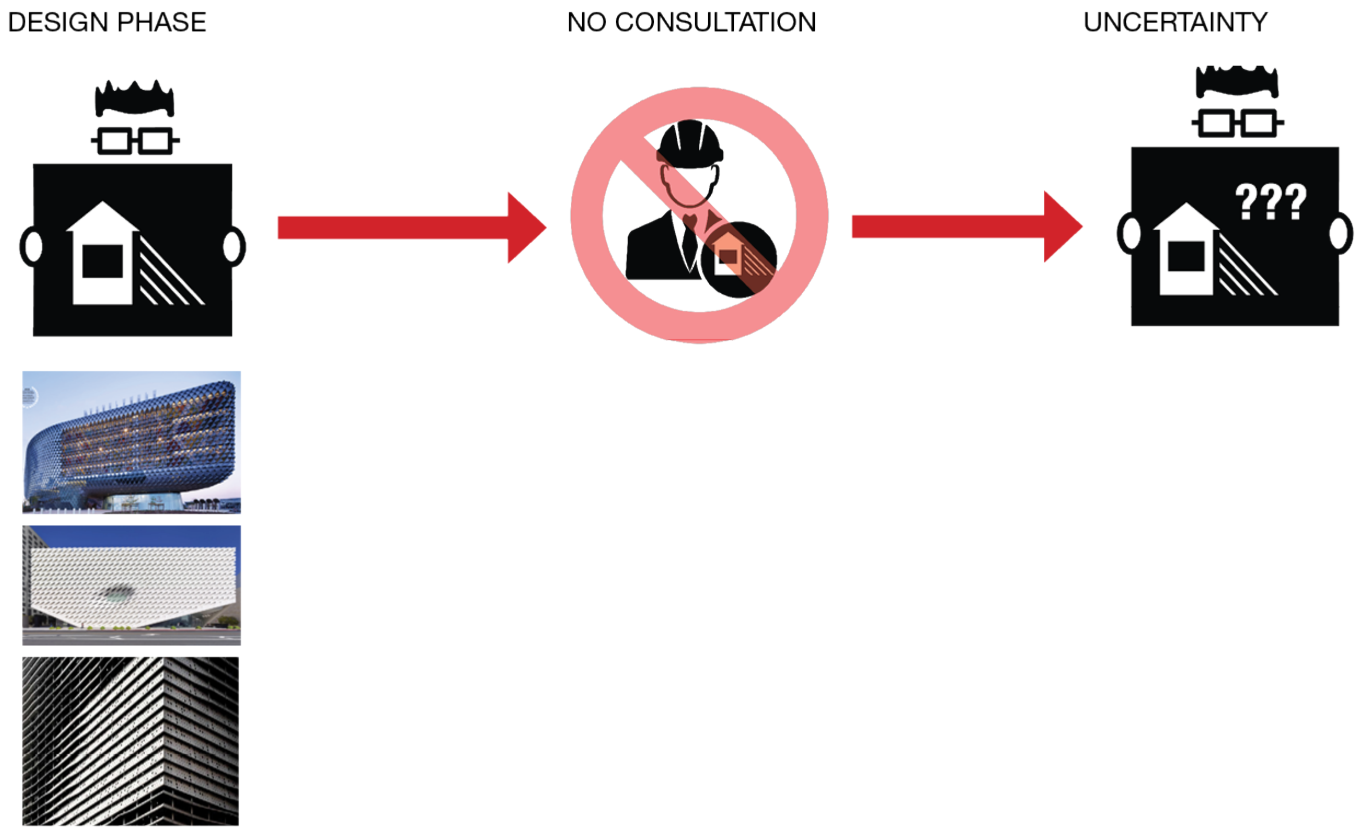
SHADING DESIGN WORKFLOW FOR ARCHITECTURAL DESIGNERS

Luis E. Lopez

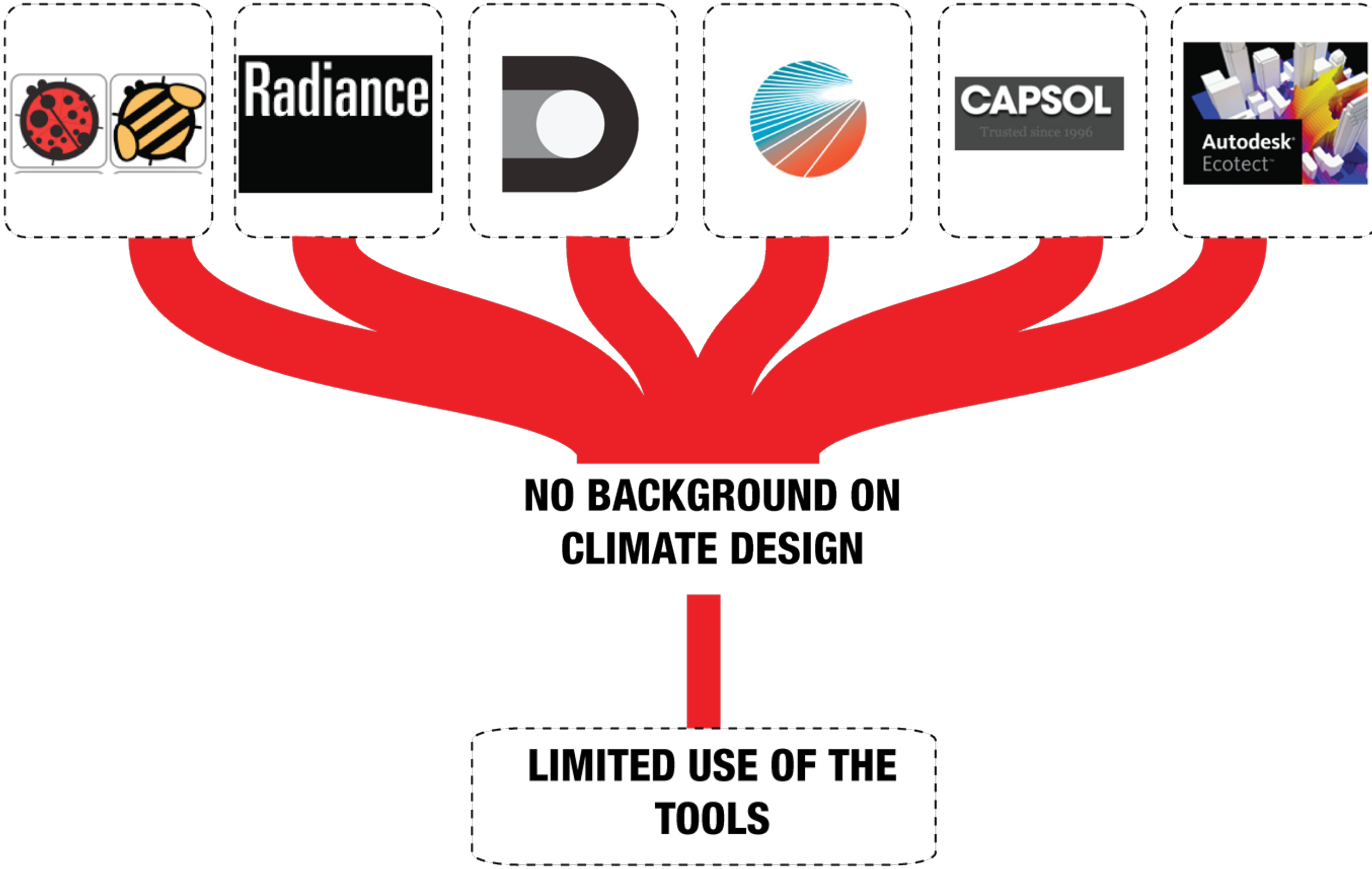
Mentors: Michela Turrin and Eric van den Ham

Motivation of the project

- Architects with **NO ACCESS TO CLIMATE SPECIALISTS** that can endorse their **SHADING DESIGNS**, therefore the **UNCERTAINTY ON PERFORMANCE** becomes an issue.

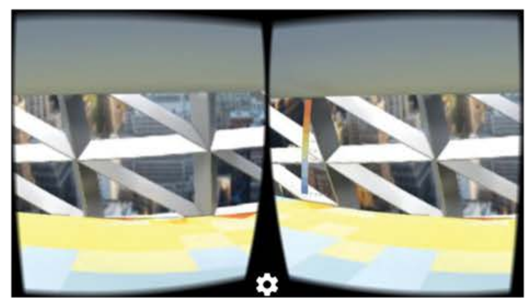


- Useful tools are available for designers to implement, the **LACK OF BACKGROUND** on the subject of climate **LIMITS THE USE OF THIS TOOLS** and their benefits.



- **CURRENTLY FORMS OF EXPLORATION IN ARCHITECTURAL DESIGN ARE EVOLVING**, and sustainability should not be left behind.

STATIC



PORTABILITY

INTERACTIVITY

WHAT?

WORKFLOW:

- Based on valid **INDICATORS**

- **DESIGN OBJECTIVES** - DAYLIGHT QUALITY and SOLAR GAIN

- With the use of a **FRIENDLY INTERFACE**

GOALS:

- Making **INFORMED DESIGN CHOICES**

- **USE OF VIRTUAL REALITY** as a form of exploration.

HOW?

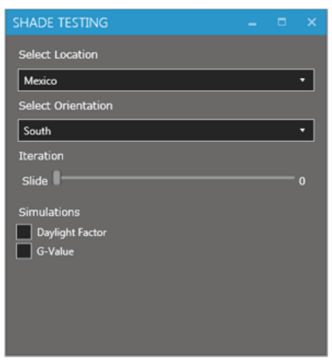
TOOLS

PARAMETRIC DESIGN TOOLS + DAYLIGHT AND ENERGY SIMULATORS + OPTIMIZATION TOOLS

METHOD

WORKFLOW

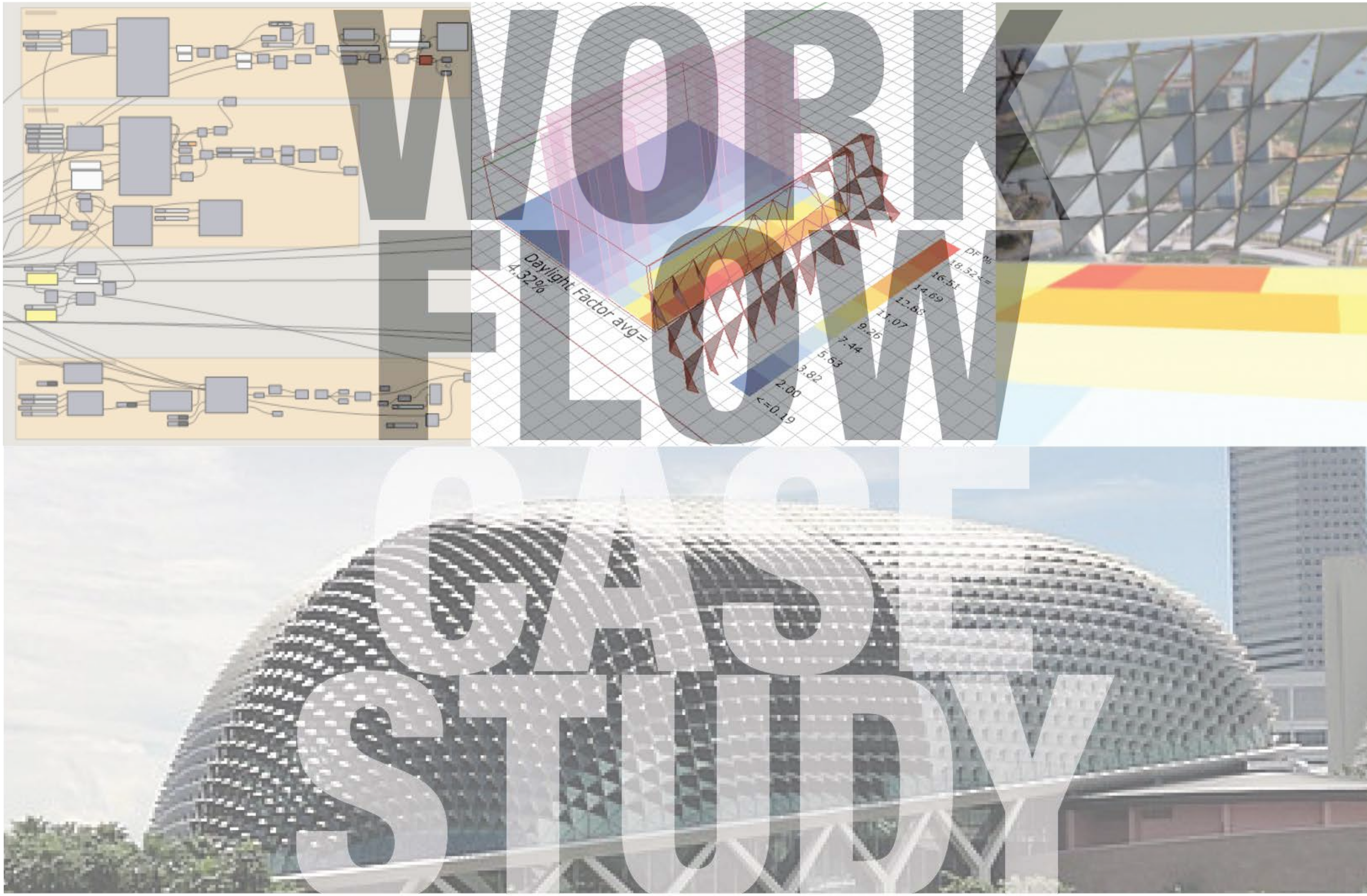
INTERFACE

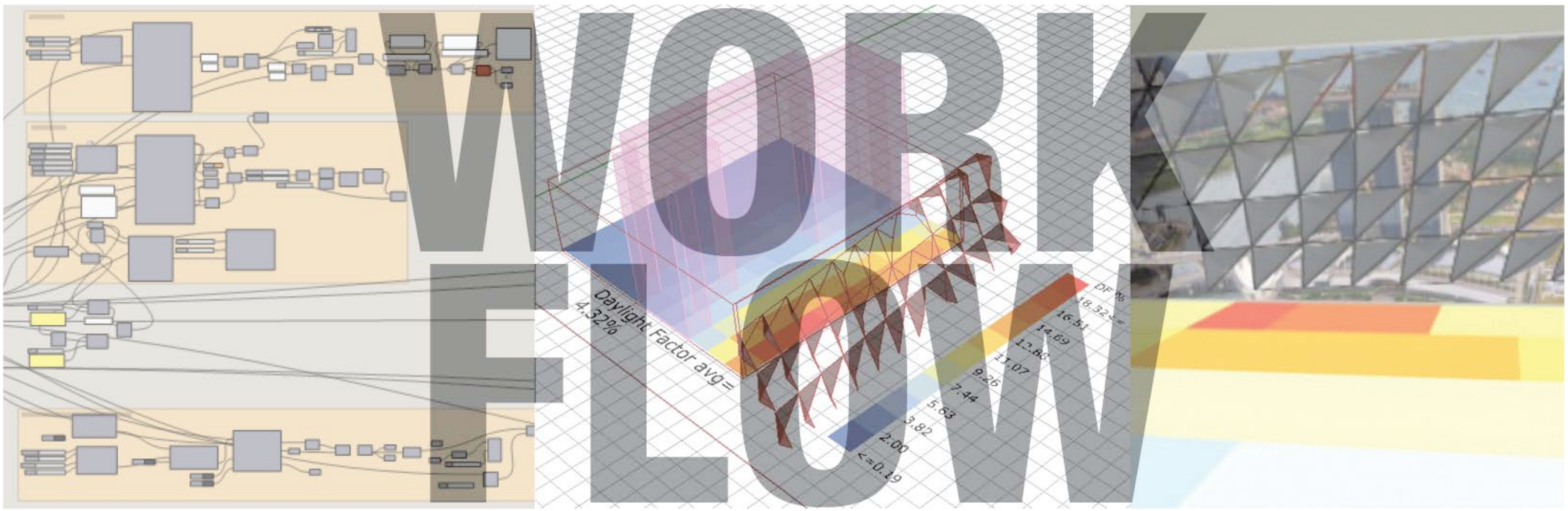


USER FRIENDLY INTERFACE

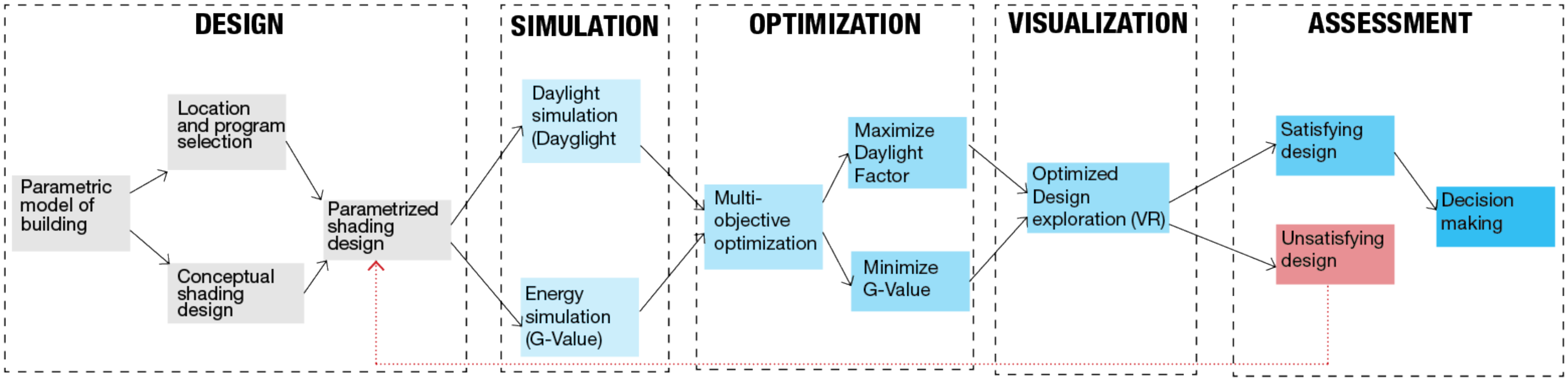
VIRTUAL REALITY

Focus of this presentation

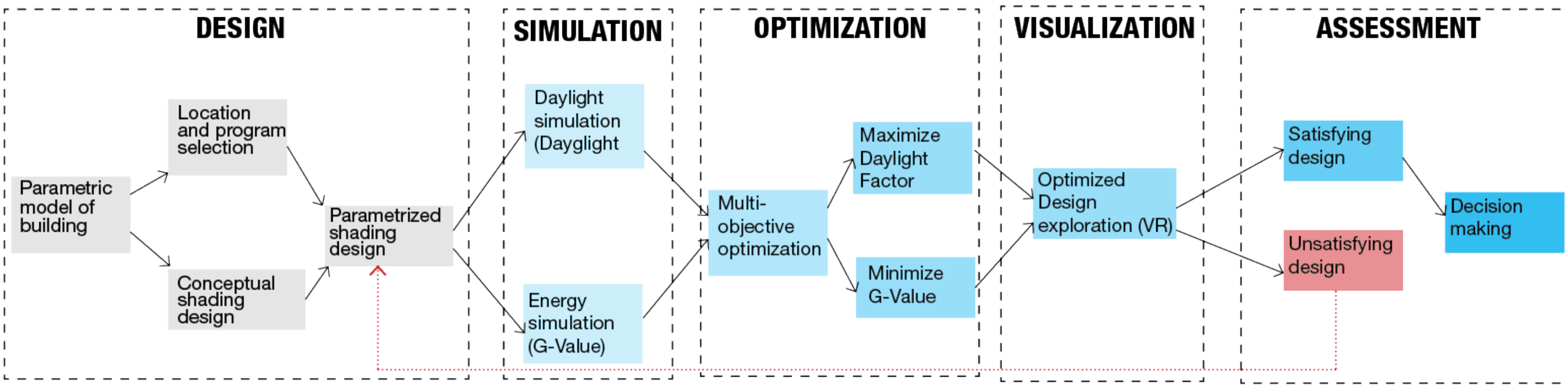



WORK
FLOW
Daylight Factor avg=
4.32%
DF %
18.52<=
16.51
14.69
12.88
11.07
9.26
7.44
5.63
3.82
2.00
<=0.19

WORKFLOW


DESIGN
SIMULATION
OPTIMIZATION
VISUALIZATION
ASSESSMENT
Parametric model of building
Location and program selection
Conceptual shading design
Parametrized shading design
Daylight simulation (Dayglight
Energy simulation (G-Value)
Multi-objective optimization
Maximize Daylight Factor
Minimize G-Value
Optimized Design exploration (VR)
Satisfying design
Unsatisfying design
Decision making

WORKFLOW



PARAMETRIC DESIGN ENVIRONMENT

Purpose:

-Building and shading design parametric modelling.

-Parametric tools for environmental simulations.

OPTIMIZATION SOFTWARE

Purpose:

-Multi-objective optimization process.

VR RENDER ENGINE

Purpose:
- Generating VR interface.

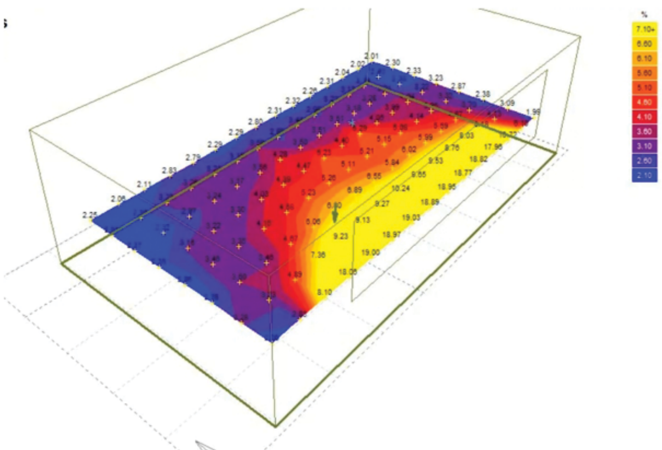
VR RENDER SIMULATOR

Purpose:
- Create an interactive an immersive experience for a designer as resource for design decision making.

INDICATORS

DAYLIGHT QUALITY

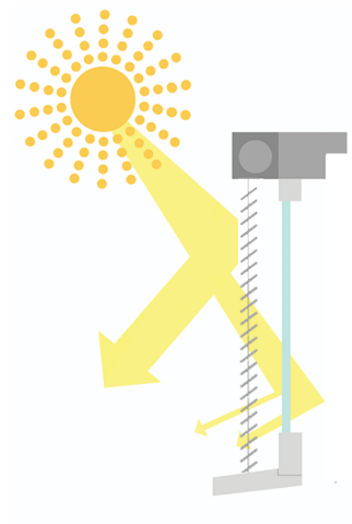
DAYLIGHT FACTOR



The use of this indicator is to inform about evenly natural light distribution on a room. It is measured through percentages.

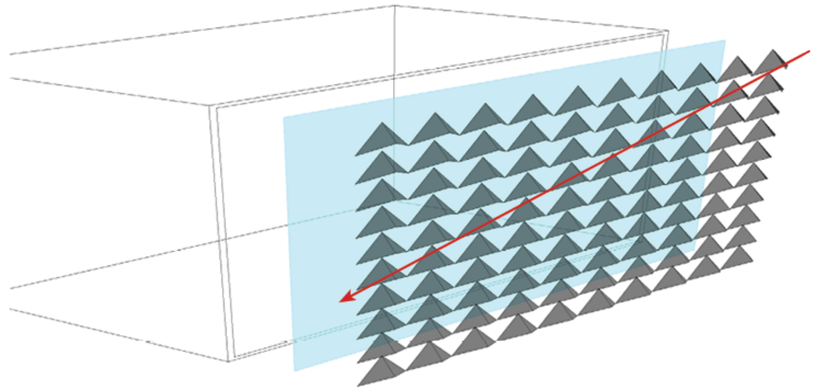
SOLAR GAIN

G-VALUE



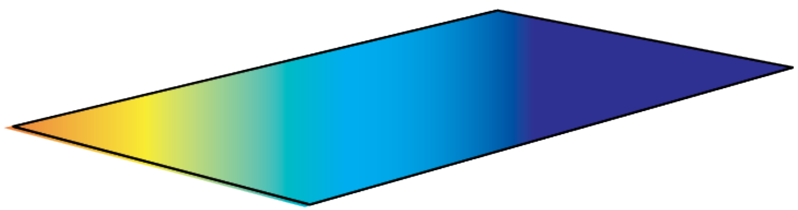
The purpose indicator is to demonstrate the reduction of the G-Value, the goal is to prove the effectiveness of a shading device, through an index resulting of a relation between the energy outside the room and the resulting infiltrated energy.

DESIGN OBJECTIVES



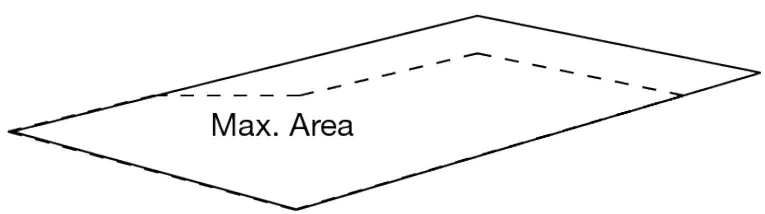
ENERGY

G-Value reduction factor



DAYLIGHT FACTOR

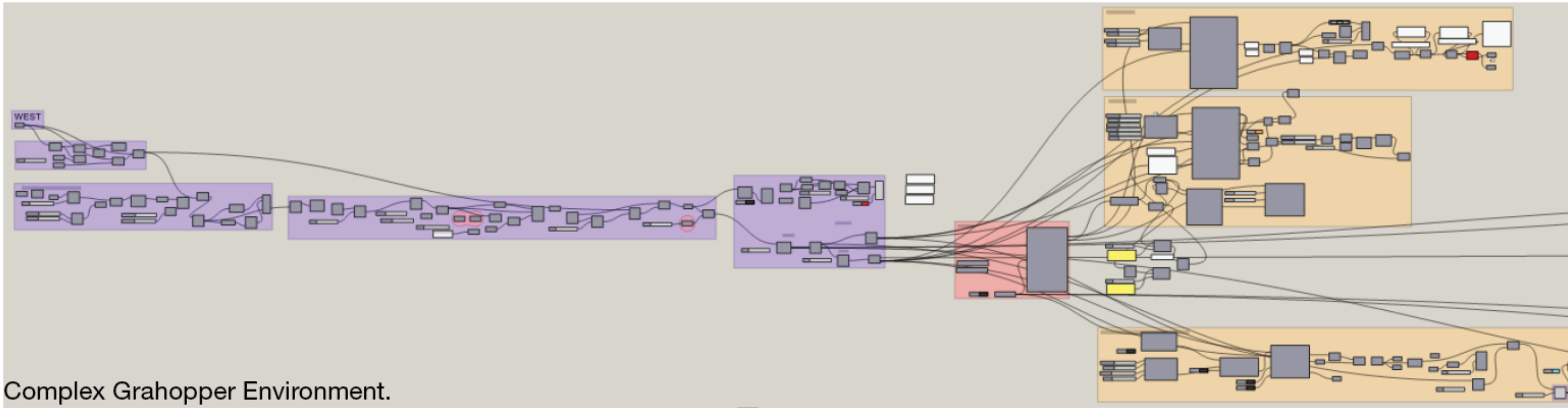
Maximize DF



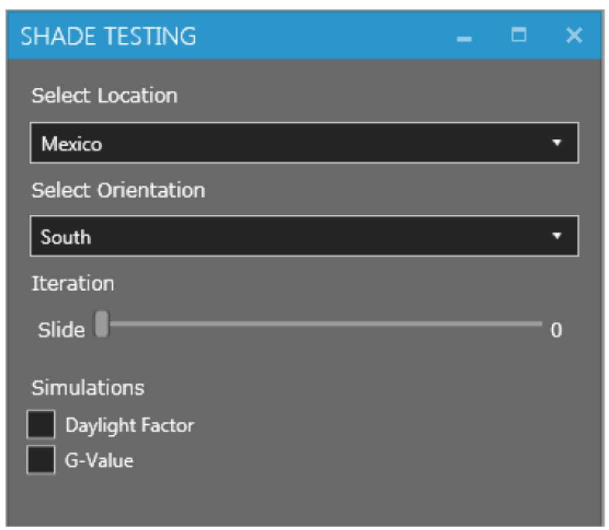
USEFUL AREA

Maximize the amount of usable space regarding the DF.

USER FRIENDLY INTERFACE



Complex Grahopper Environment.



Simplified User Friendly front-end environment.

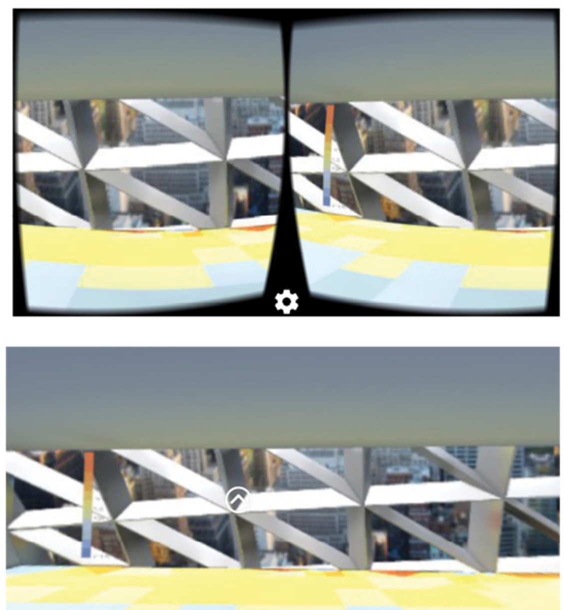
MAKING AN INFORMED DECISION

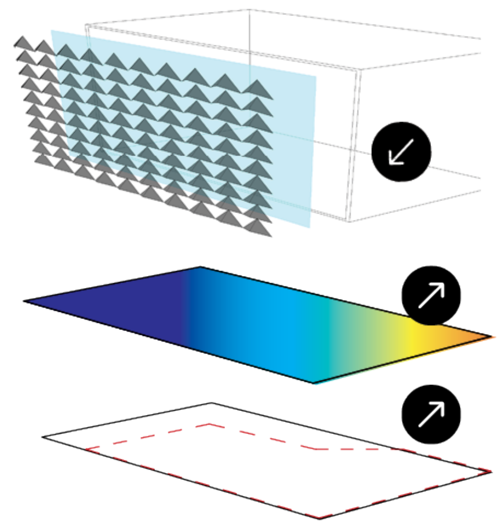
EXPLORING

Using VR to have a broader perspective of on the shading performance.

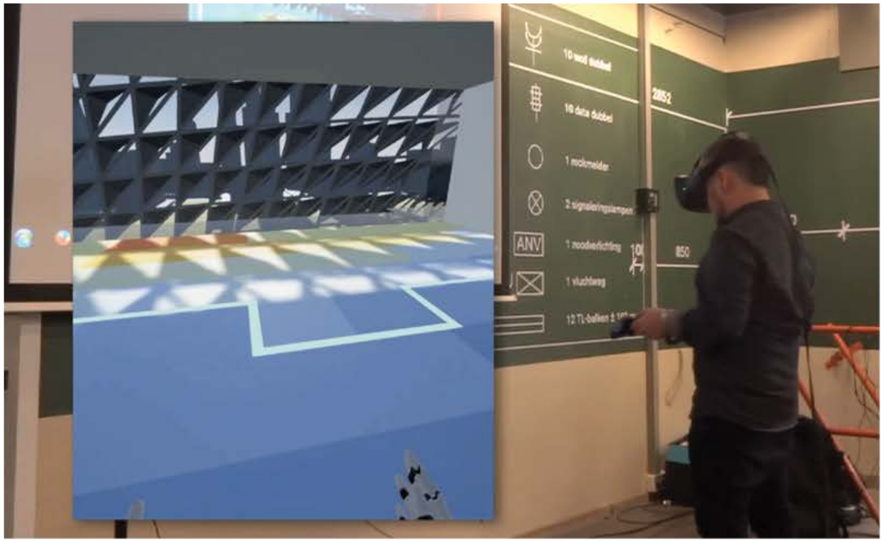
ASSESSMENT

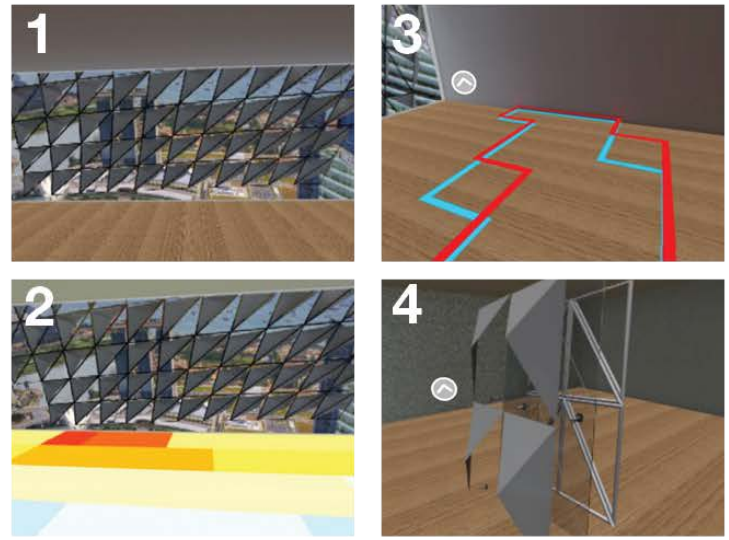
Through the observation and analysis of the results in the a VR environment. The user can support a decision or decide to make changes in the project.





USE OF VIRTUAL REALITY





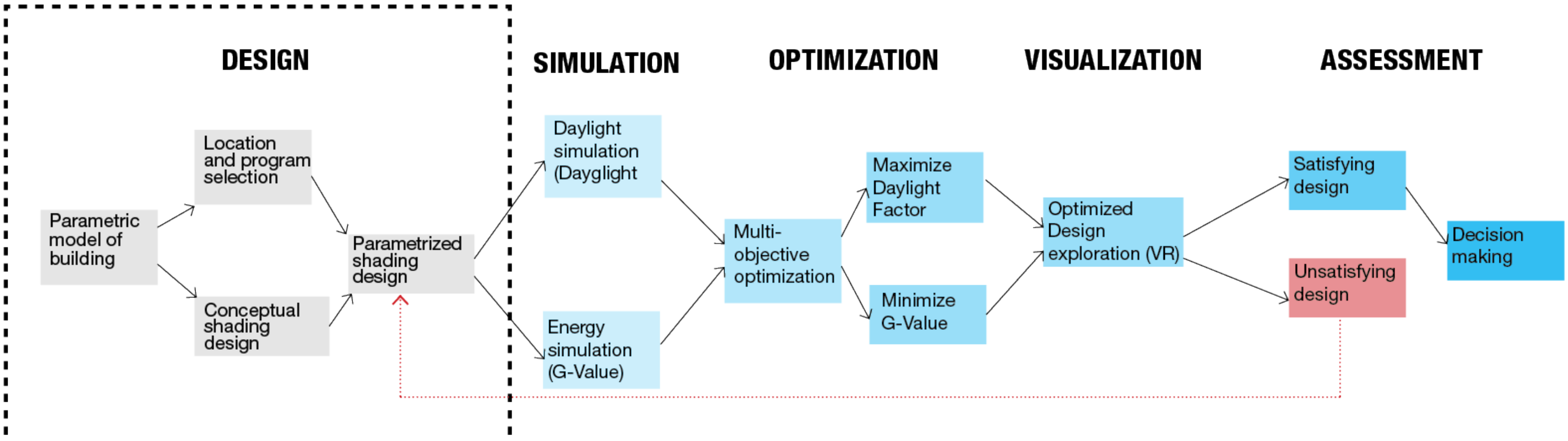
ADVANTAGES:

1. **Decision making** process is not only **supported by** analysis data and **user experience.**

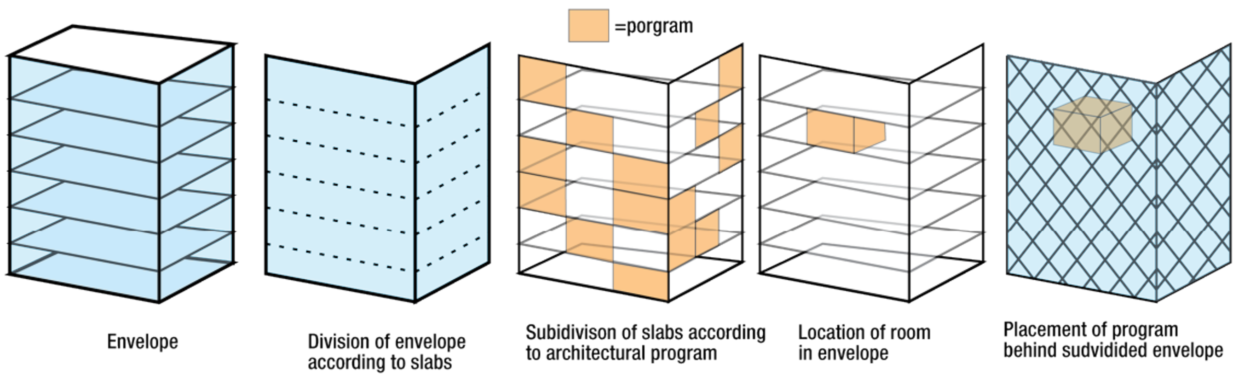
2. Possibility to **explore variations of results** and the effect of the indicators on a room in **real time**.

3. Exploration through **realistic point of view**.

4. **Visualization** and study of **detailed mock-ups** of shading device modules.


DESIGN
SIMULATION
OPTIMIZATION
VISUALIZATION
ASSESSMENT
Parametric model of building
Location and program selection
Conceptual shading design
Parametrized shading design
Daylight simulation (Dayglight
Energy simulation (G-Value)
Multi-objective optimization
Maximize Daylight Factor
Minimize G-Value
Optimized Design exploration (VR)
Satisfying design
Unsatisfying design
Decision making

DESIGN - Parametric model of building



1 - Model of envelope.
2 - Slab subdivisions generated in the envelope.
3 - Subdividing the slabs into a module(s) to fit the glass is part from the architectural program in the facade.
4 - Location of the architectural program in the envelope.
5 - Locate architectural program behind the window subdivision of the envelope.

DESIGN - Conceptual shading design

DESIGN ACCORDING TO ORIENTATION

OVERHANG

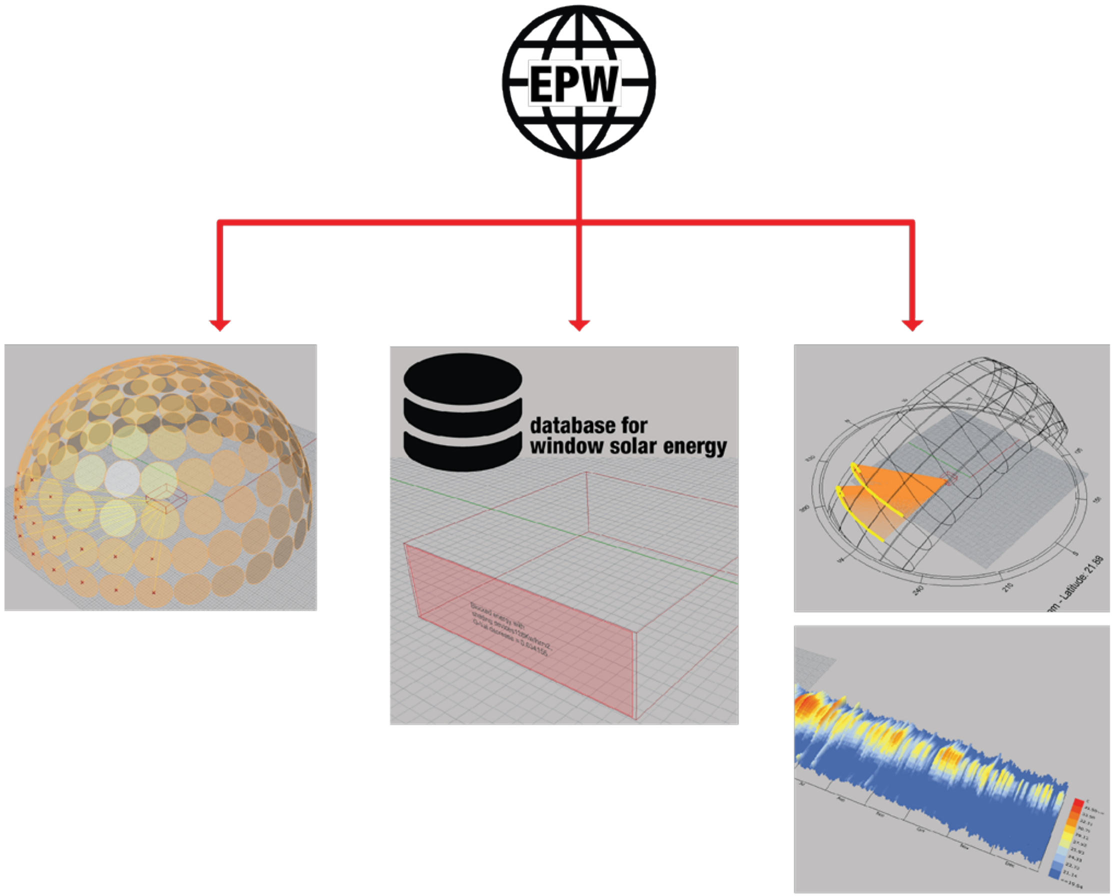
FINS

LOUVERS

EGGCRATE

AWNINGS

DESIGN - Location and program selection

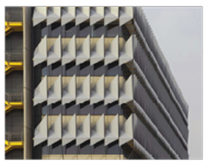


1- The Tergenza dome > Daylight factor
2 - Energy flow and window total energy > G-Value
3 - Sunpath and drybulb temperature graph > Ray-tracing

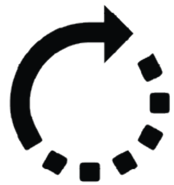
DESIGN - Parametric Shading Design

SHADING PARAMETERS

DESIGN ACCORDING ORIENTATION

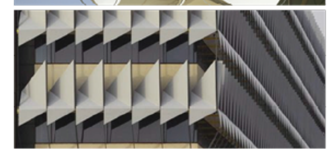


PERFORMANCE FUNCTIONALITIES



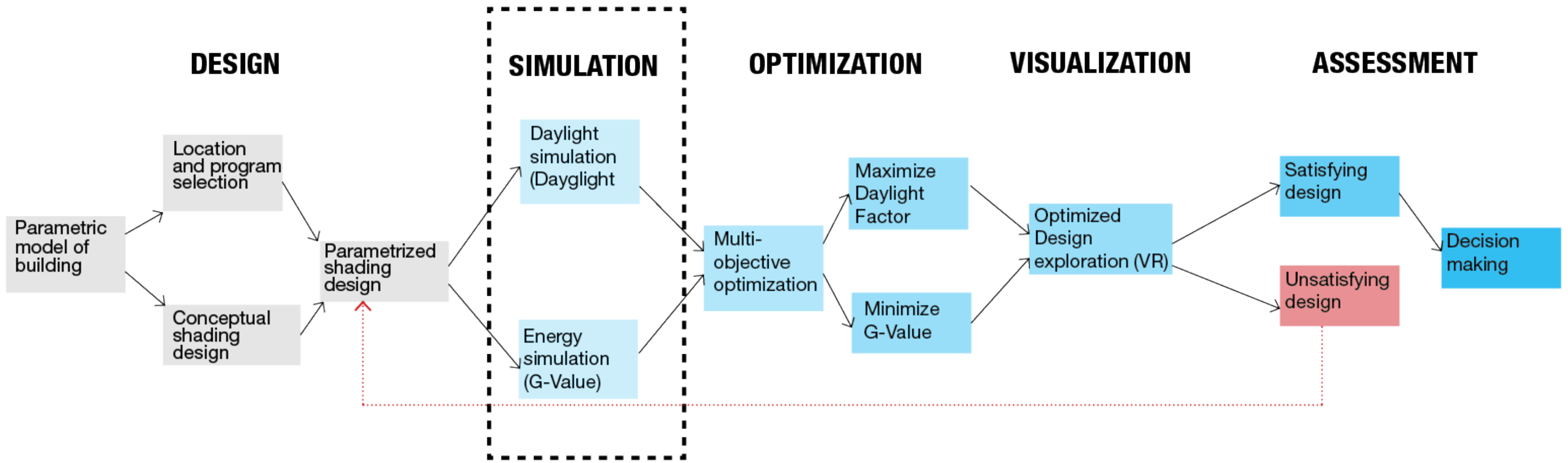
SIMULATION PARAMETERS

MATERIAL



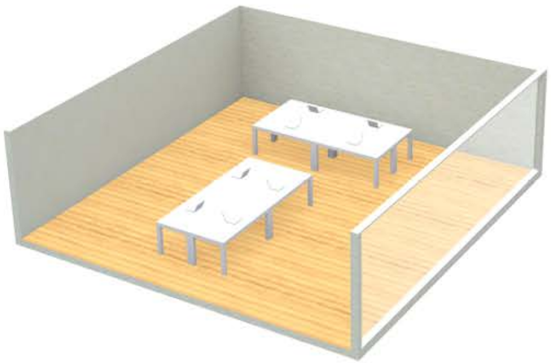
COLOR

DESIGN | SIMULATION | OPTIMIZATION | VISUALIZATION | ASSESSMENT

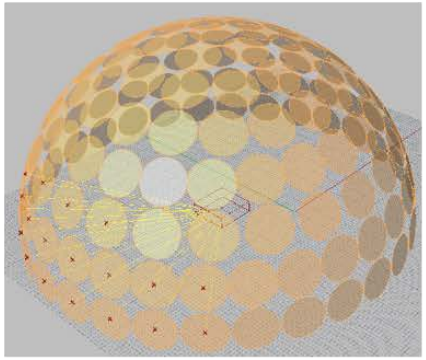

DESIGN
SIMULATION
OPTIMIZATION
VISUALIZATION
ASSESSMENT
Parametric model of building
Location and program selection
Conceptual shading design
Parametrized shading design
Daylight simulation (Dayglight
Energy simulation (G-Value)
Multi-objective optimization
Maximize Daylight Factor
Minimize G-Value
Optimized Design exploration (VR)
Satisfying design
Unsatisfying design
Decision making

SIMULATION - Daylight simulation

MODEL ROOM

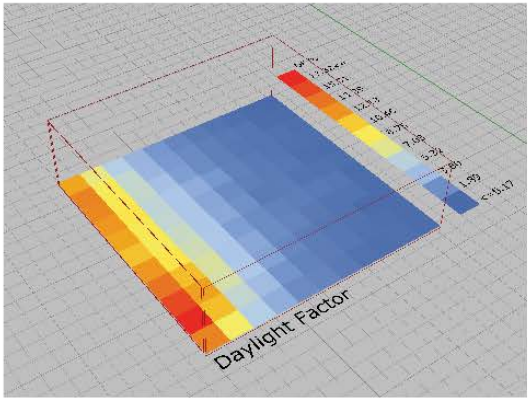


SIMULATION

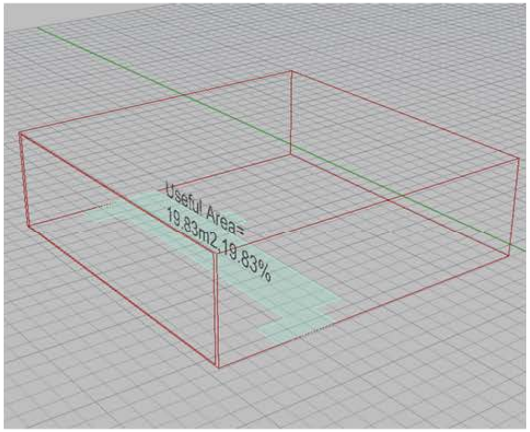


Daylight simulation recipe:
Based on Radiance Material Library

RESULTS



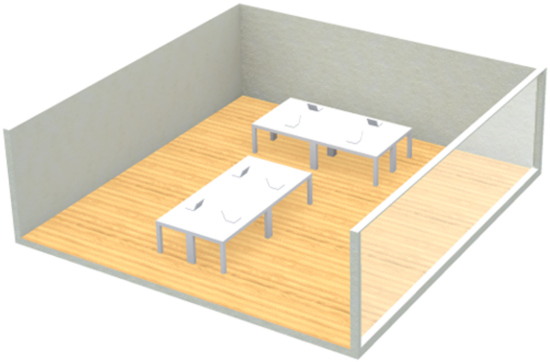
DAYLIGHT FACTOR GRID



USEFUL AREA

SIMULATION - Energy simulation

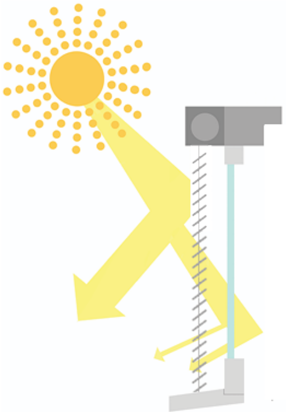
MODEL ROOM



SIMULATION

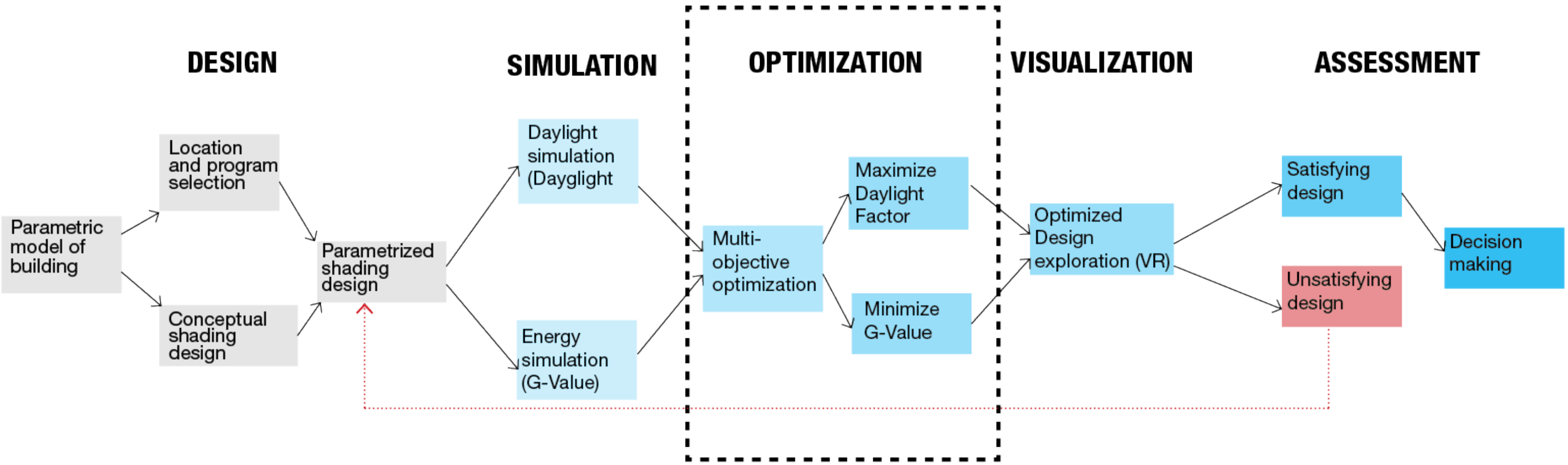
Energy simulation recipe:
Based on ASHRAE code library material

RESULTS



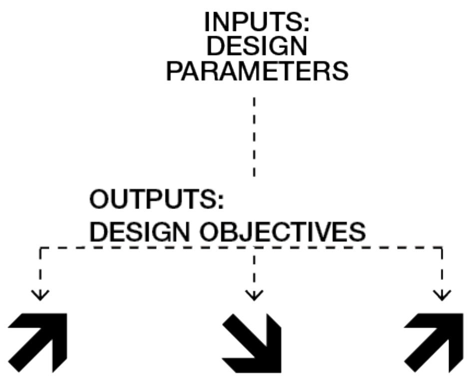
G-VALUE

DESIGN	SIMULATION	OPTIMIZATION	VISUALIZATION	ASSESSMENT

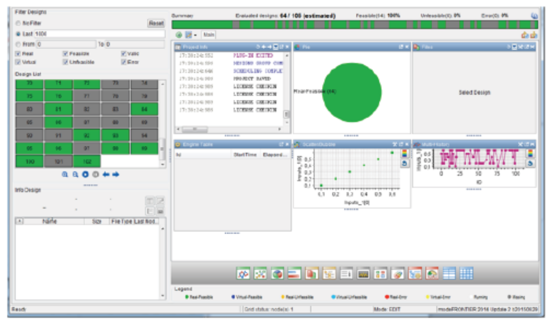

DESIGN
SIMULATION
OPTIMIZATION
VISUALIZATION
ASSESSMENT
Parametric model of building
Location and program selection
Conceptual shading design
Parametrized shading design
Daylight simulation (Dayglight
Energy simulation (G-Value)
Multi-objective optimization
Maximize Daylight Factor
Minimize G-Value
Optimized Design exploration (VR)
Satisfying design
Unsatisfying design
Decision making

OPTIMIZATION - Multiobjective optimization

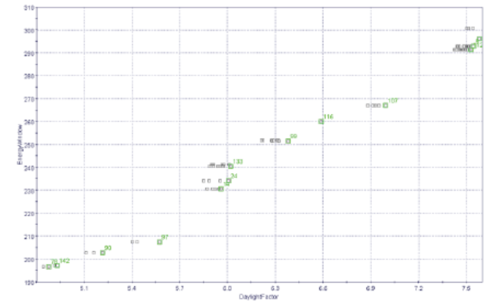
OPTIMIZATION MAP

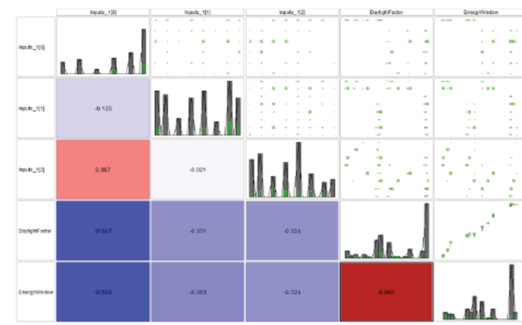


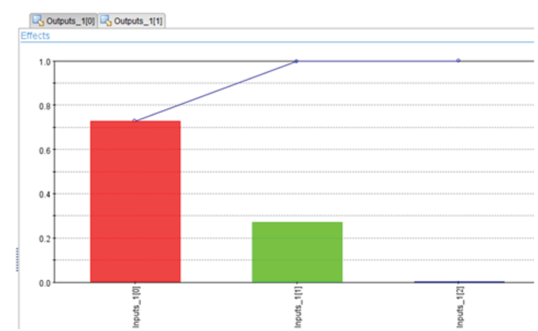
PROCESS



RESULTS

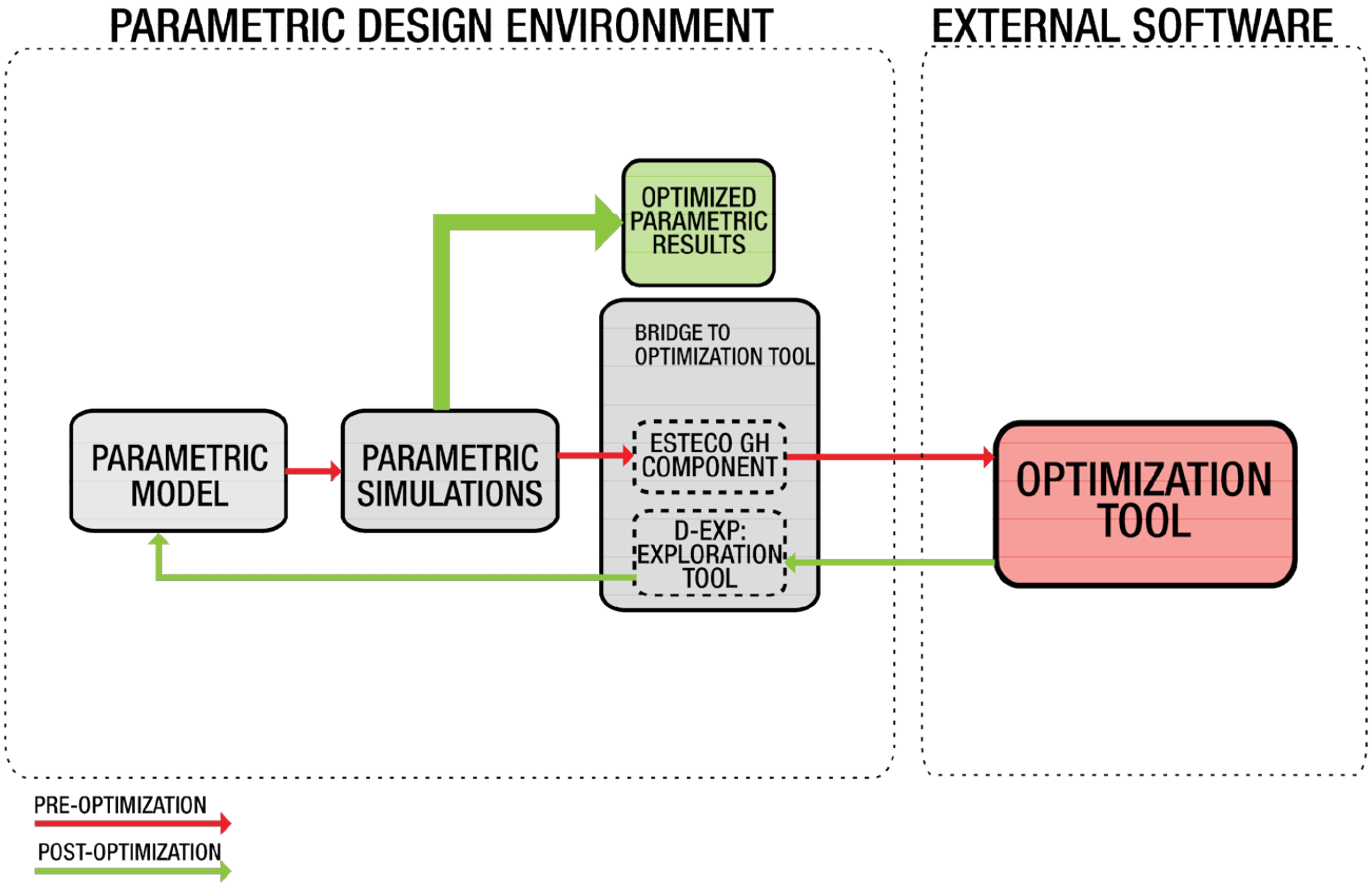




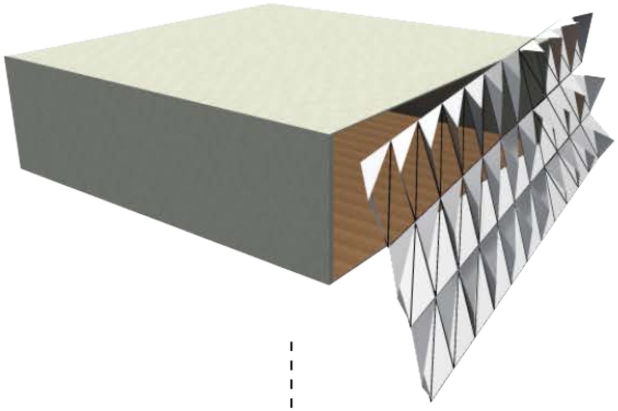


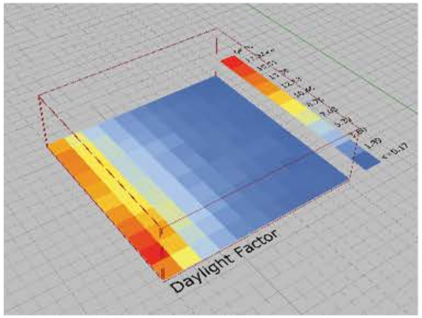
DESIGN | SIMULATION | OPTIMIZATION | VISUALIZATION | ASSESSMENT

OPTIMIZATION - Process for parametric optimization

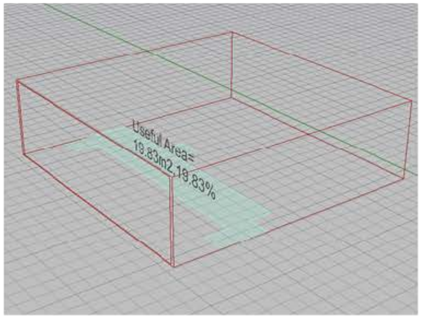


OPTIMIZATION - Results for optimization in 3D

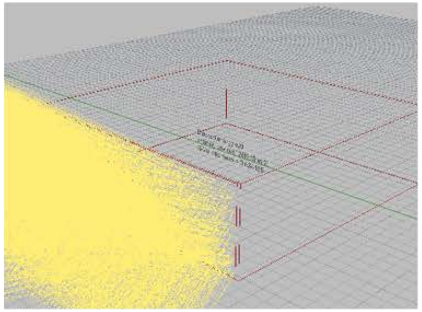




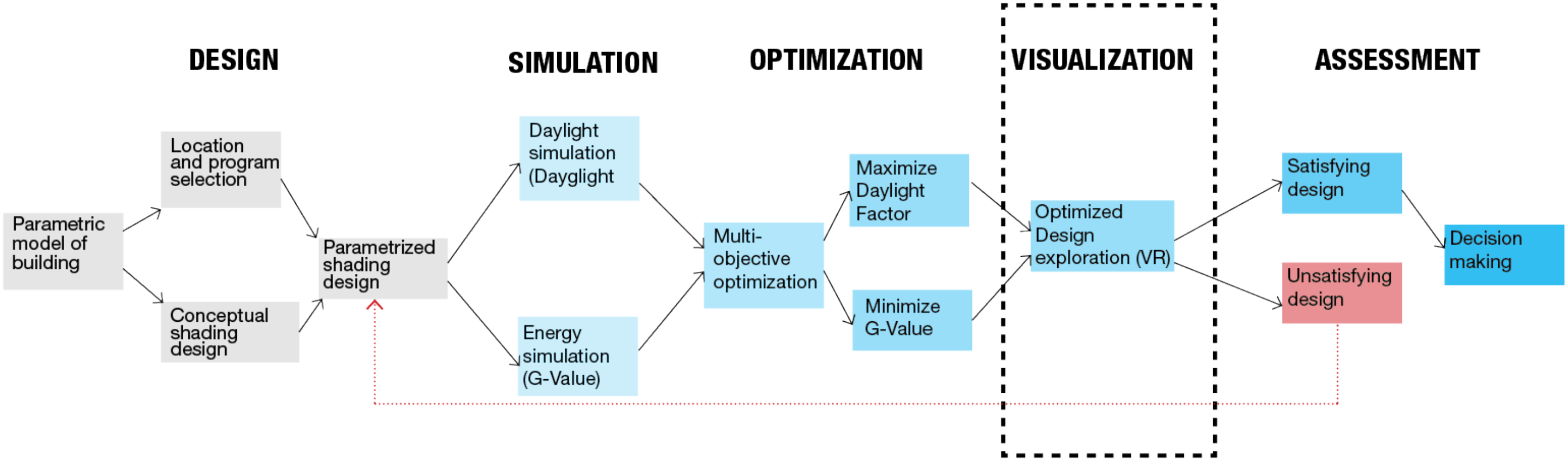
DAYLIGHT FACTOR



USEFUL AREA



G-VALUE

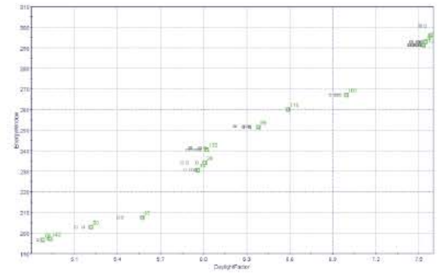
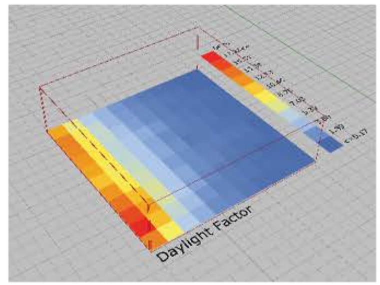

DESIGN
SIMULATION
OPTIMIZATION
VISUALIZATION
ASSESSMENT
Parametric model of building
Location and program selection
Conceptual shading design
Parametrized shading design
Daylight simulation (Dayglight
Energy simulation (G-Value)
Multi-objective optimization
Maximize Daylight Factor
Minimize G-Value
Optimized Design exploration (VR)
Satisfying design
Unsatisfying design
Decision making

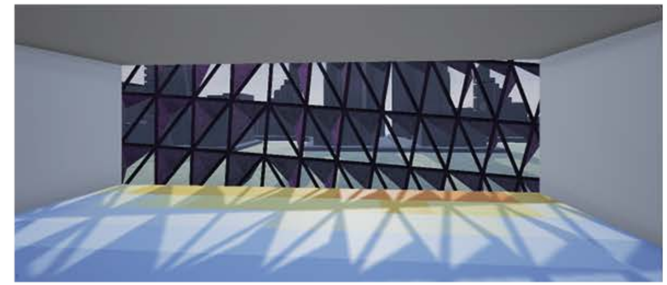
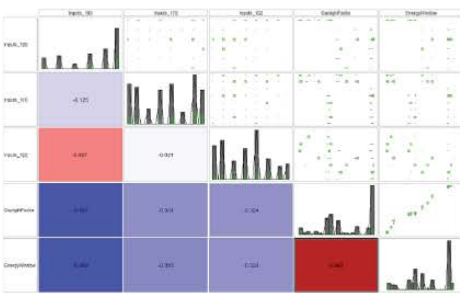
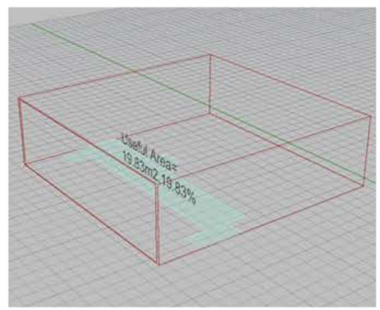
VISUALIZATION - Optimized result exploration

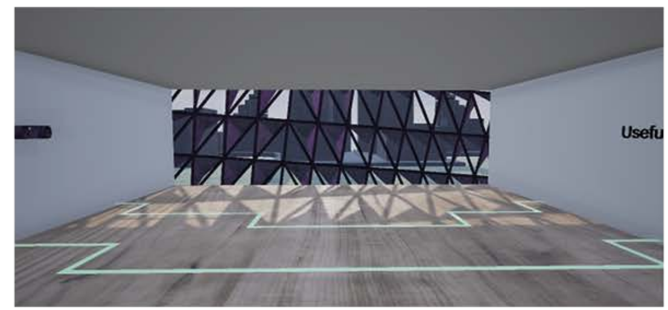
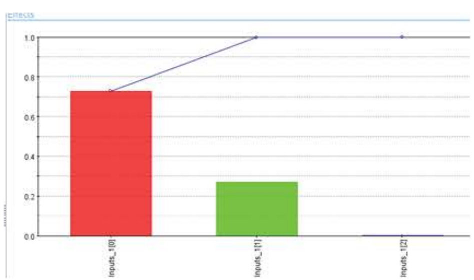
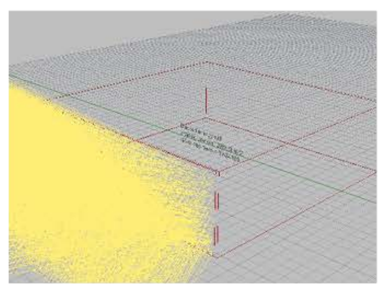
STATISTICAL

THREE-DIMENSIONAL

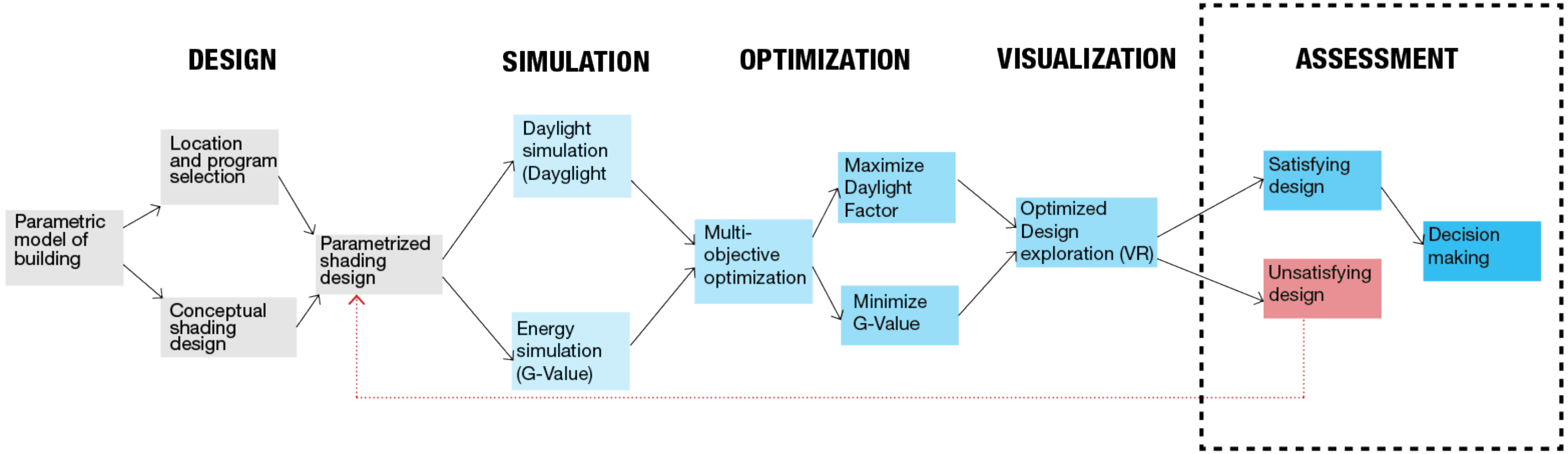
IMMERSIVE

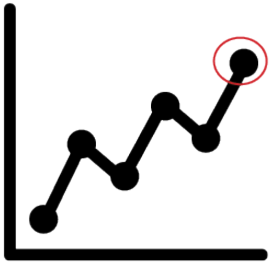





DESIGN | SIMULATION | OPTIMIZATION | VISUALIZATION | ASSESSMENT

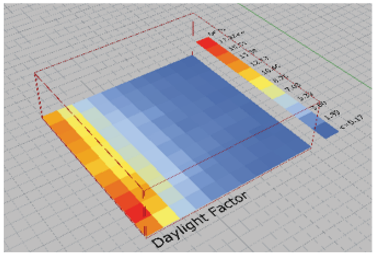

DESIGN
SIMULATION
OPTIMIZATION
VISUALIZATION
ASSESSMENT
Parametric model of building
Location and program selection
Conceptual shading design
Parametrized shading design
Daylight simulation (Dayglight
Energy simulation (G-Value)
Multi-objective optimization
Maximize Daylight Factor
Minimize G-Value
Optimized Design exploration (VR)
Satisfying design
Unsatisfying design
Decision making

ASSESSMENT

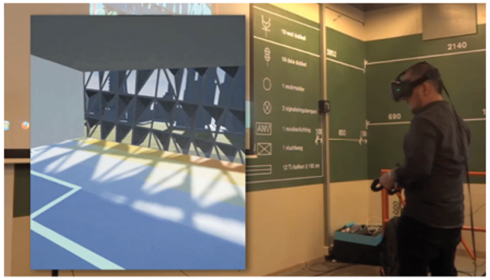
Three levels of a discarding process will help the user decide which optimized results will be explored with Virtual Reality.



1. Level 1: Analysis and selection of post optimization results, directly from the statistical data presented from the optimization tool, that best suit the design objectives.

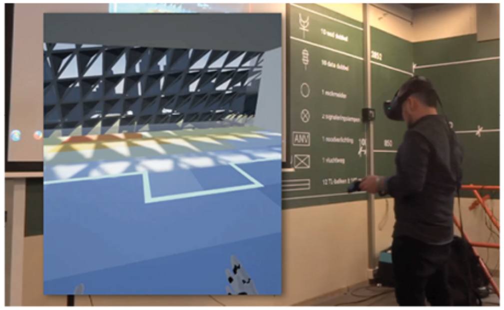


2. Level 2: The selected sample of results, are submitted to the daylight and energy simulation software in order to retrieve the 3-D models for the pre visualizations of the optimized results. Through visual and analytical process it will be determined which of the optimized results work better according to the model room and the design objectives.



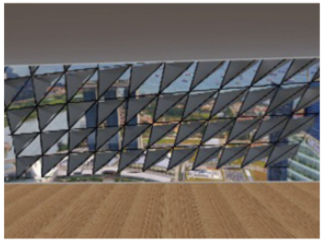
3. Level 3: Selected results from level 2 can be analysed in deep detail through post optimization features through Virtual Reality, with immersive exploration giving a deeper insight that will have the added value of experience.

ASSESSMENT

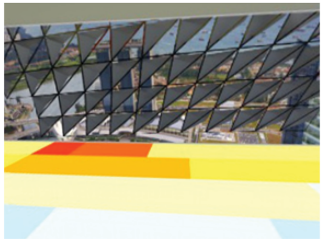


What is expected from the added value of **VR** is:

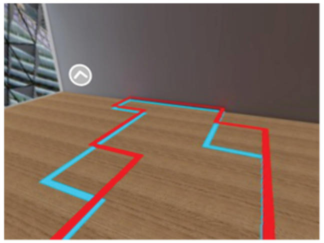
EXPERIENCE with
DIRECT FEEDBACK on
DESIGN DECISIONS.



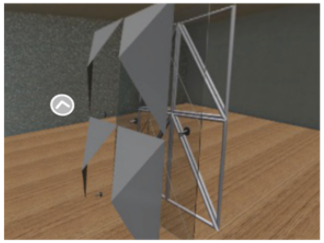
Comparison of the visual qualities between different design results.



Visualization of daylight distribution of different results through the Daylight factor grid.



Comparison of resulting Usable Areas.



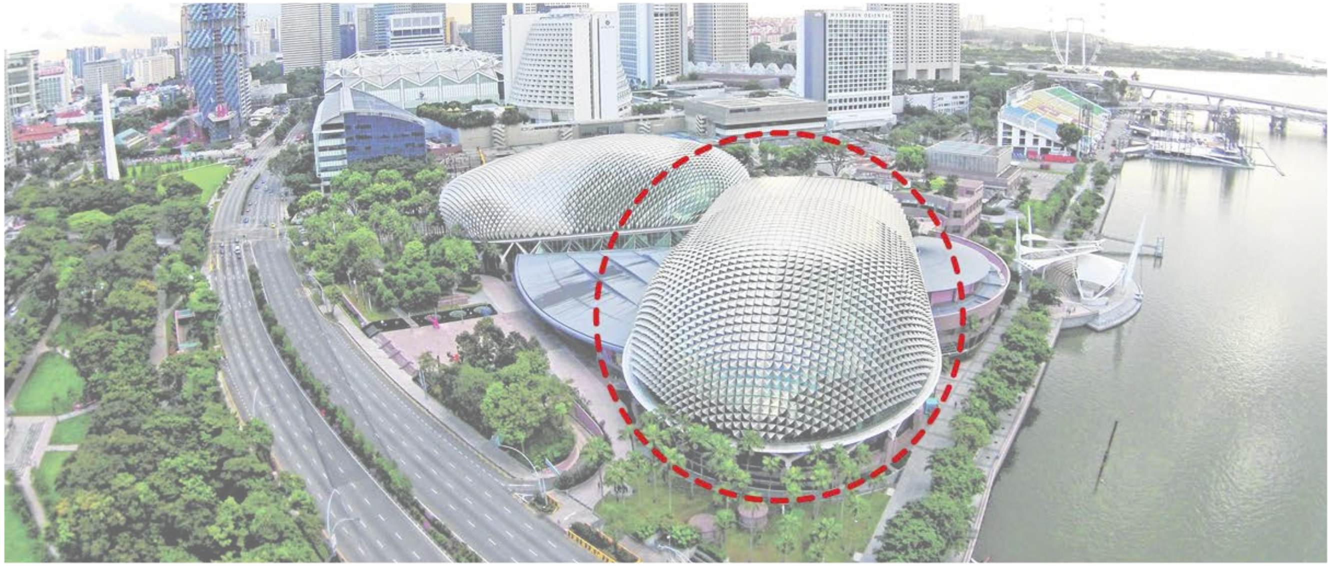
Exploration and interaction with 1:1 detail models of the shading devices.


CASE
STUDY

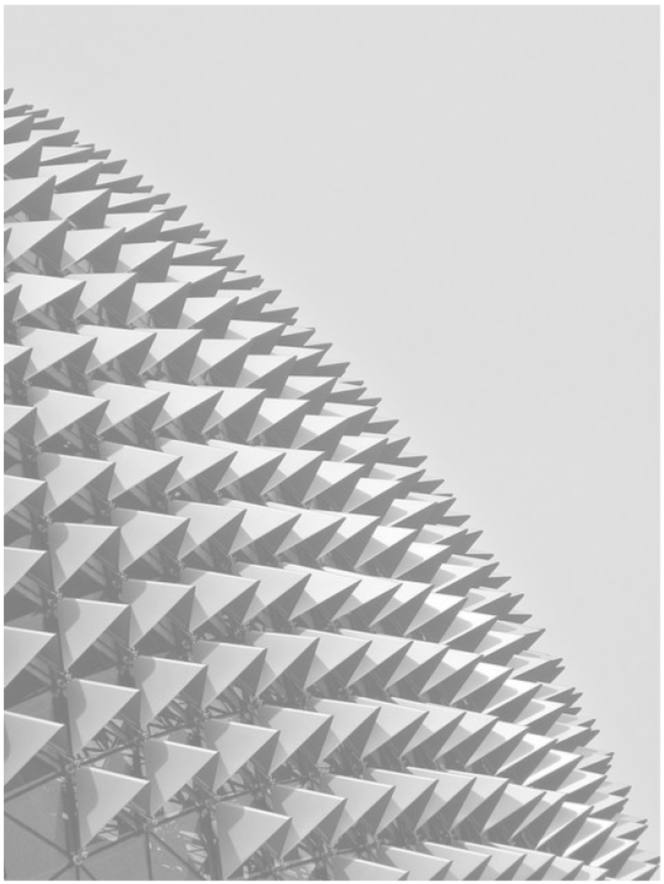
CASE STUDY - The Esplande (Singapore Opera House)

CLIMATE ZONE:
1-A
VERY HOT AND HUMID

CASE STUDY



CASE STUDY - Background



Total of shading devices: **7140**
Shading devices in Lyric Theatre: **3840**
Shading devices in Concert Hall: **3300**

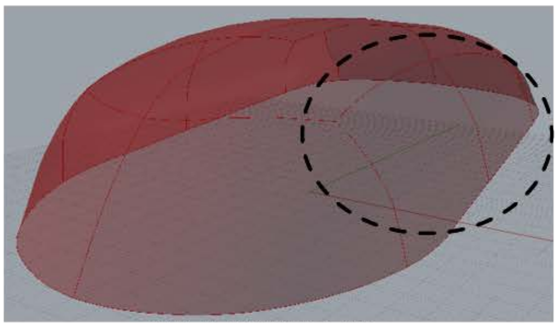
Estimated time to accomplish the analysis: **18 months**

Design objectives: **Maximum shading**

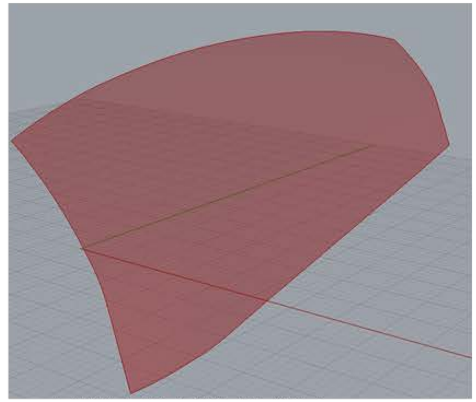
Climatic indicators taken into account: **None**

Total of customized designs: **12**

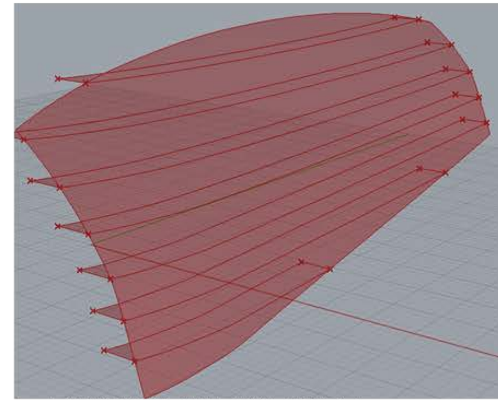
DESIGN - Parametric model of building



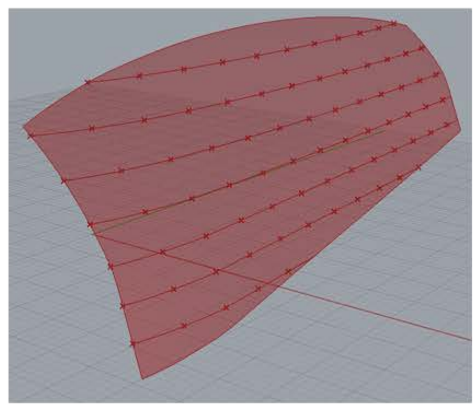
ENVELOPE MODEL



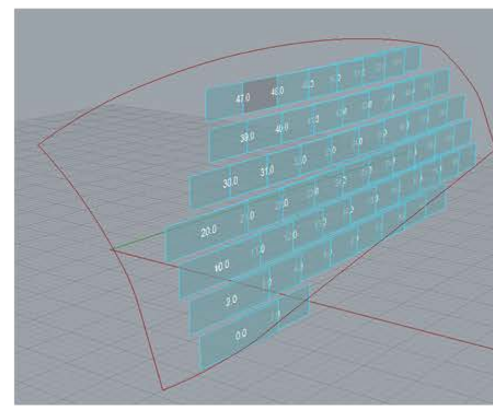
ENVELOPE SECTION



DIVISION OF ENVELOPE ACCORDING TO MODEL ROOM EXPECTED HEIGHT

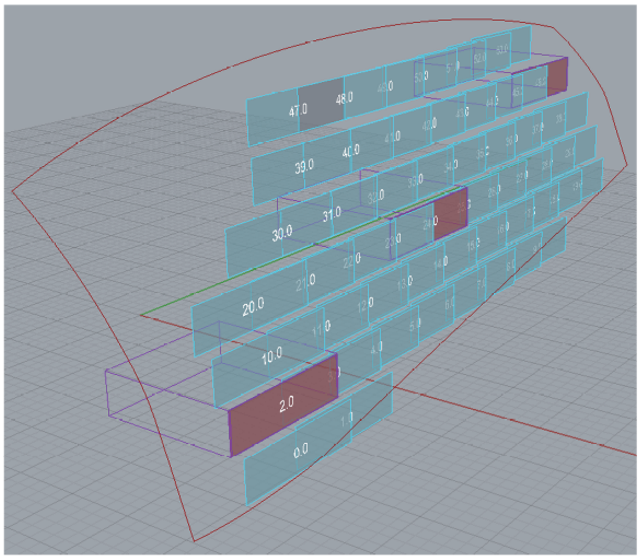


POSSIBLE OF POSITION OF MODEL ROOMS IN ENVELOPE

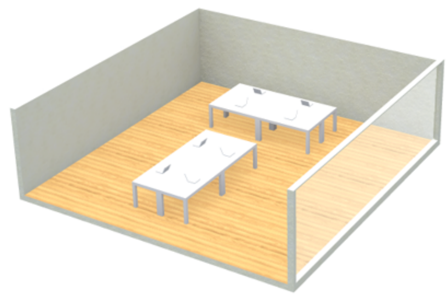


LOCATIONS IN ENVELOPE OF MODEL ROOMS ACCORDING TO THE ENVELOPE GEOMETRY

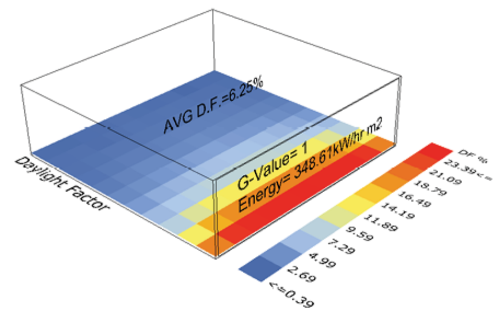
DESIGN - Reference point



MODEL ROOM SELECTION

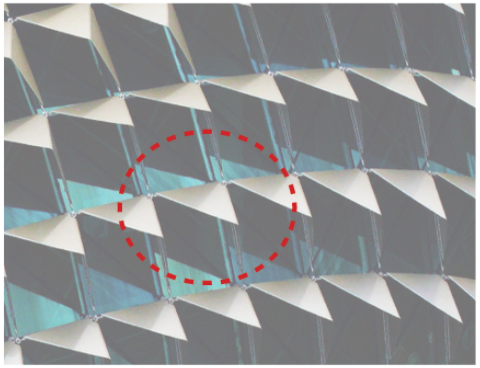


ROOMS WITH NO SHADING

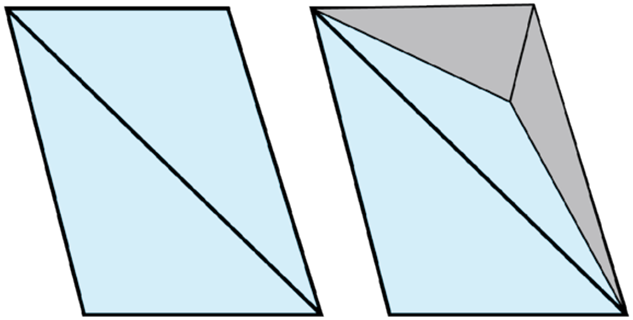


AVG. DAYLIGHT FACTOR = 6.25%
G-Value = 1
Energy infiltrating = 349 kW/hr m2

DESIGN - Conceptual Shading Design



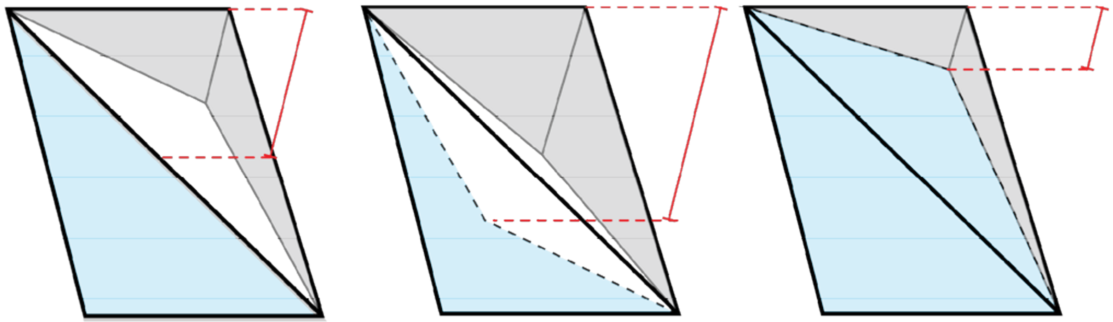
SHADING SAMPLE



BASIC SHADING MODULE

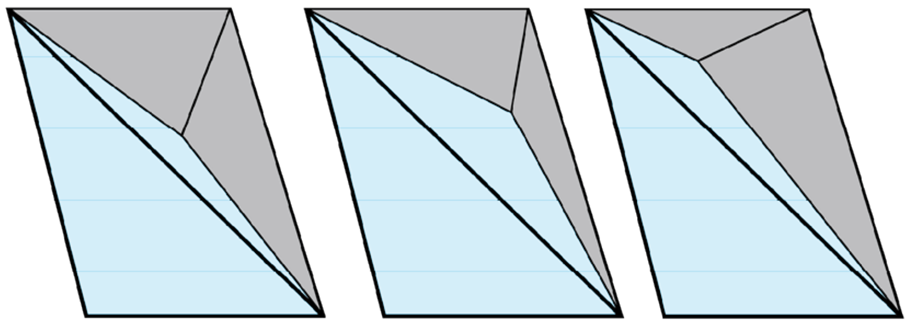
DESIGN - Design parameters

VISIBILITY



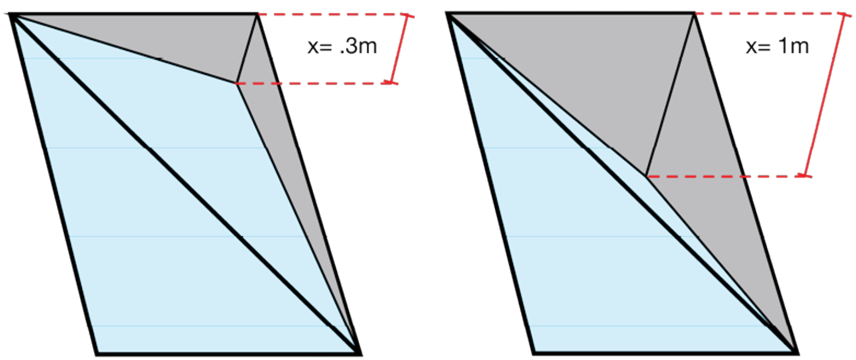
Mean visibility 50% | Miminum visibility 25% | Maximum visibility 70%

HEIGHT VARIATION

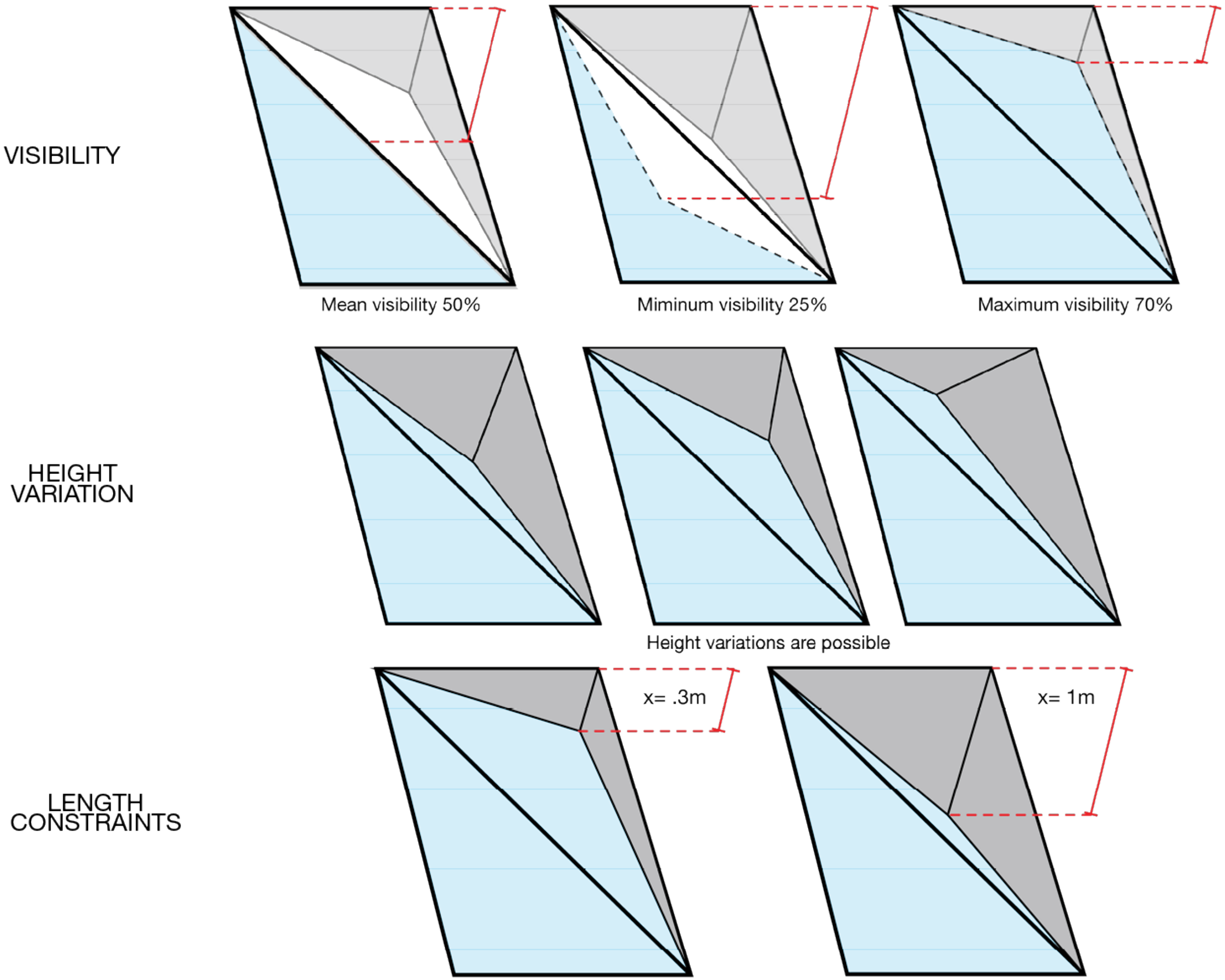


Height variations are possible

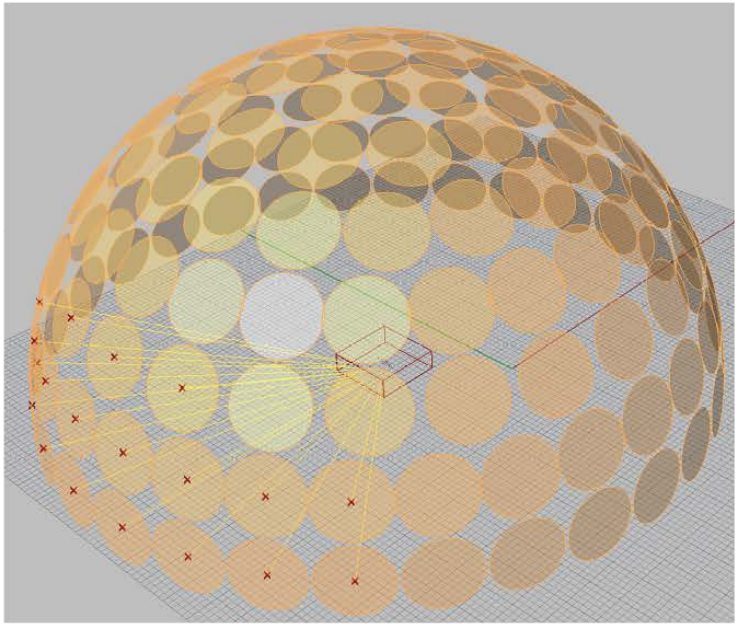
LENGTH CONSTRAINTS



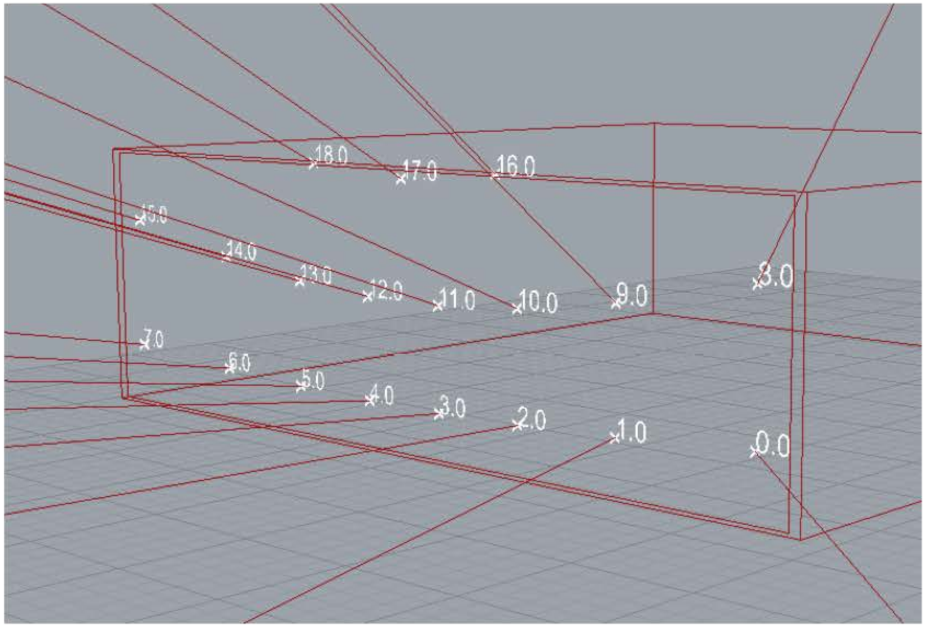
DESIGN - Design parameters



DESIGN - Parametric Shading Design



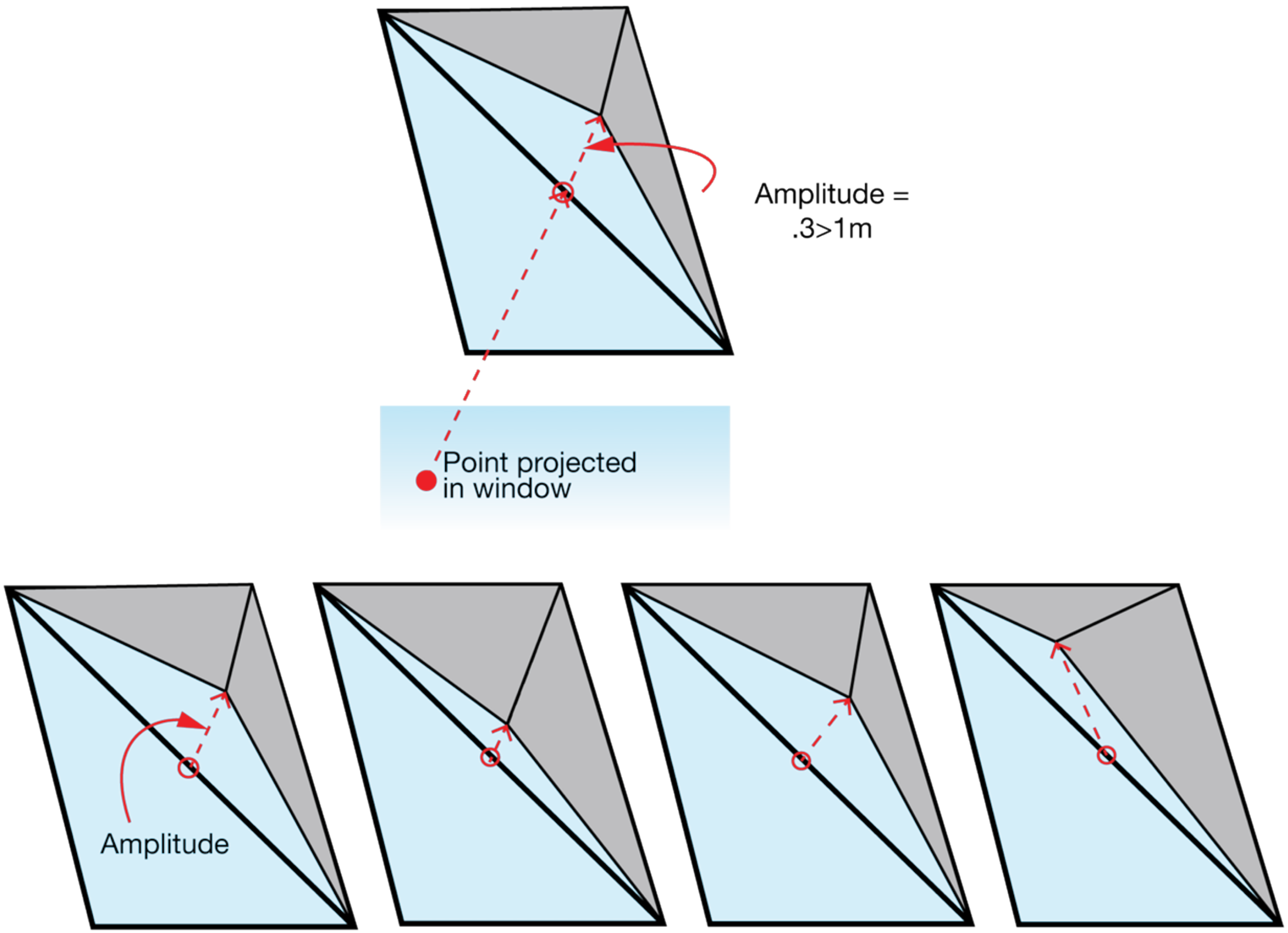
DAYLIGHT TERGENZA DOME - direct daylight influencing the model room.



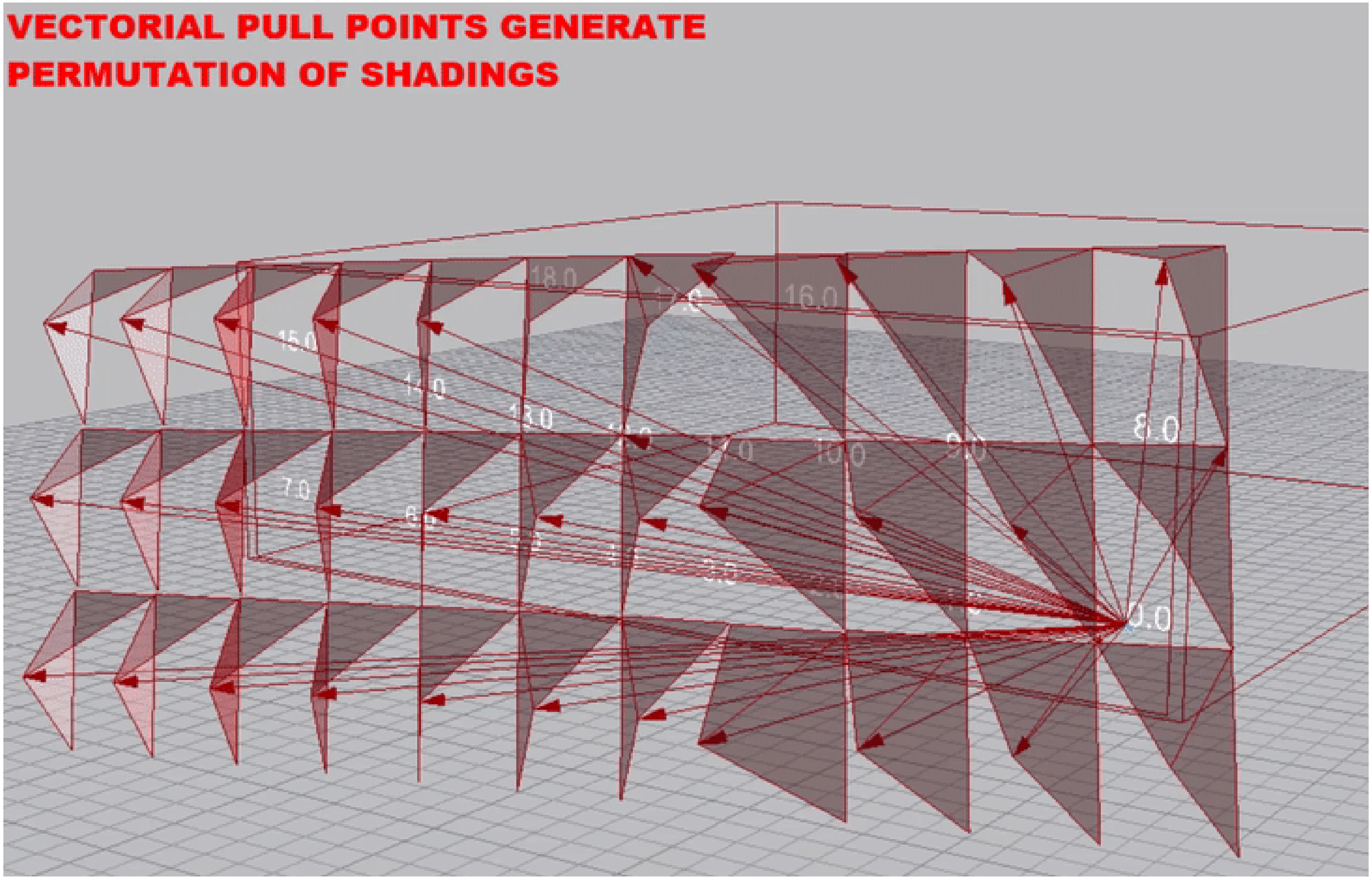
POINT PROJECTION - from the dome patches that relate to the window of the model room.

DESIGN | SIMULATION | OPTIMIZATION | VISUALIZATION | ASSESSMENT

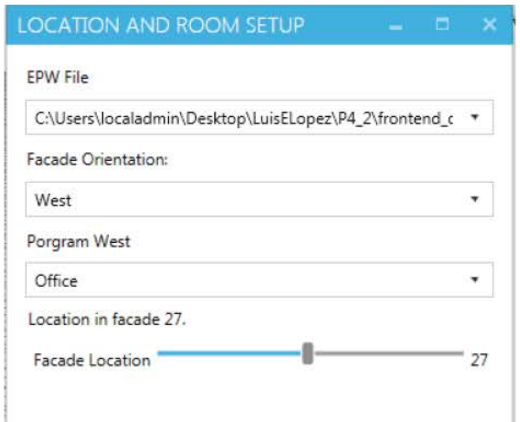
DESIGN - Parametric Shading Design



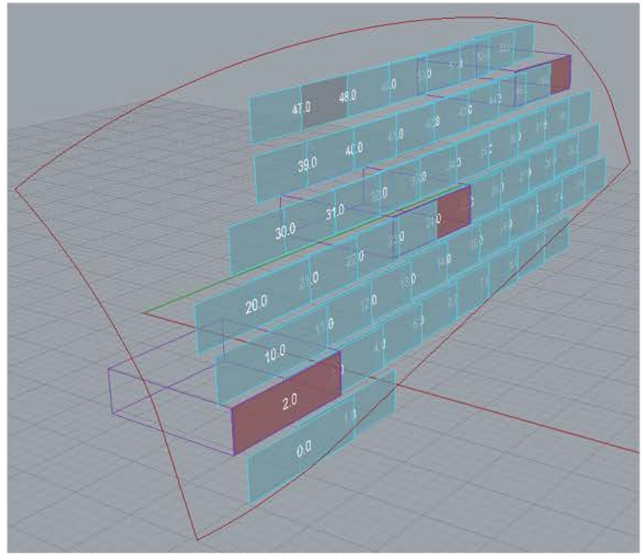
DESIGN - Parametric Shading Design



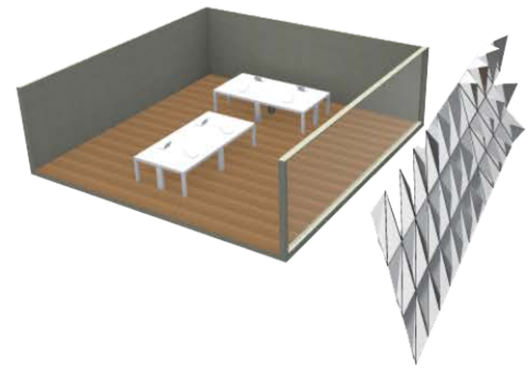
DESIGN - Parametric Shading Design



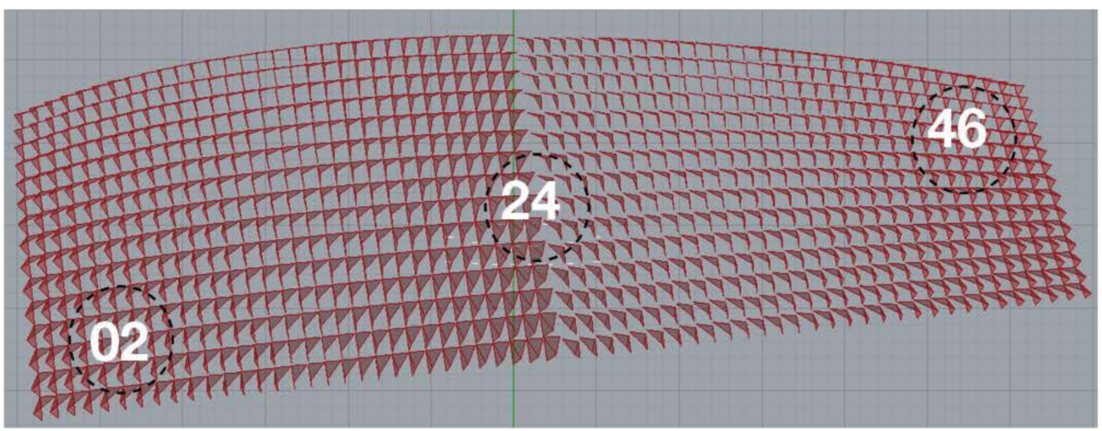
MODEL SET-UP

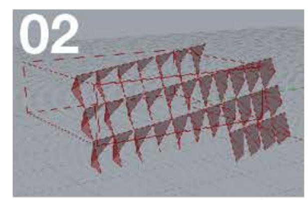


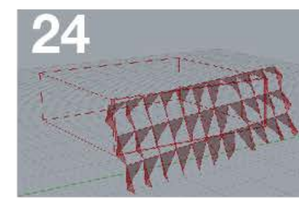
MODEL ROOM SELECTION

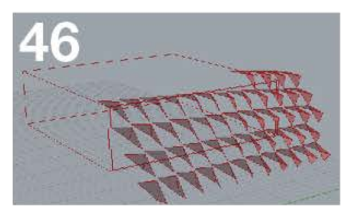


EXPECTED RESULT OF MODEL SET-UP

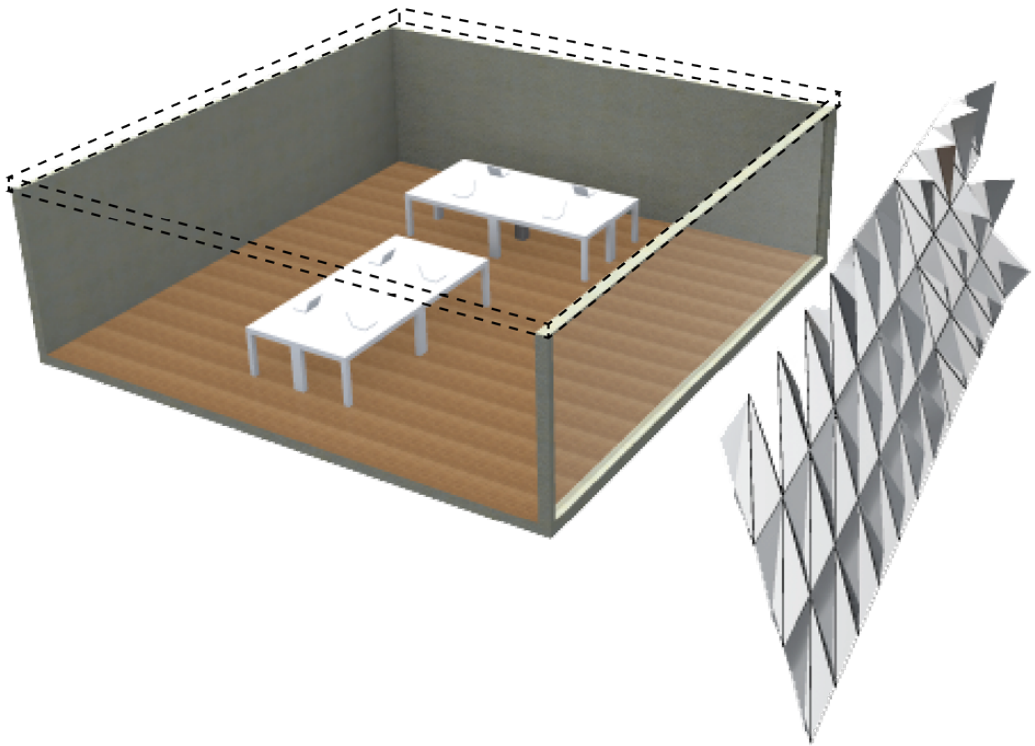








SIMULATION



ROOF
DAYLIGHT = Gypsum: 255,255,255
ENERGY = ASHRAE 90.1-2004 EXTROOF IEAD CLIMATEZONE 1-4

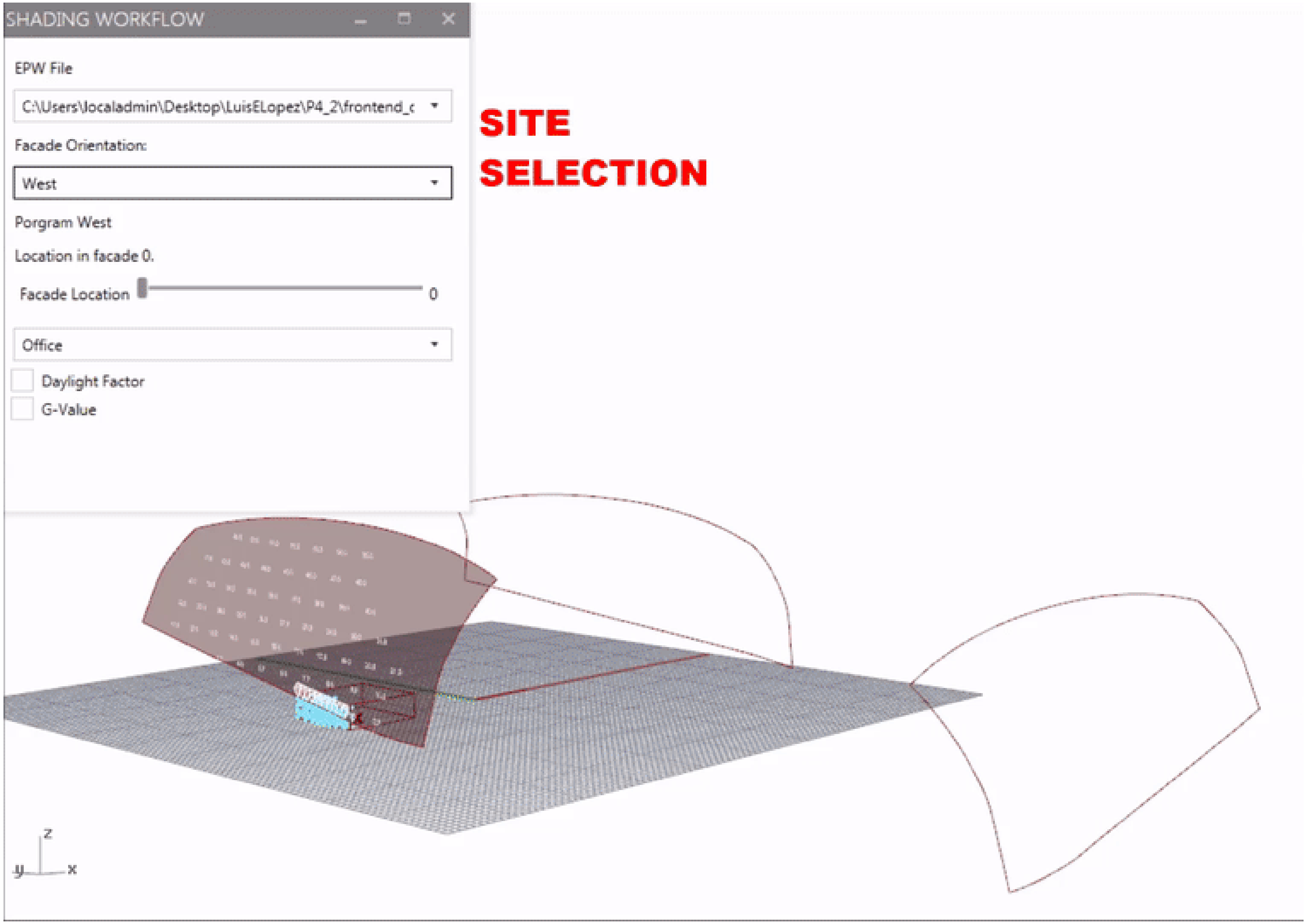
GLASS
DAYLIGHT = Low-e Argon glass, TVis_.714
ENERGY = Alum2 Frame, Low-e Argon

SHADING
DAYLIGHT = Aluminum: .900,.880,.880,.800
ENERGY = Aluminum

WALLS
DAYLIGHT = Gypsum: 255,255,255
ENERGY = ASHRAE 90.1-2004 EXTWALL MASS CLIMATEZONE 1-2

FLOOR
DAYLIGHT = Parquet: .309, .165, .083, .03, .1
ENERGY = ASHRAE 90.1-2004 ATTICFLOOR CLIMATEZONE 1-5

SIMULATION


SHADING WORKFLOW
EPW File
C:\Users\localadmin\Desktop\LuisELopez\P4_2\frontend_c
Facade Orientation:
West
Porgram West
Location in facade 0.
Facade Location
0
Office
Daylight Factor
G-Value
SITE
SELECTION
z
y
x

OPTIMIZATION

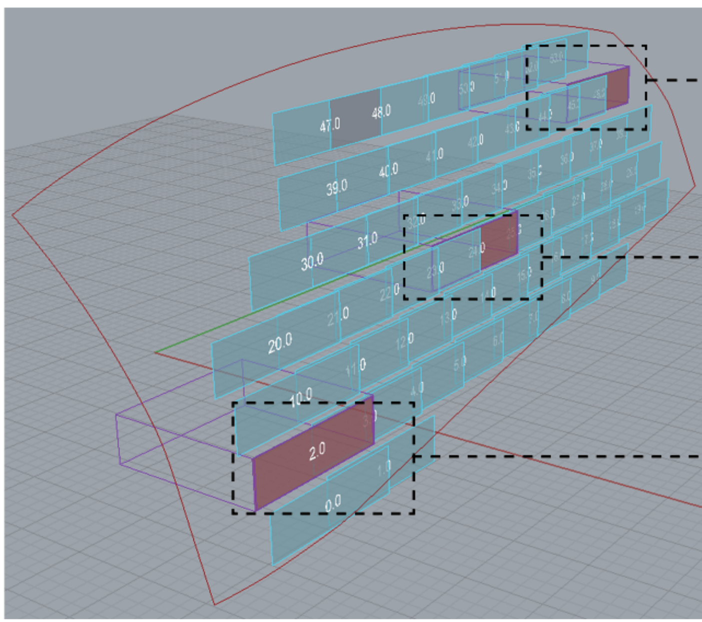
DESIGN PARAMETER: AMPLITUDE

DESIGN OBJECTIVES:

DAYLIGHT FACTOR ↗

G-VALUE ↘

USEFUL AREA ↗



At location No.46: 5 total optimal
19, 29, 31, 44 and 74.

At location No.24: 7 total optimal results
6,10, 22, 29, 49, 57 and 92.

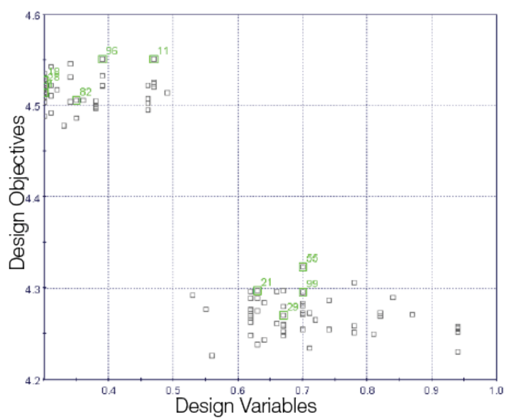
At location No.2 : 7 total optimal results
1, 18, 21,28, 29, 55 and 82.

SUMMARY:

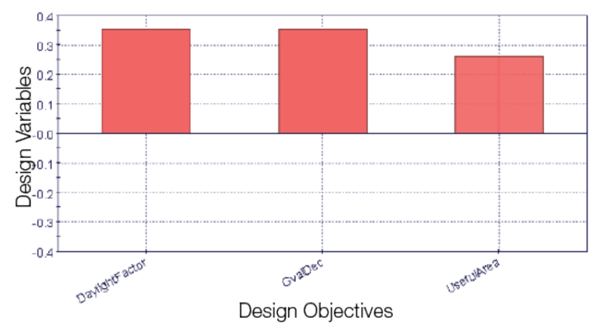
19 total optimal results out of 300 simulations.

OPTIMIZATION

SPECIAL ATTENTION WAS GIVEN TO PARETO FRONT RESULTS FRONT FOR ALL DESIGN OBJECTIVES AND RELATIVE STRENGTH BETWEEN OF DESIGN OBJECTIVES TOWARDS DESIGN PARAMETERS

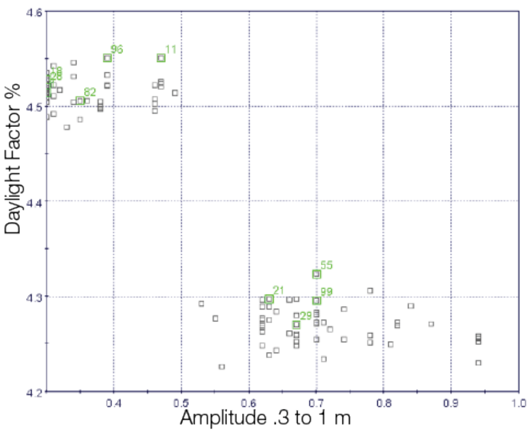


Pareto Front (Scatter Matrix)

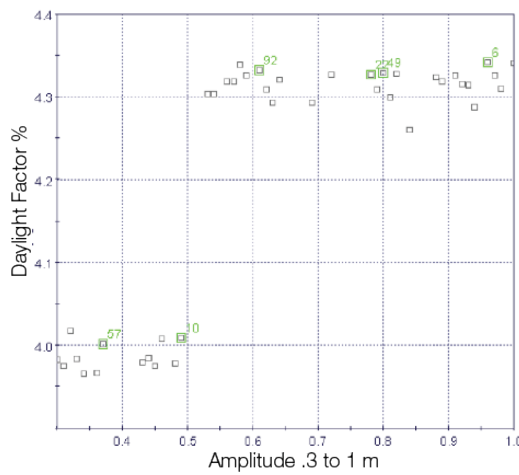


Relative Strength

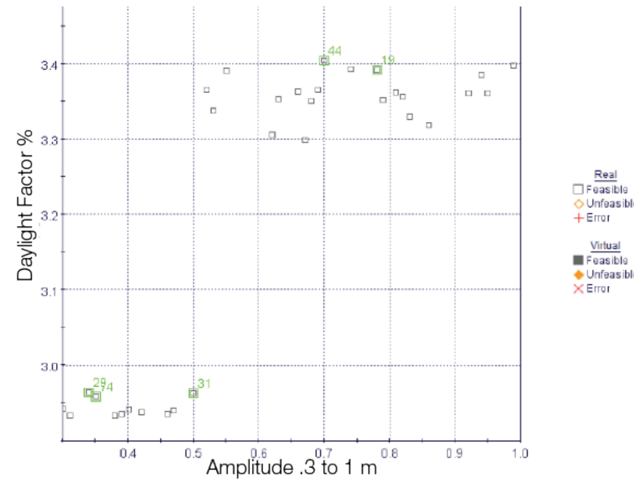
VISUALIZATION - Optimized result exploration



Scatter chart position No. 2



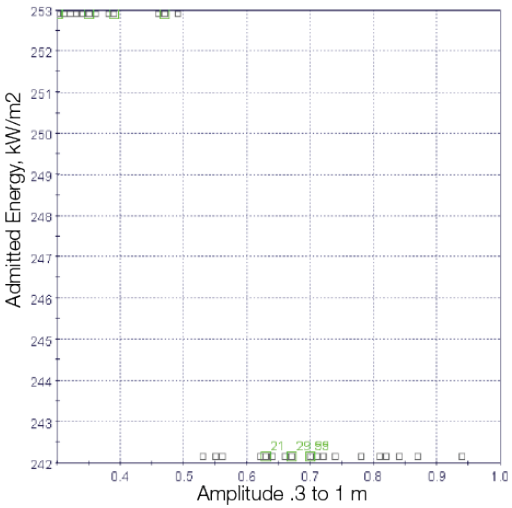
Scatter chart position No. 24



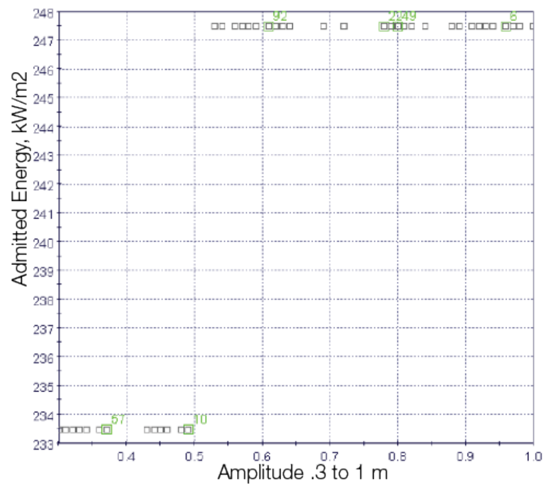
Scatter chart position No. 46

The average Daylight Factor for all model rooms give results within the expected values between 2% and 5%.

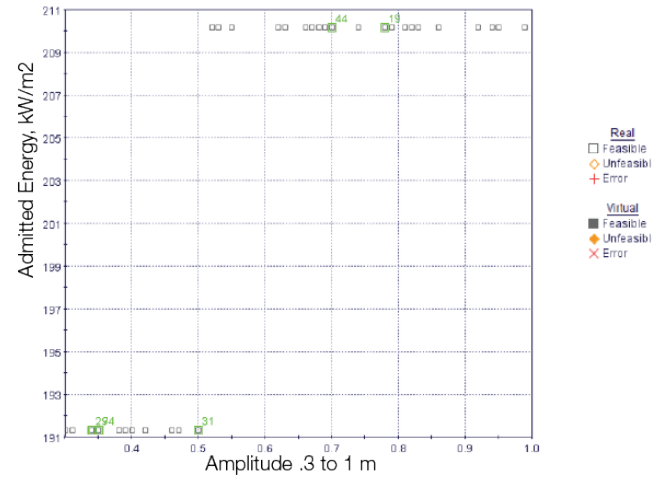
VISUALIZATION - Optimized result exploration



Scatter chart position No. 2



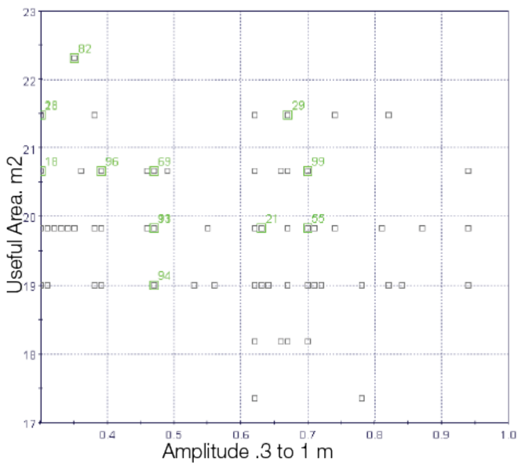
Scatter chart position No. 24



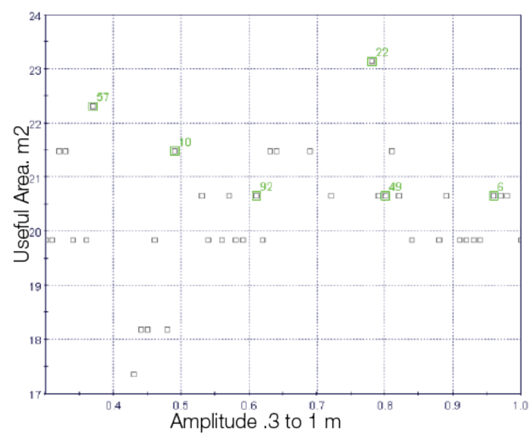
Scatter chart position No. 46

Every model room shows a value variation within its sample results, showing that every model room has optimal results to choose for G-Value reduction.

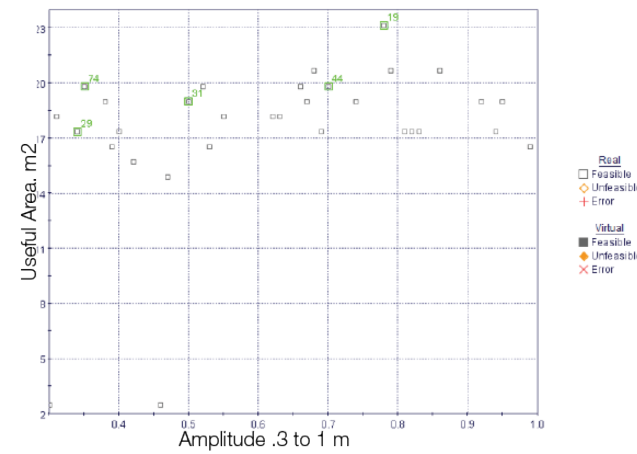
VISUALIZATION - Optimized result exploration



Scatter chart position No. 2



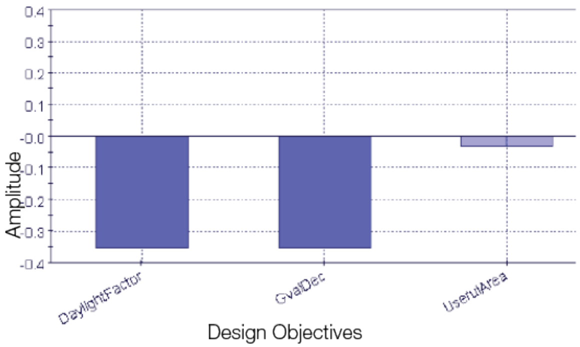
Scatter chart position No. 24



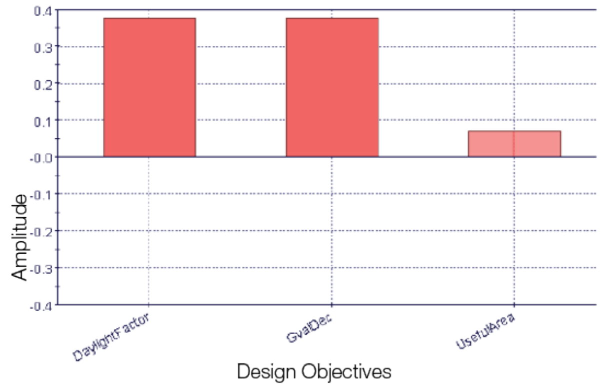
Scatter chart position No. 46

Only result samples for position 24 and 46 show a relevant result with an acceptable Useful Area above 23m2.

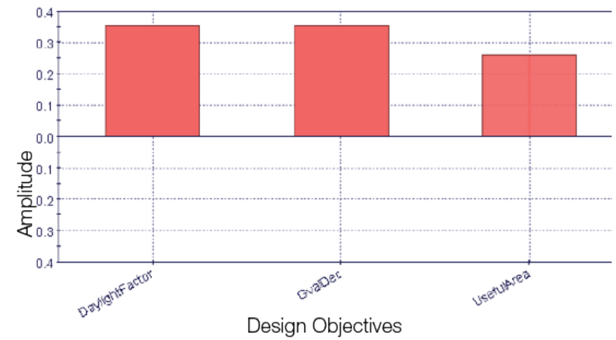
VISUALIZATION - Optimized result exploration



Relative strength
chart for position No. 2



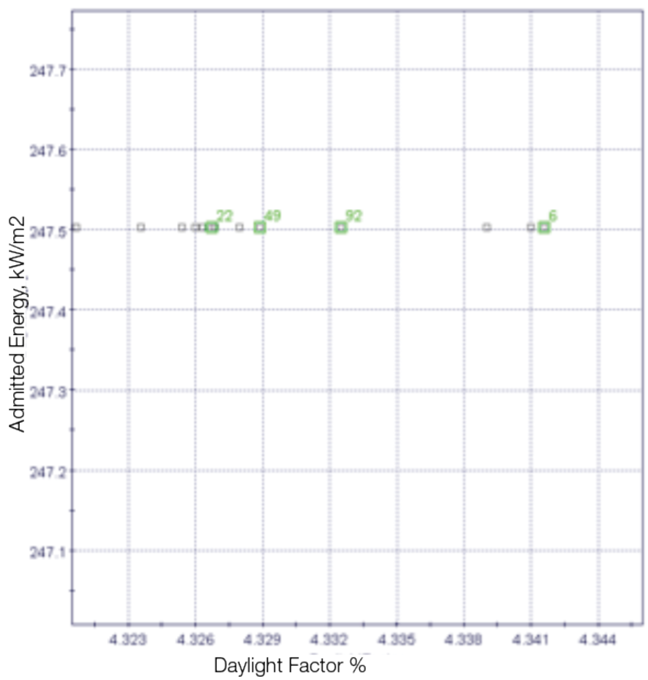
Relative strength
chart for position No. 24

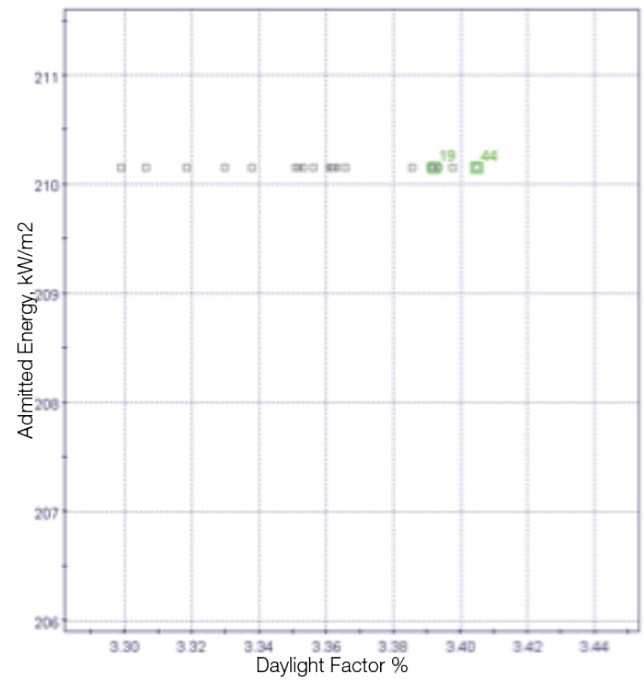


Relative strength
chart for position No.46

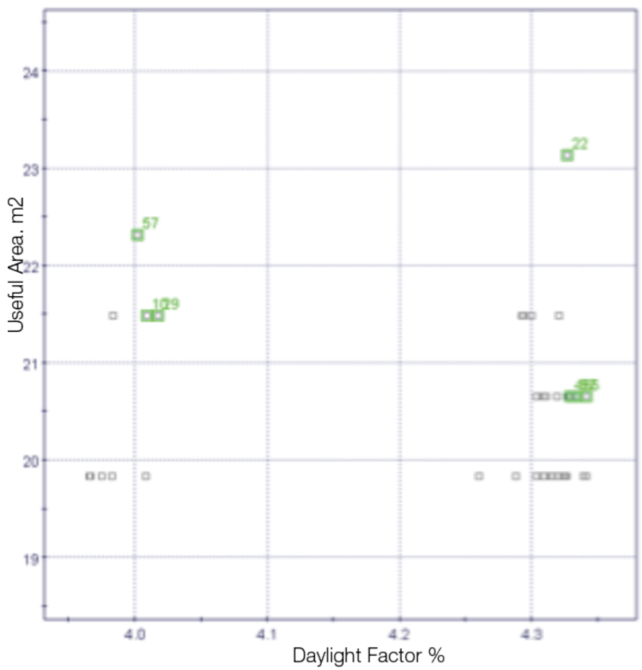
As it is shown not at al design objectives were influenced in the same way by the design parameters, useful area was the least affected, whereas daylight factor and g-value performed almost evenly.

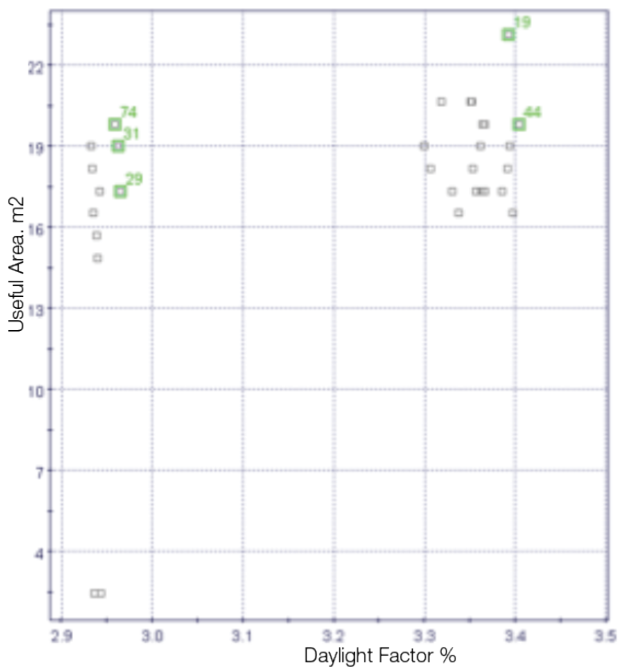
VISUALIZATION - Optimized result exploration



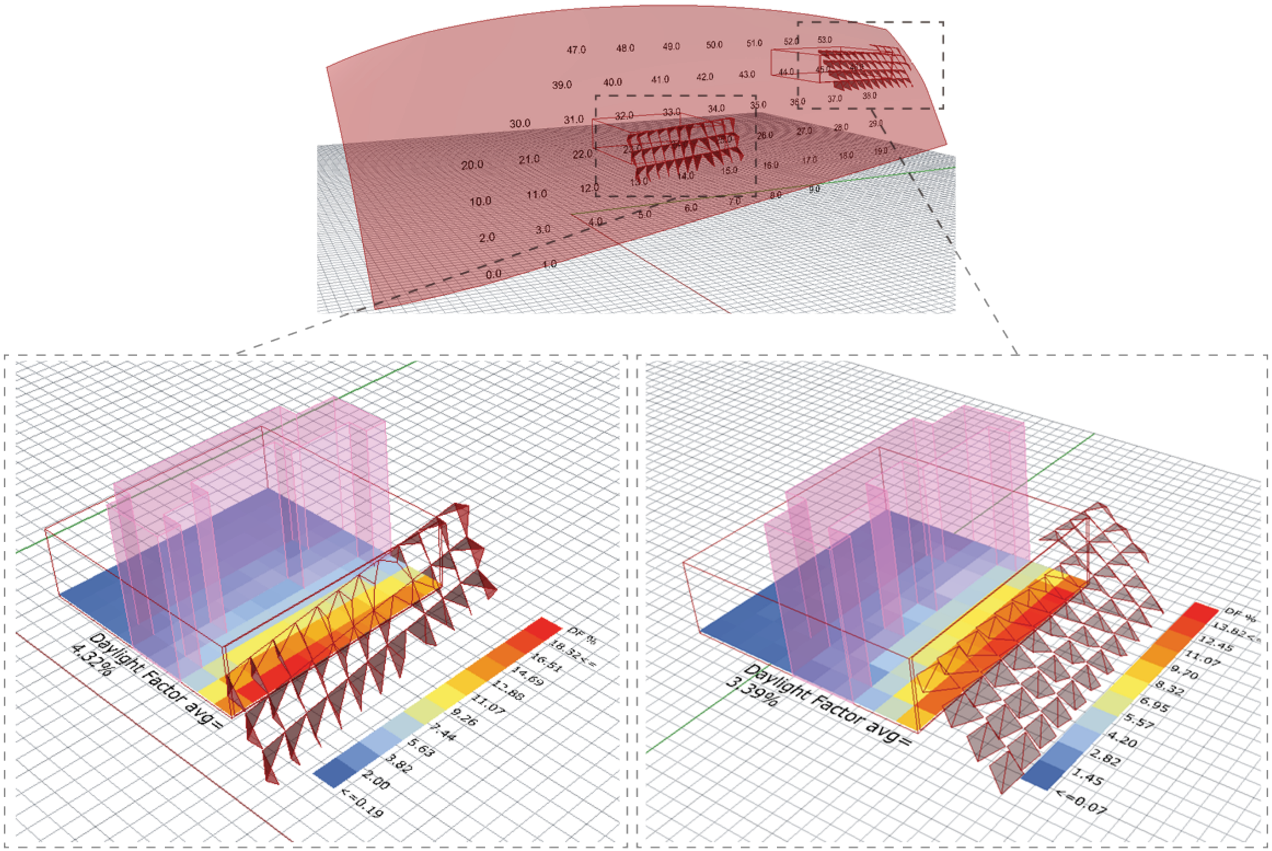


VISUALIZATION - Optimized result exploration





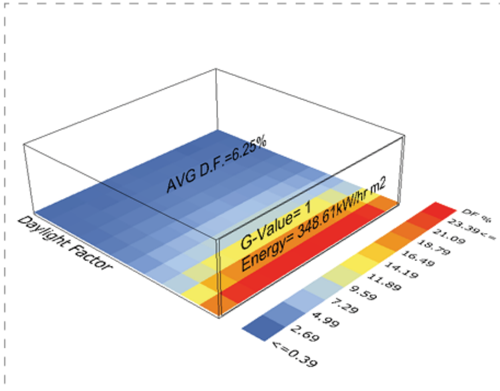
VISUALIZATION - Optimized result exploration



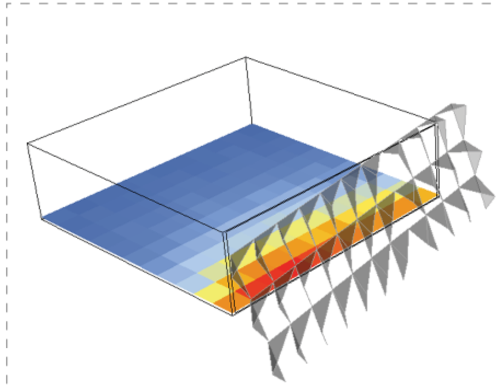
Result 22 at No.24:
Daylight factor: 4.32 avg. %
G-val reduction: 0.71
Energy infiltrating = 102 kW/hr m2
Useful Area: 23.14 m2

Result 19 at No.46:
Daylight factor: 3.39 avg. %
G-val reduction: 0.60
Energy infiltrating = 139 kW/hr m2
Useful Area: 23.14 m2

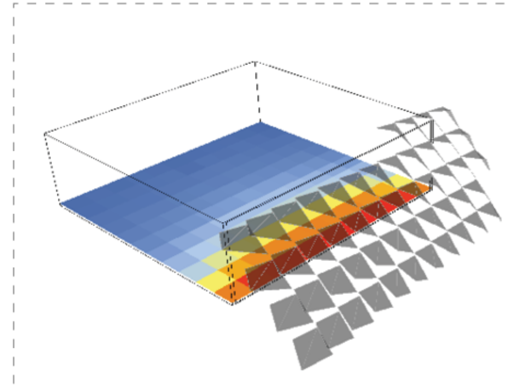
VISUALIZATION - Optimized result exploration



With no shadings:
AVG. DAYLIGHT FACTOR = 6.25%
G-Value = 1
Energy infiltrating = 349 kW/hr m2

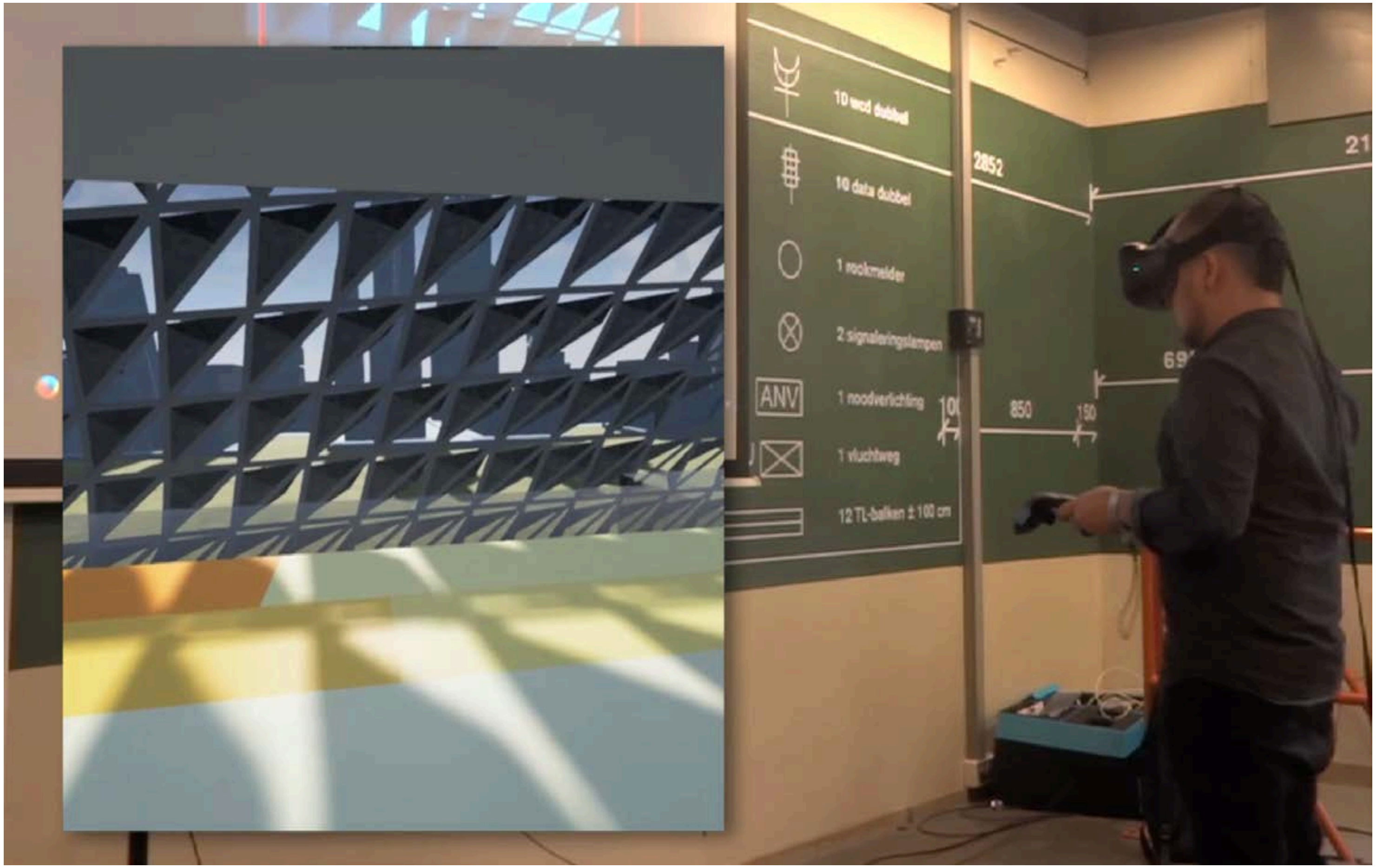


Result 22 at No.24:
AVG. DAYLIGHT FACTOR= 4.32 %
G-val reduction: 0.71
Energy infiltrating = 102 kW/hr m2
Useful Area: 23.14 m2



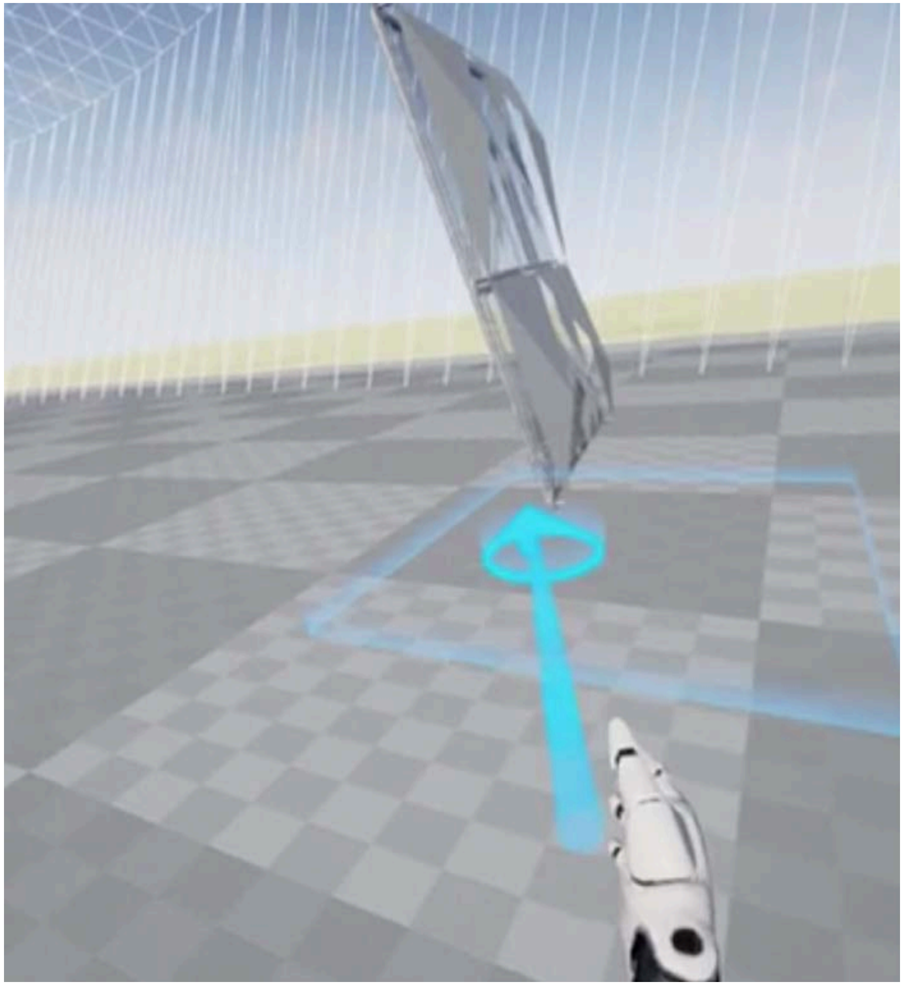
Result 19 at No.46:
AVG. DAYLIGHT FACTOR= 3.39 avg. %
G-val reduction: 0.60
Energy infiltrating = 139 kW/hr m2
Useful Area: 23.14 m2

VISUALIZATION - Optimized result exploration in Virtual Reality



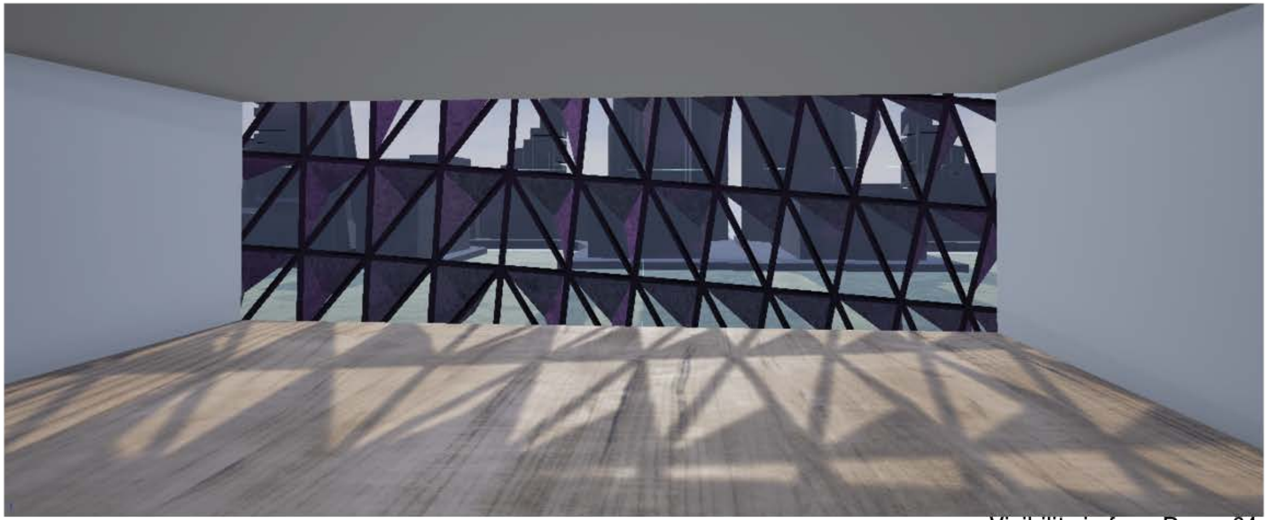
(Click on image for video)

VISUALIZATION - Optimized result exploration in Virtual Reality

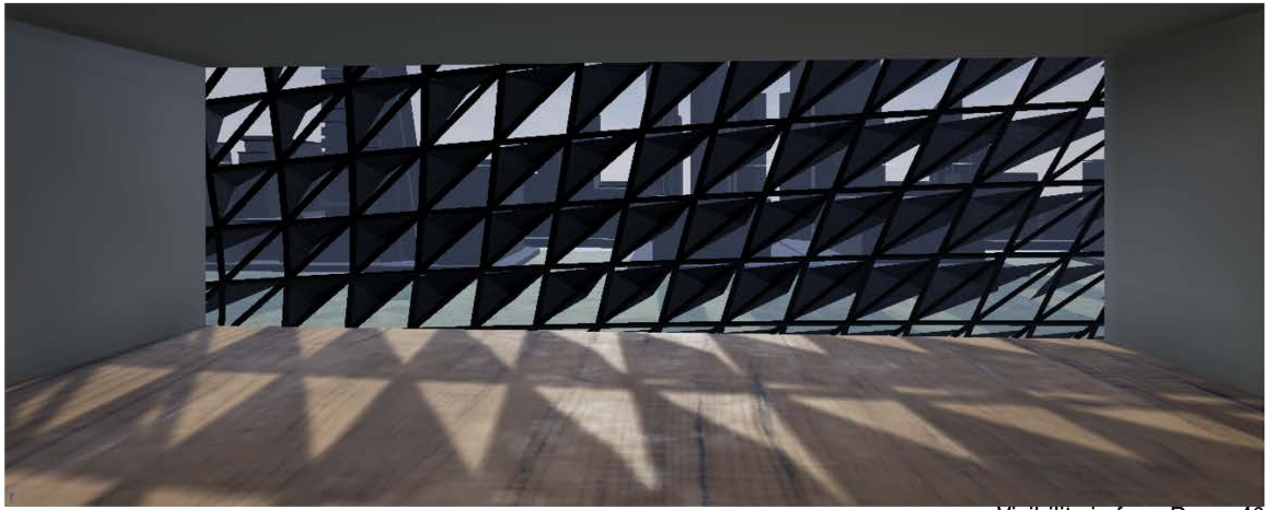


(Click on image for video)

ASSESSMENT

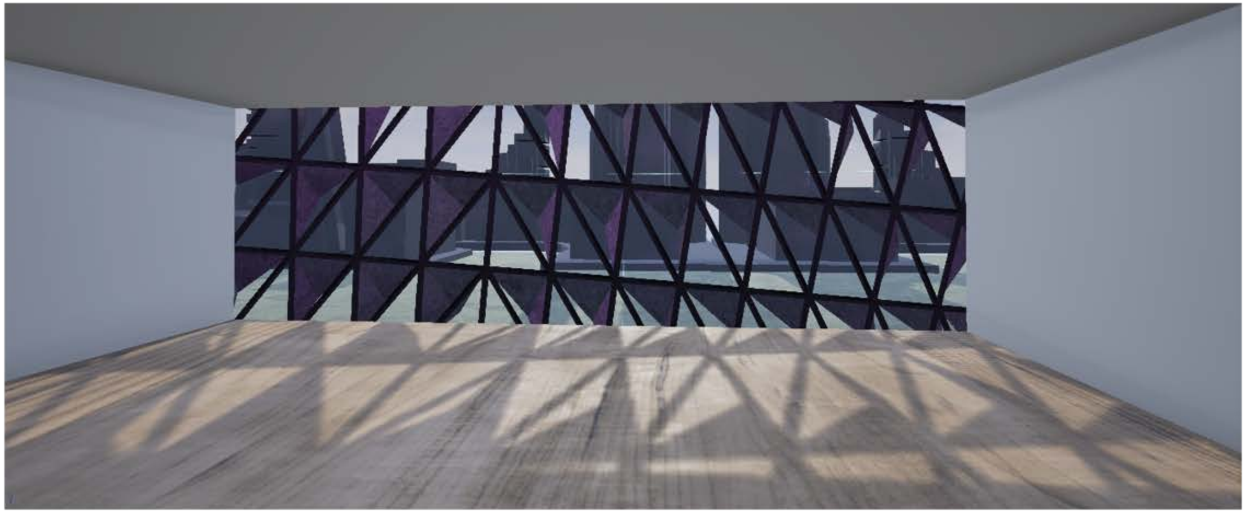


Visibility in from Room 24



Visibility in from Room 46

ASSESSMENT

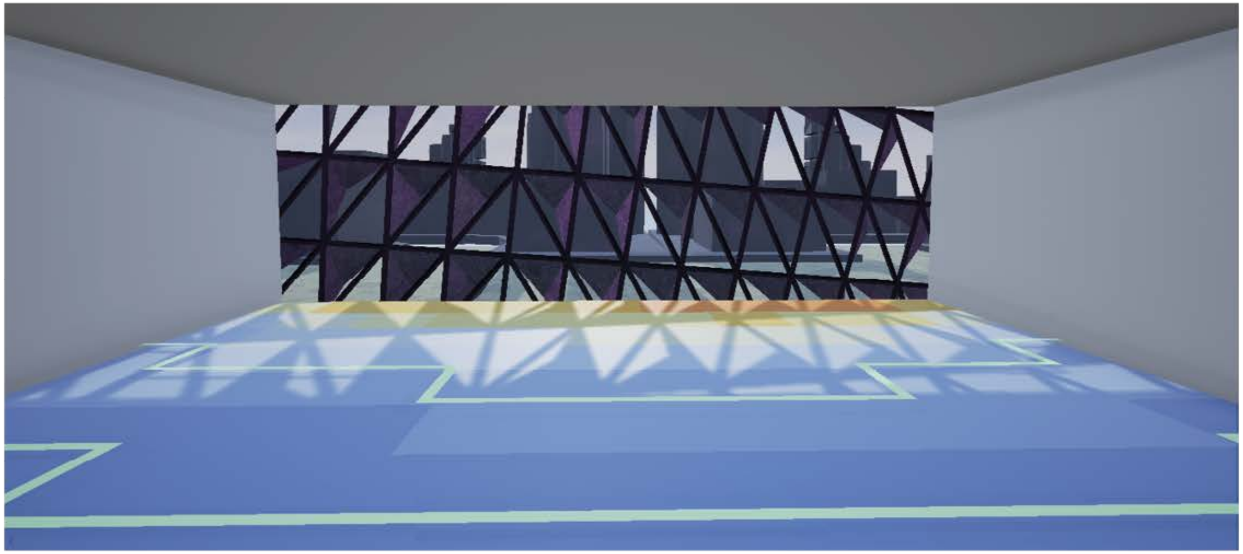


ROOM 24:

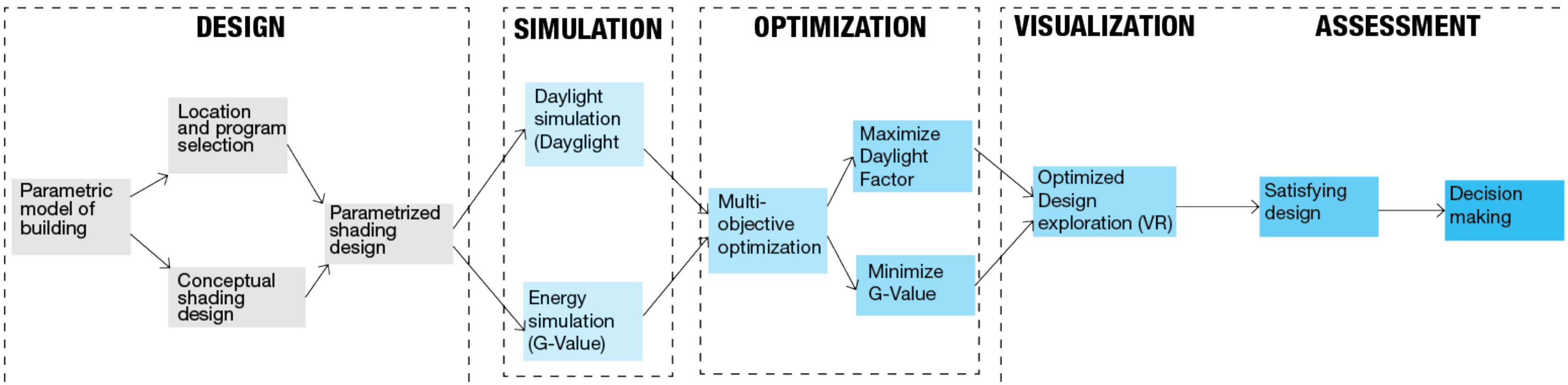
Daylight factor: 4.32 avg. %
Higher avg. percentage of
Daylight distribution

G-val reduction: 0.71
Higher rate of
efficiency in blocking
energy

Useful Area: 23.14 m2
when DF= 2% to 5%



IMPACT OF VR ON DESIGN PROCESS (demonstration in P-5)



- Exploration of sets of optimized results per model room.

- Visualization of environmental features for: daylight (sun) and context.

- Experience of hight differences according to model room position in the building, towards the context.

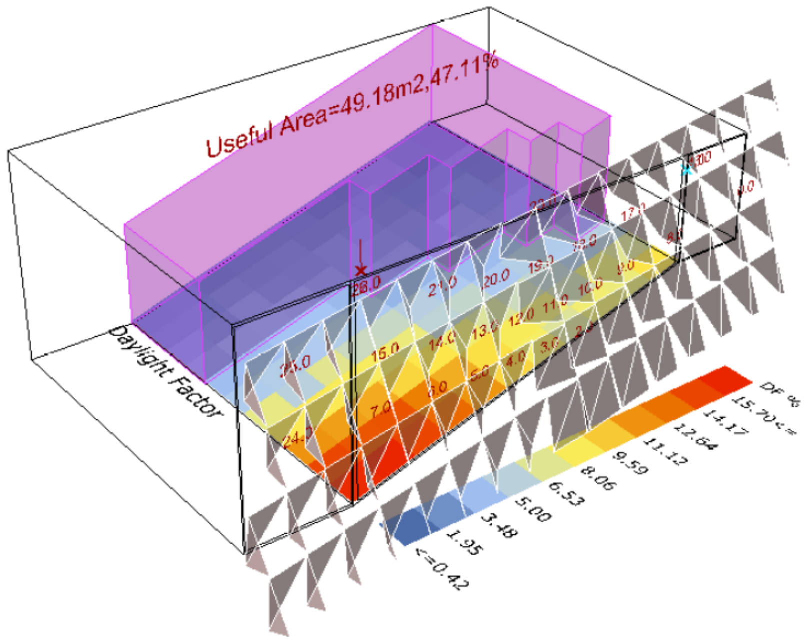
-Visualization and comparing simulation results for optimized results in real time.

-Shadow-casting effect on the room in real time throughout specified dates.

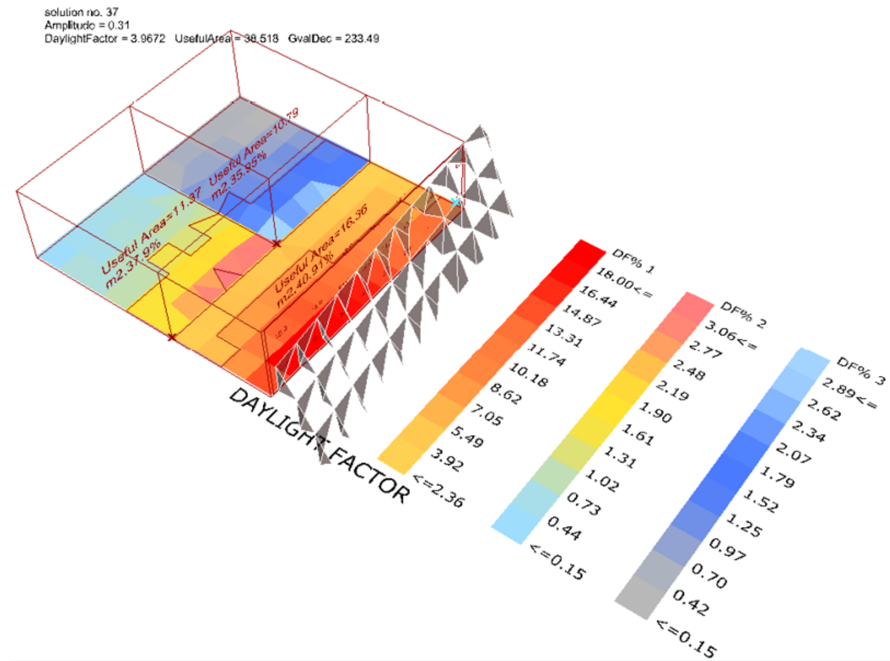
-Manipulation and interaction with detailed shading device mock-ups.

-Interaction and impact visualization on testing different lay-outs for architectural programs.

WHAT ELSE CAN BE DONE?

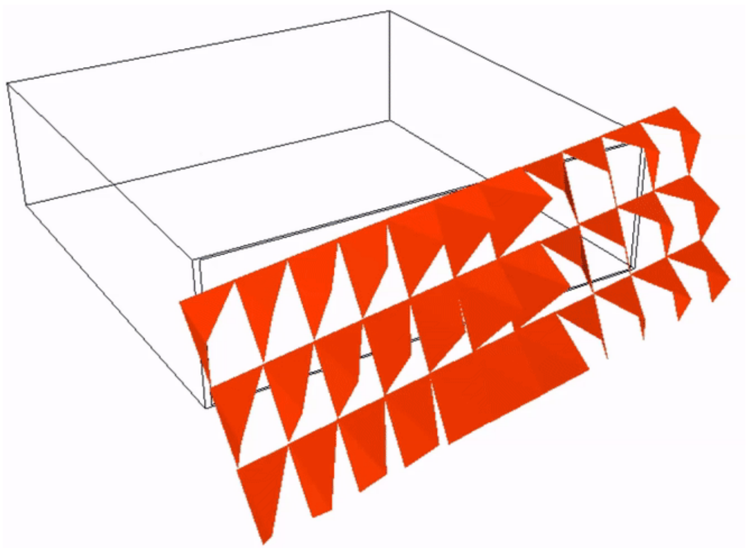


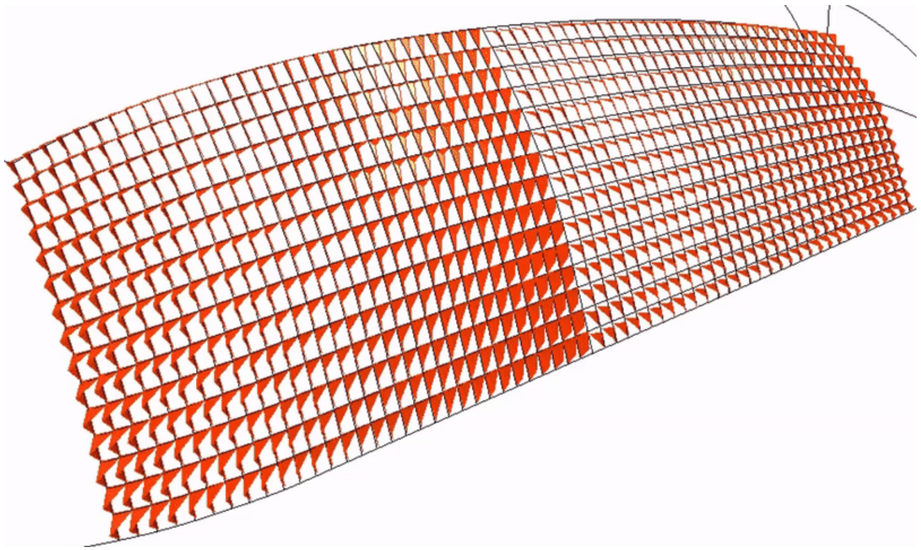
ANALYSIS FOR MULTIPLE TYPOLOGIES AND PROGRAMS



ANALYSIS FOR MULTIPLE OBJECTIVES IN ONE SINGLE SPACE

WHAT ELSE CAN BE DONE?



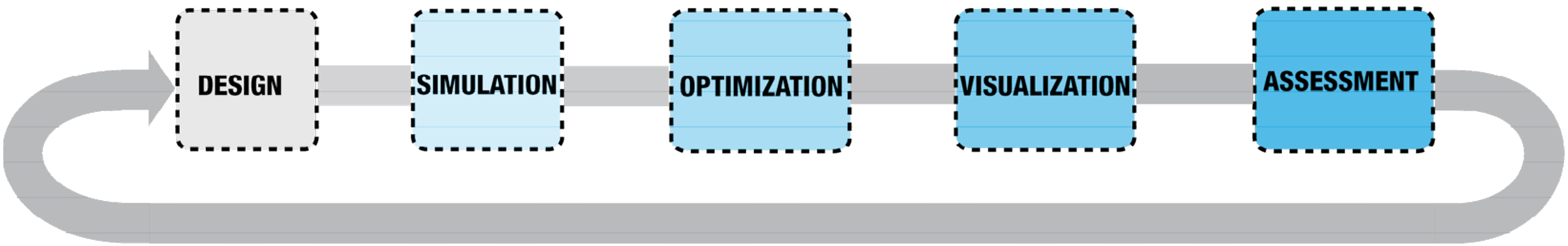


ROOM

FACADE

RATIONALIZATION OF THE SHADING ELEMENTS

CONCLUSIONS



CONCLUSIONS