P5 PRESENTATION
ALVARO RODRIGUEZ GARCIA

JULY 11 / 2018

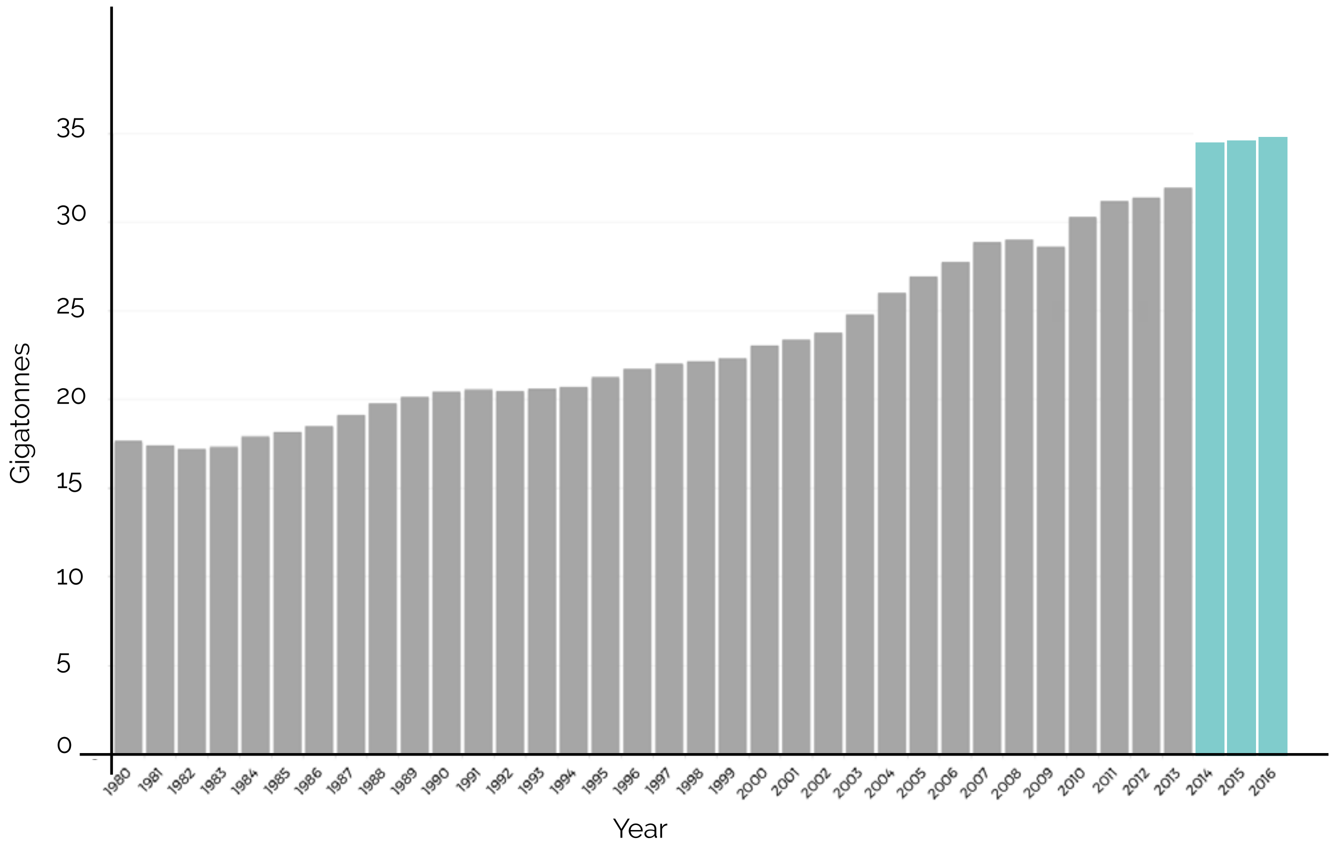
COMPUTATIONAL DESIGN METHOD based on **MULTIDISCIPLINARY DESIGN** optimization and optioneering techniques for **ENERGY EFFICIENCY AND COST EFFECTIVENESS**

INTRODUCTION

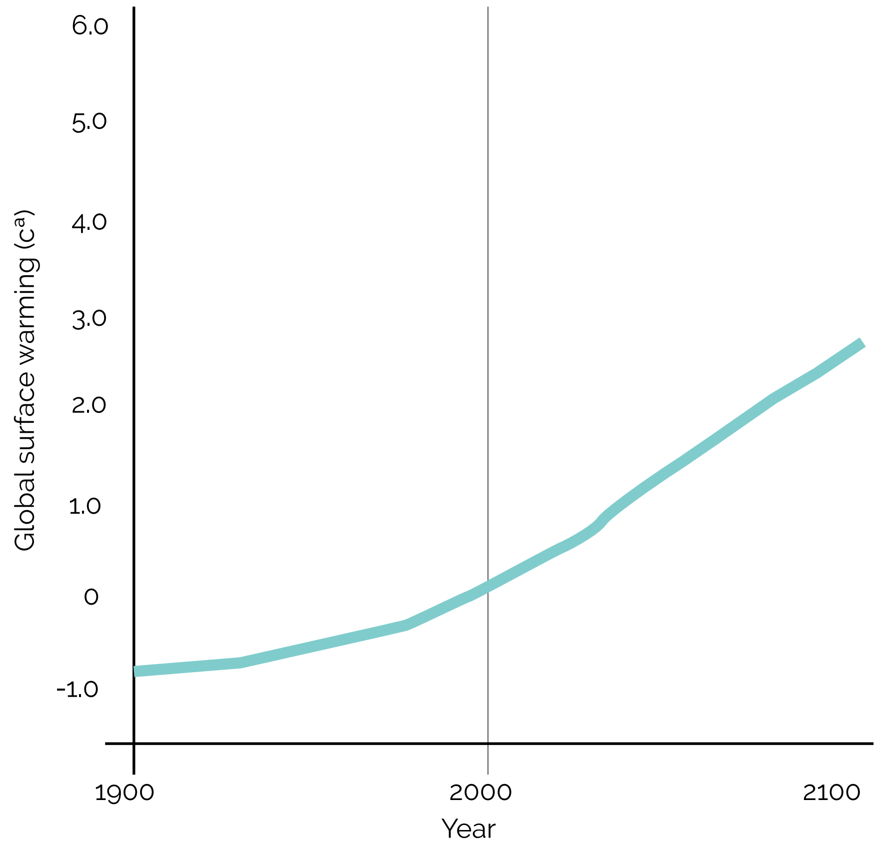
PROBLEM DEFINITION

(Left) Pollution in Mexico City, (Right) Resources shortage in La Paz Potosí Bolivia

PROBLEM DEFINITION



Global Carbon Dioxide Emissions (1980-2016) - IEA 2017



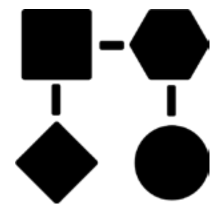
Predicted global surface warming - IPCC 4th Assesment Report

“ARCHITECTURE IS THE WILL OF AN EPOCH TRANSLATED INTO SPACE “ - Mies van der Rohe

RESEARCH QUESTIONS

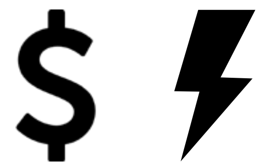
How architects and designers can benefit from the use **computational design techniques** to integrate specific **performative aspects in an energy and cost efficient conceptual design** for complex buildings such as Sports halls.

- How can computer aided conceptual design can support the generation of geometric design alternatives?



- To what extend can computer aided design support the designers learning process and be easily understandable and interactive for the future users?

- Can an automated performance-based computational design method be able to achieve an optimal balance between energy regulations, sustainable rankings, restricted budgets and the return of investments?



METHODOLOGY

RESEARCH

1. Current practice
2. Performance based design
3. Sports venues design
4. Optimization & design exploration

RESEARCH BY DESIGN

5. Workflow definition

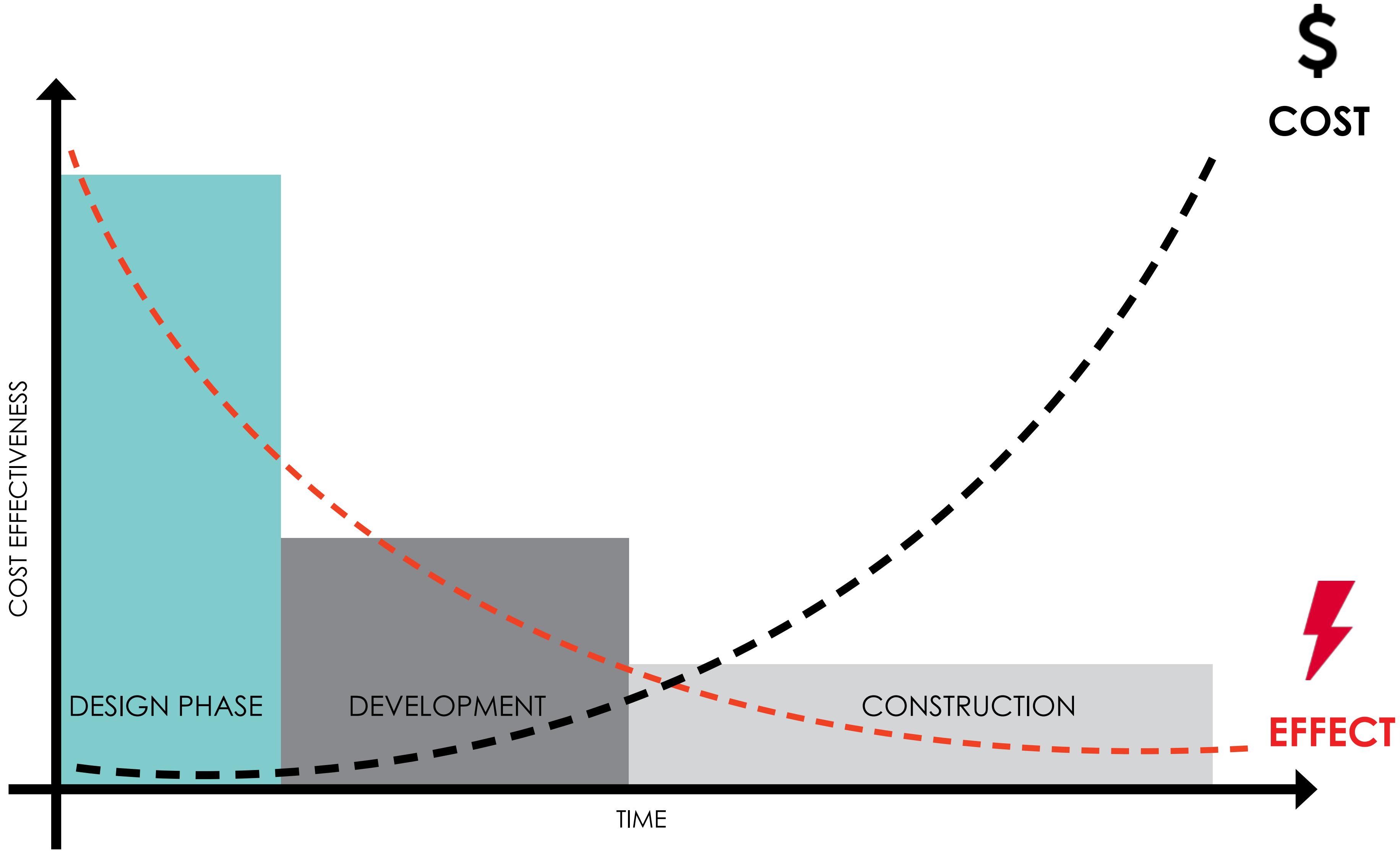
6. Case study

VALIDATION

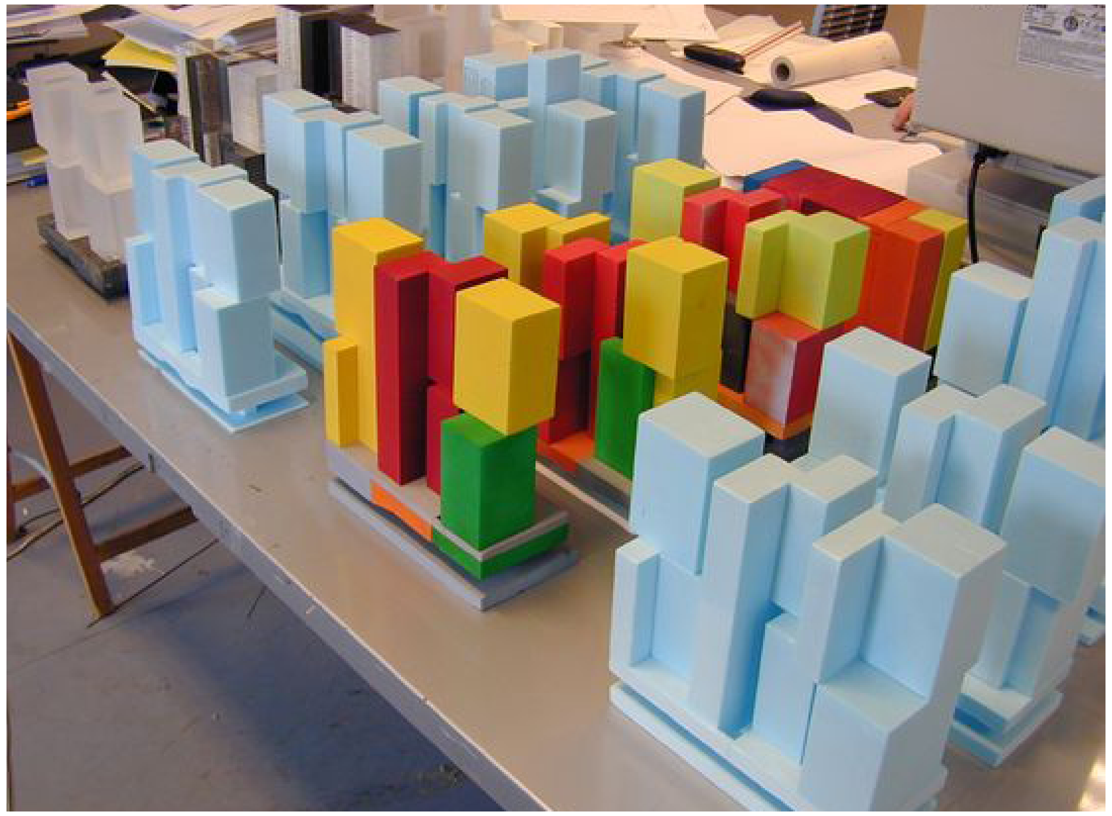
7. Workflow comparison
8. Users validation

BACKGROUND RESEARCH

CURRENT PRACTICE



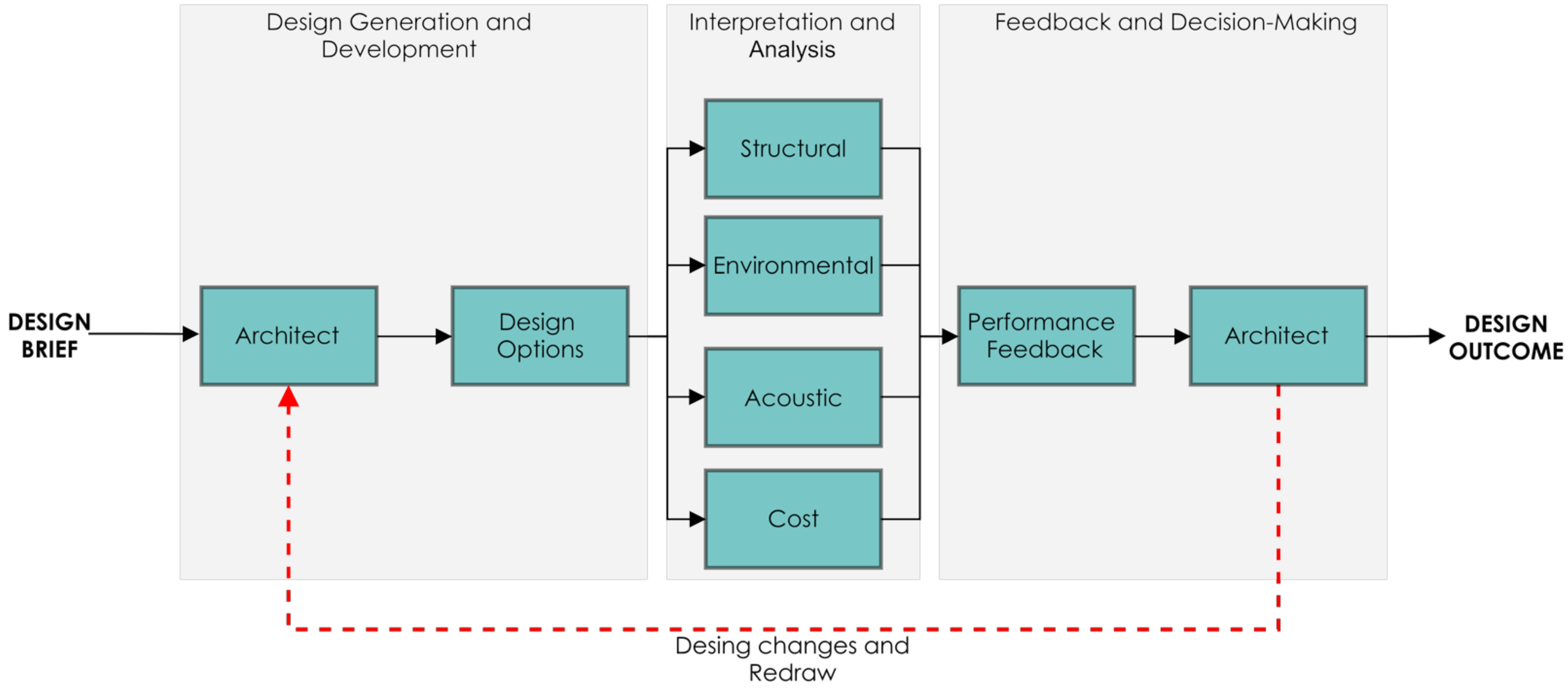
CURRENT PRACTICE

CURRENT PRACTICE

CURRENT PRACTICE

TRADITIONAL WORKFLOW



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ARCHITECT - STUDENT

JULIO ENDARA
MASTER STUDENT
TU DELFT MASTER IN ARCHITECTURE

TU Delft

1. **What is your background?**

I am Julio Endara, a 30 year old student at TU Delft-Faculty of Architecture and the Built Environment. I am doing my master on the Architecture track and I am specializing on Dwelling. Before I came here I worked for 5 years at my home country (Ecuador)

2. **How do you use the computer for design purposes?**

I use the computer for most of the process. After I pass the sketching stage I rely on the computer for all the design work. I first create 2D basic drawings and after that I simultaneously combine the 2D and 3D explorations. When I finish my design drawings I make a post production process for my final product.

3. **What kind of software do you normally use for your projects?**

☒OFFICE(Basic tools)	☒3D Modelling	☐Structural (Specify)________
☒CAD	☒3D Visualization /VR	☐Climate/Energy(Specify)________
☐BIM	☐3D Parametric Modelling	☐Cost estimation(Specify)________
		☐Optimization(Specify)________

4. **How do you deal with sustainability, energy and costs aspects, at which stage of the design process, do you implement these considerations, please clarify?**

☒Conceptual (Early) ☒Development ☐Construction documentation(Late)

5. **What do you think about Performance -based architecture (Quantitative /numerical assessment of a design) and Multidisciplinary design optimization design strategies.?**

I feel that Performance-based architecture is an essential need for the future of the profession. Its really useful to rely on numerical data to organize your work an to have a solid backup for the decisions you take on the design and construction process. I also feel that Multidisciplinary design is efficient and should be more applied, specially on big offices.

6. **How do you see the future of the architect in a technological era?**

I wish that in the future I could learn more about these new techniques. At the moment I don´t use them, but it is definitely imperative for the Architect to get involved with the technological solutions as the world in every sense is getting more involved with it. My plans are to learn about numerical assessment methods and programs and implement that knowledge into the development of myself as an architect.

4

ARCHITECT

SEBASTIAN NAVARRO
ARCHITECT AND CEO
PABELLON DE ARQUITECTURA

PABELLON de arquitectura

1. **What is your background?**

In the office we make a lit of bit of all, since the conceptual to the construction with all the details, included furniture

2. **How do you use the computer for design purposes?**

At the begin we use computer to general investigation like context, orientation, and some simple things, then the process starts with put our ideas in a model to look the 3d model, and the we devolp the idea in SketchUp or AutoCad to advance with the function, it's a two ways process.

Finally we use the model to make renders and a presentation, and then if the idea its approved we make a Cost estimation in excel or neodata

3. **What kind of software do you normally use for your projects?**

☒OFFICE(Basic tools)	☒3D Modelling	☐Structural (Specify)________
☒CAD	☐3D Visualization /VR	☐Climate/Energy(Specify)________
☐BIM	☐3D Parametric Modelling	☒Cost estimation(Specify)____NEODATA________
		☐Optimization(Specify)________

4. **How do you deal with sustainability, energy and costs aspects, at which stage of the design process, do you implement these considerations, please clarify?**

☒Conceptual (Early) ☐Development ☒Construction documentation(Late)

5. **What do you think about Performance -based architecture (Quantitative /numerical assessment of a design) and Multidisciplinary design optimization design strategies.?**

It's an interesting idea but very complex for us, we really don't know first how to use it, and second the paper of the architect behind of this technology , although we know it's the future.
We think that it's a very useful tool for the architects if they really know how to use it.

6. **How do you see the future of the architect in a technological era?**

The future of the architecture will be different in several things, first in the materials, that don't mean that the stone or wood won't be used any more, but will appear new elements to work, like already exist different types of concrete with nano-technology o different chemical combinations.

In the process of design we know we aren't actualized in the BIM technology and we don't use Revit or other programs, but the environment with other firms its complicate

And finally with the process of design we think that the architects will have a lot of tools, **more easily** to work and make changes, were orientation, structure, cost will be integrated, but like a tool, not to replace the architect role, maybe in little constructions will be more easy to supplant, but not totally

6

ARCHITECT

LEO STUCKARDT
EXPERIMENTAL TECHNOLOGIES RESEARCH UNIT
MVRDV

MVRDV

1. **What is your background?**

Bsc. and Msc. Arch. from TU Berlin and TU Delft.I started with experimental computational design during my studies with The Why Factory at TU Delft.

2. **How do you use the computer for design purposes?**

Digital tools are part of the design process starting from the earliest design stages. From testing ideas in Photoshop and 3d modeling software to quantitative design evaluation (Grasshopper/Dynamo/Excel) and prototyping (CAM).

3. **What kind of software do you normally use for your projects?**

☒OFFICE(Basic tools)	☒3D Modelling	☐Structural (Specify)________
☒CAD	☒3D Visualization /VR	☒Climate/Energy:Grasshopper Ladybug/Honeybee
☒BIM	☒3D Parametric Modelling	☒Cost estimation: Grasshopper/Dynamo + Excel
		☒Optimization: Genetic Algorithms (GH), experimenting with Neural Network architectures

Although the software listed above covers most requirements for regular architectural and urban designs, some projects offer the opportunity to add tools from other industries or develop custom plug-ins and scripts (within BIM / 3D Modelling in particular).

The use of game engines (Unity, Unreal), video editing (After Effects, Premiere) and simulation software (Houdini) can help to develop a compelling narrative and develop a project from different angles.

4. **How do you deal with sustainability, energy and costs aspects, at which stage of the design process, do you implement these considerations? please clarify.**

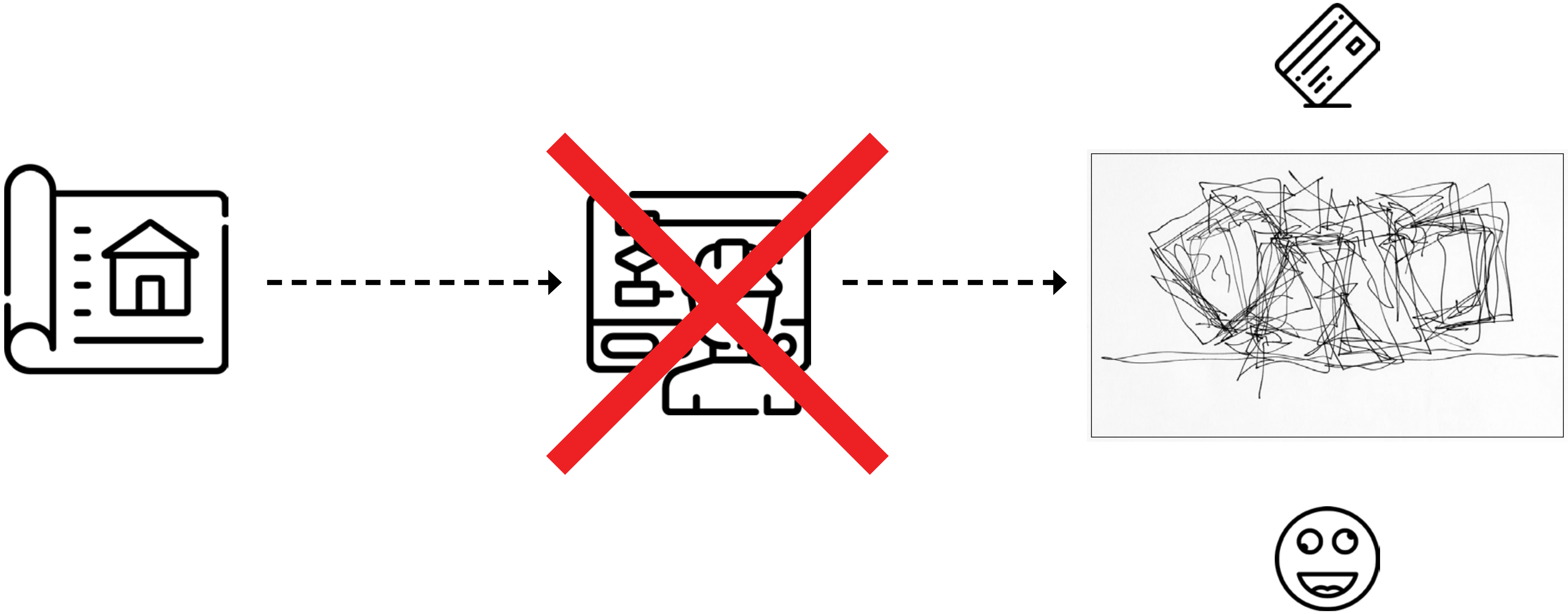
☒Conceptual (Early) ☒Development ☒Construction documentation(Late)

Clearly all of those aspects need to be considered from early sketch design onwards. However their relevance in each of the design phases depends on so many project characteristics (client, context, competition/commission/…) that it is difficult to answer the question in such a broad way.

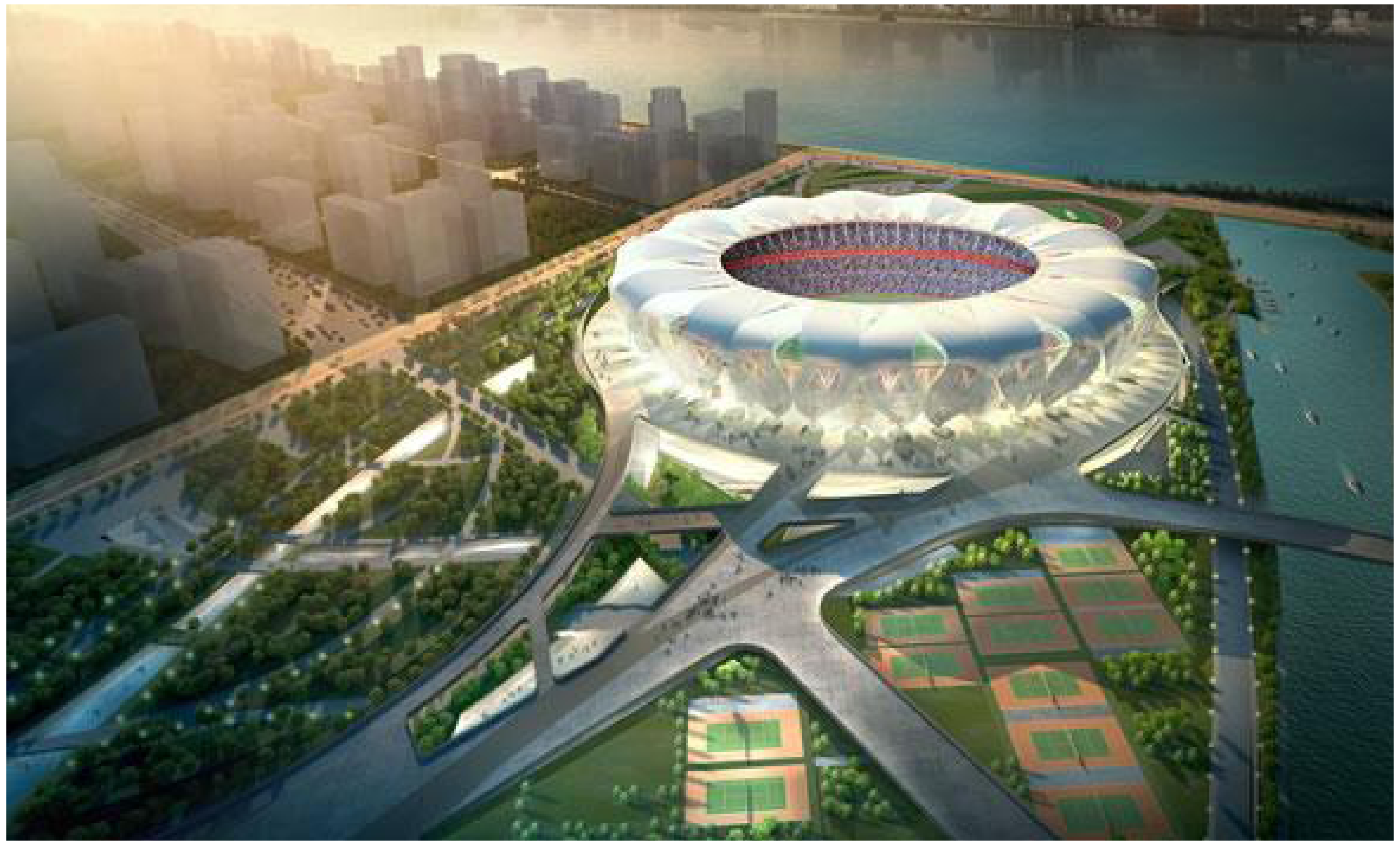
5. **What do you think about Performance -based architecture (Quantitative /numerical assessment of a design) and Multidisciplinary design optimization design strategies.?**

In general I am skeptical of the notion of optimization and much more interested in the use of algorithms to create design variations, effectively opening design space up rather than narrowing it down.
In addition the term optimization suggests that certain solutions are superior to other design variations although even multi-objective optimization algorithms can only optimize for a limited range of (usually) geometric constraints. The subjective definition of those constraints (it is still a designer, who defines the inputs of optimization algorithms) gets obscured behind the seeming neutrality of a computed, optimum state.
Having said that we quantify every design project in various ways and have used Genetic Algorithms to improve façade/cantilever configurations and occasionally even building envelopes.

CURRENT PRACTICE



PERFORMANCE BASED DESIGN



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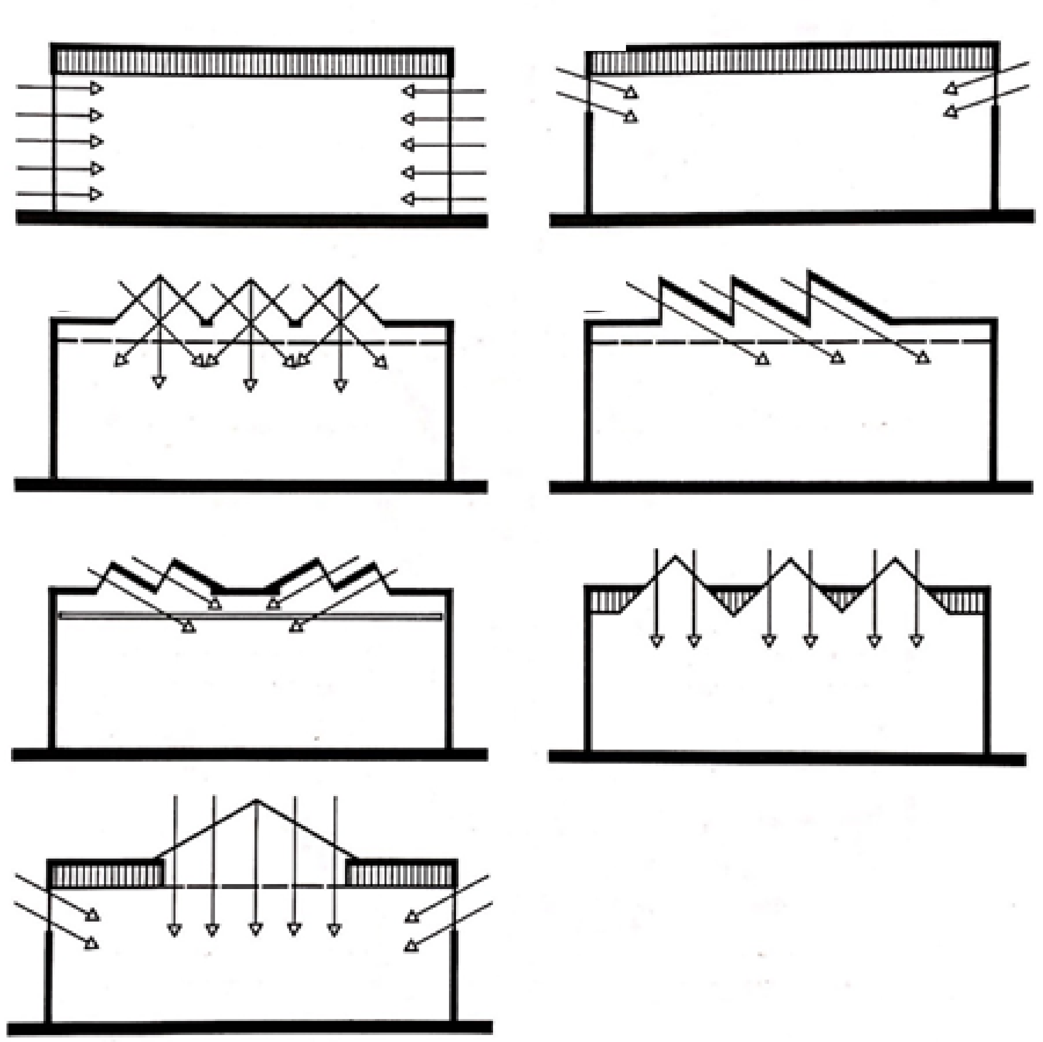
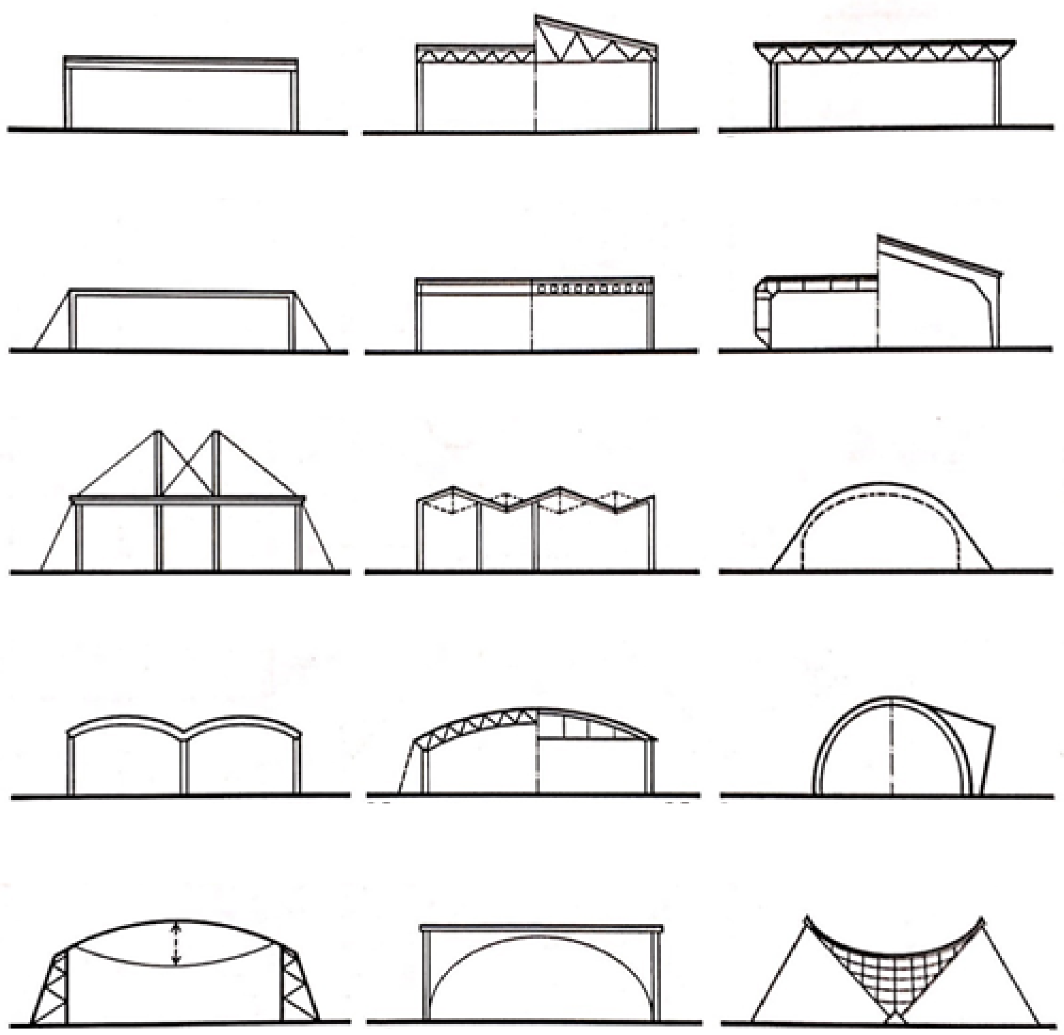
PERFORMANCE BASED DESIGN

DAYLIGHT



STRUCTURE



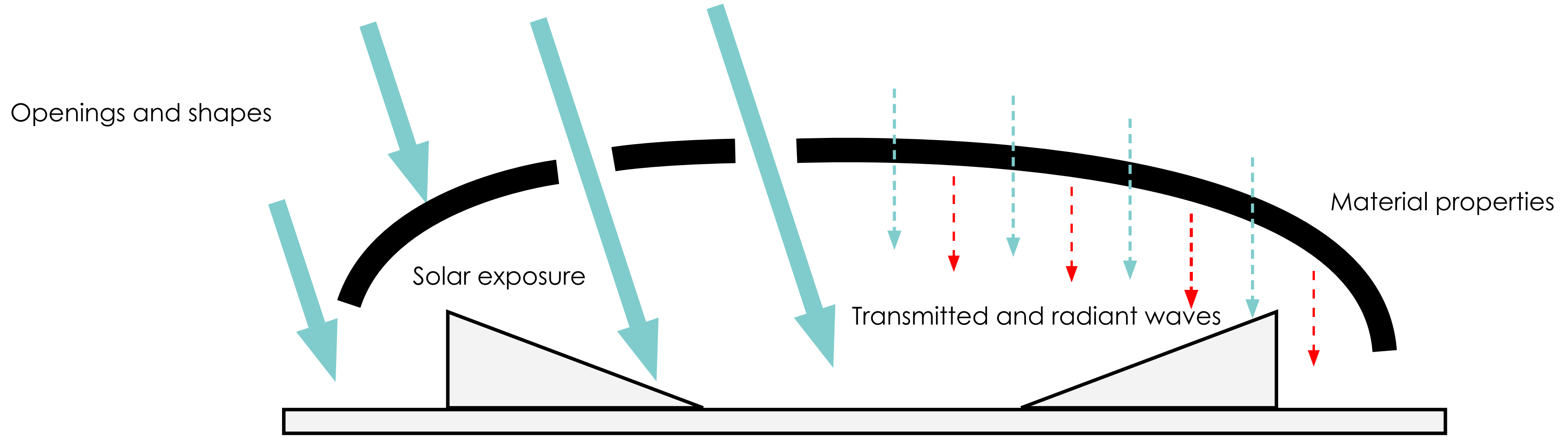
PERFORMANCE BASED DESIGN

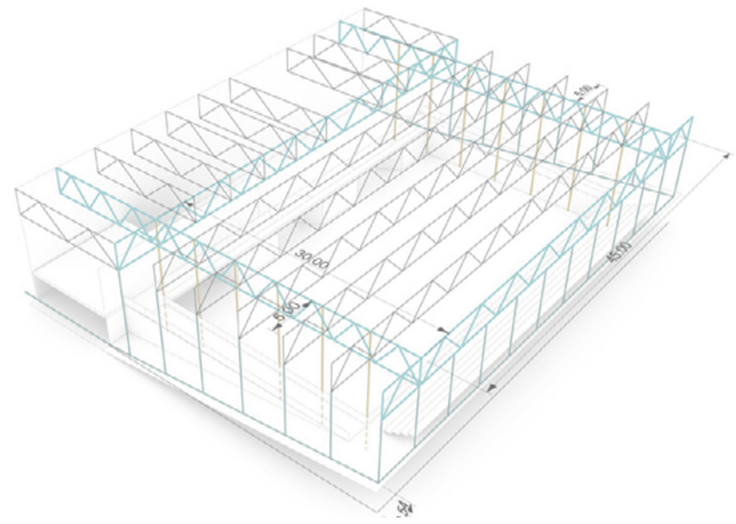
ENVELOPE

STRUCTURE

80% ENVIRONMENTAL STRATEGY **30%** CONSTRUCTION COSTS

20% CONSTRUCTION COSTS

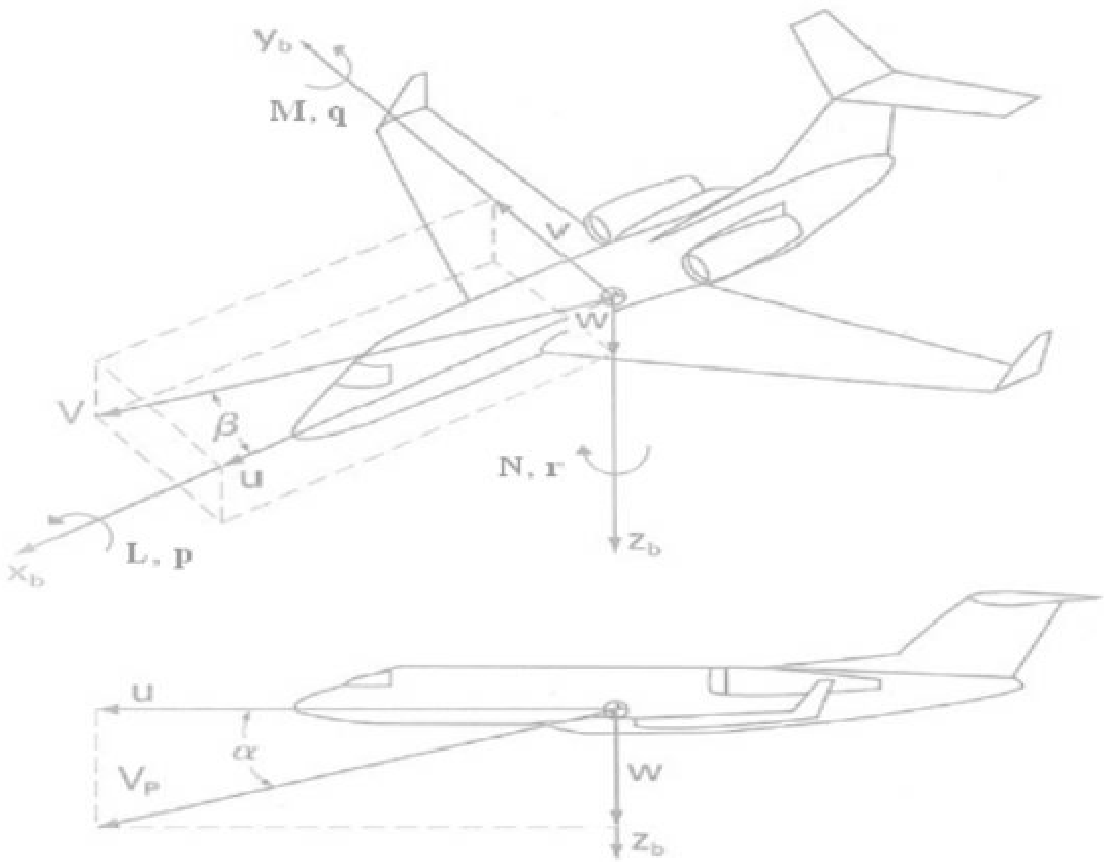




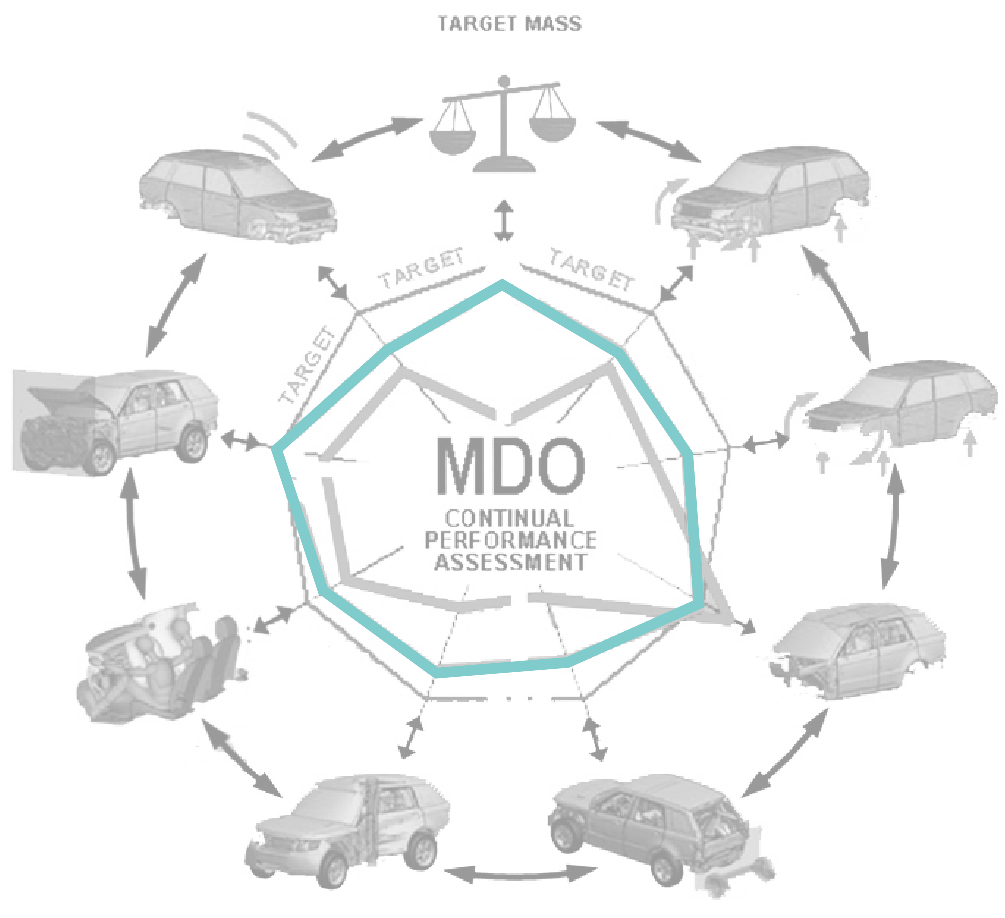
SO THEY NEED TO BE DESIGNED IN AN EFFICENT WAY AND THIS REPRESENTS A CHAL-LENGE

DESIGN OPTIMIZATION

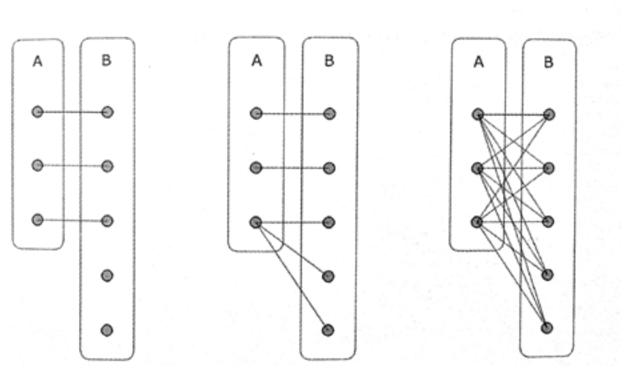
AEROSPACE

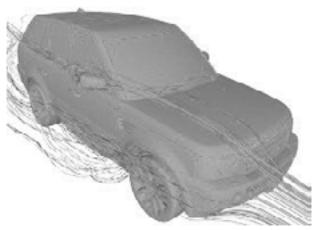


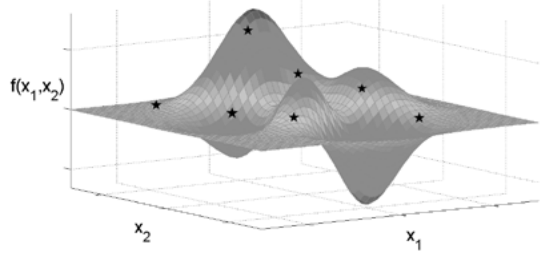
AUTOMOTIVE



SIMULATION-BASED OPTIMIZATION



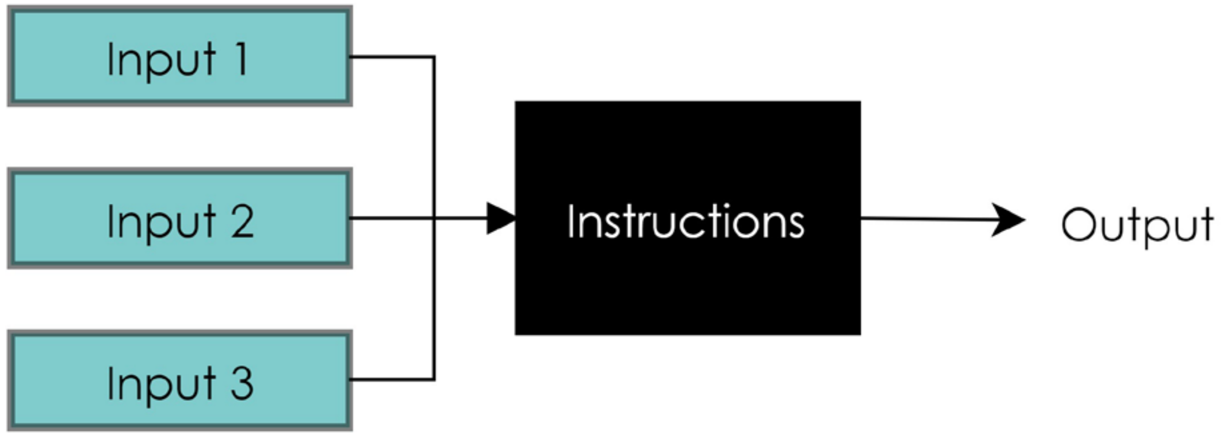


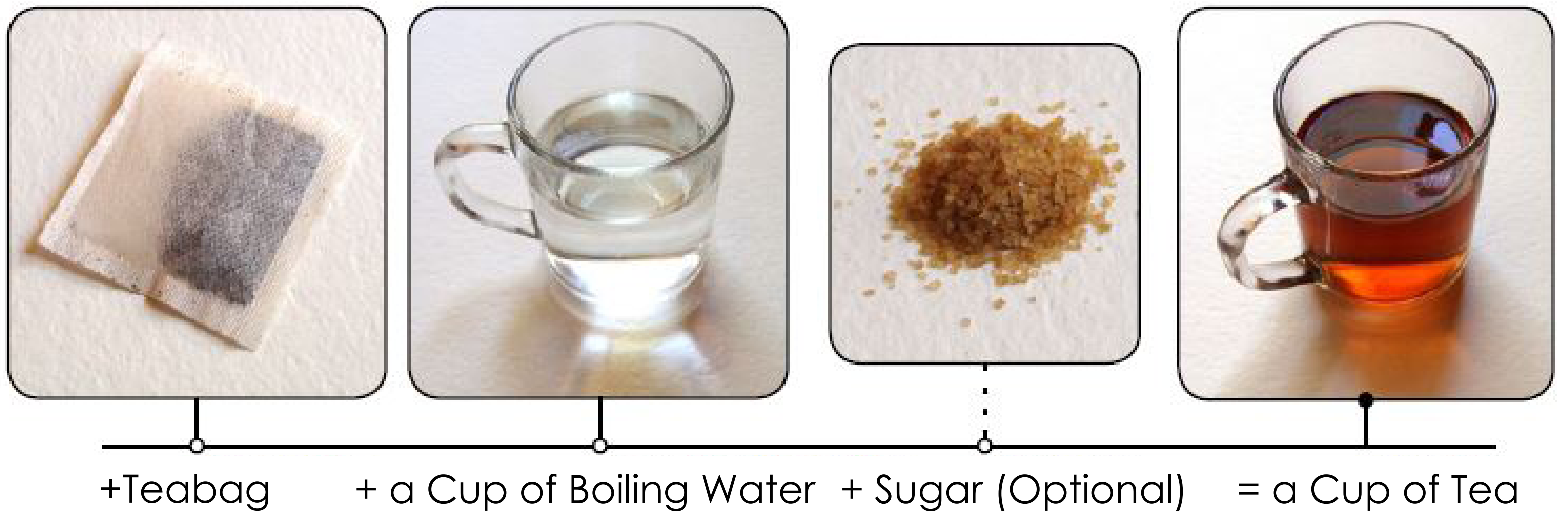


1. PRE-PROCESSING → **2. PROCESSING** → **3. POST-PROCESSING**

PRE-PROCESSING

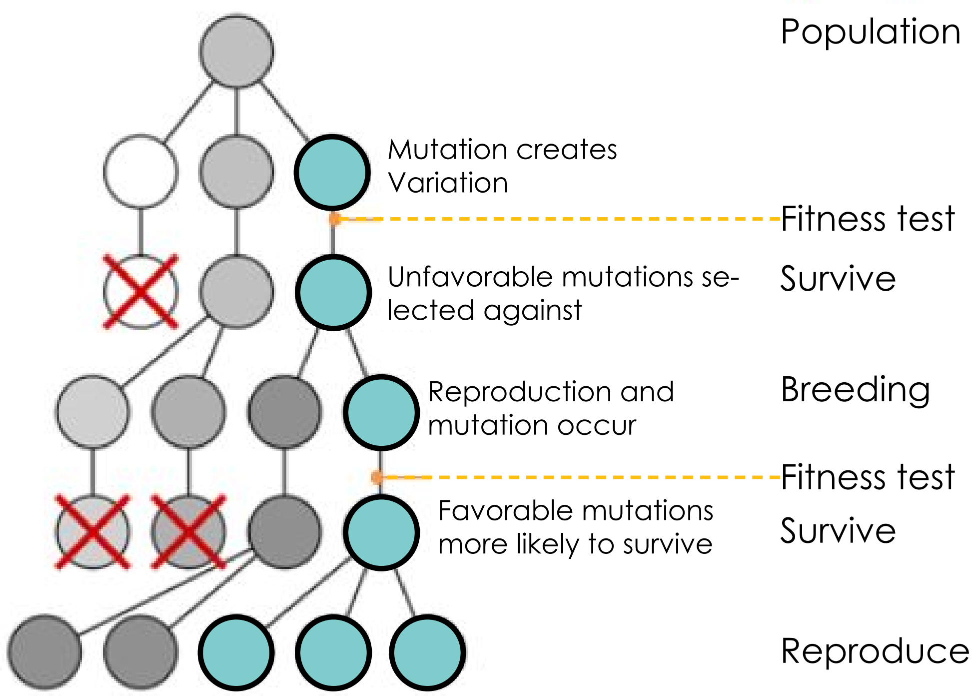
ALGORITHM DESIGN

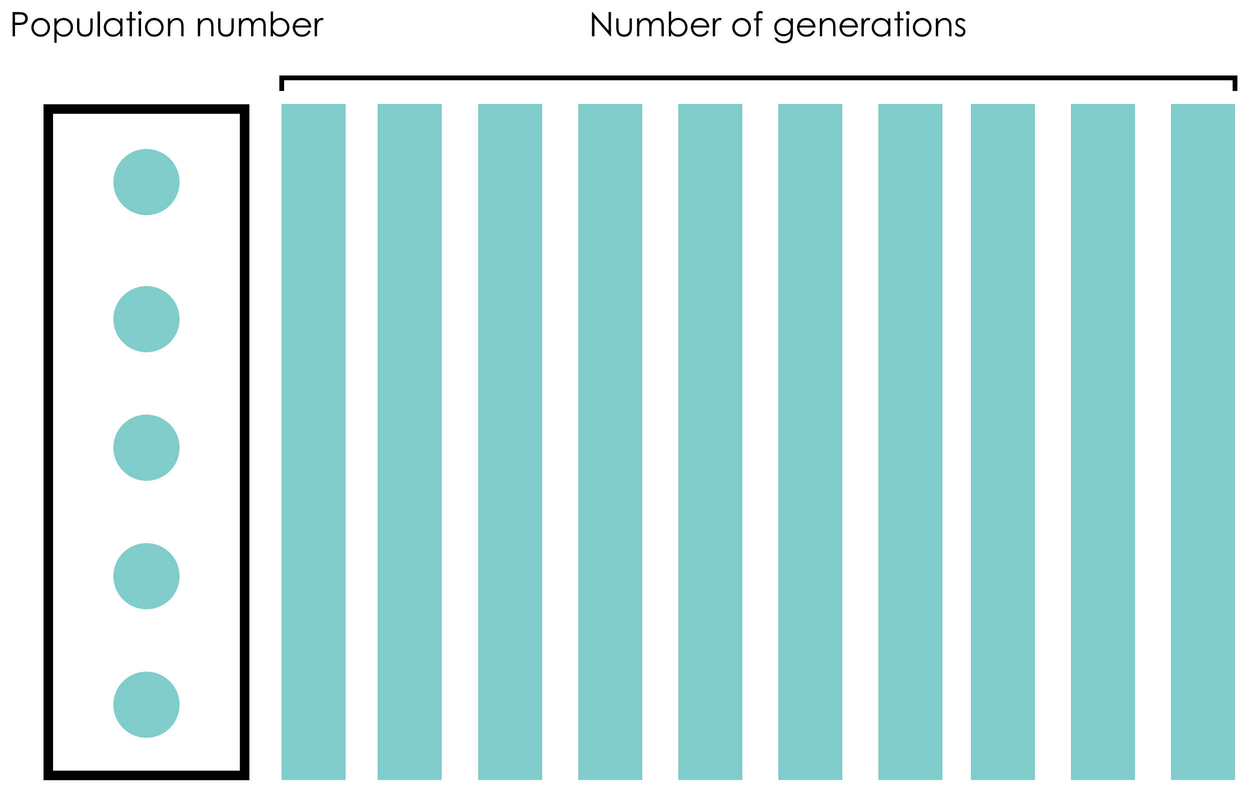




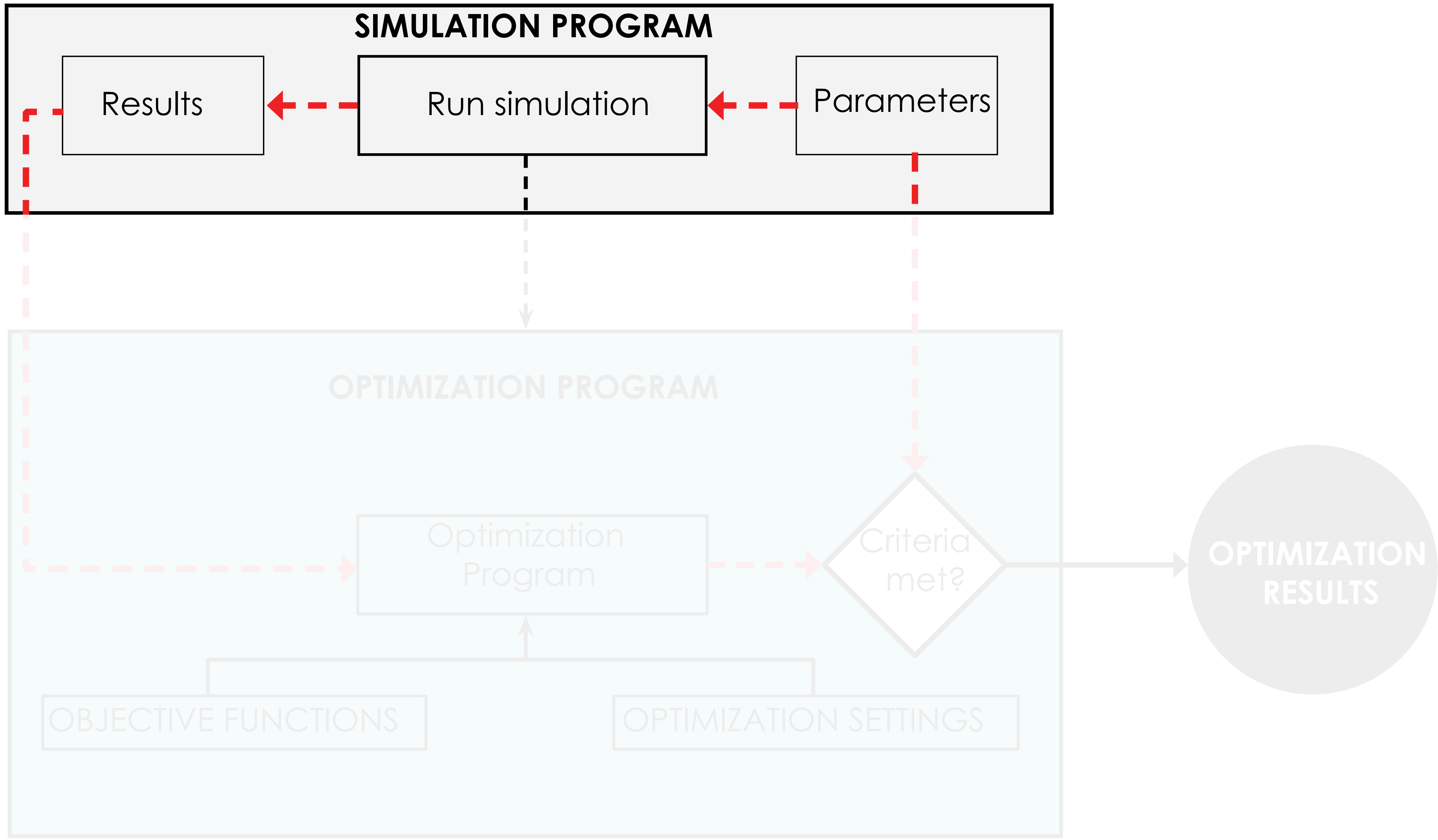
PRE-PROCESSING

EVOLUTIONARY ALGORITHMS



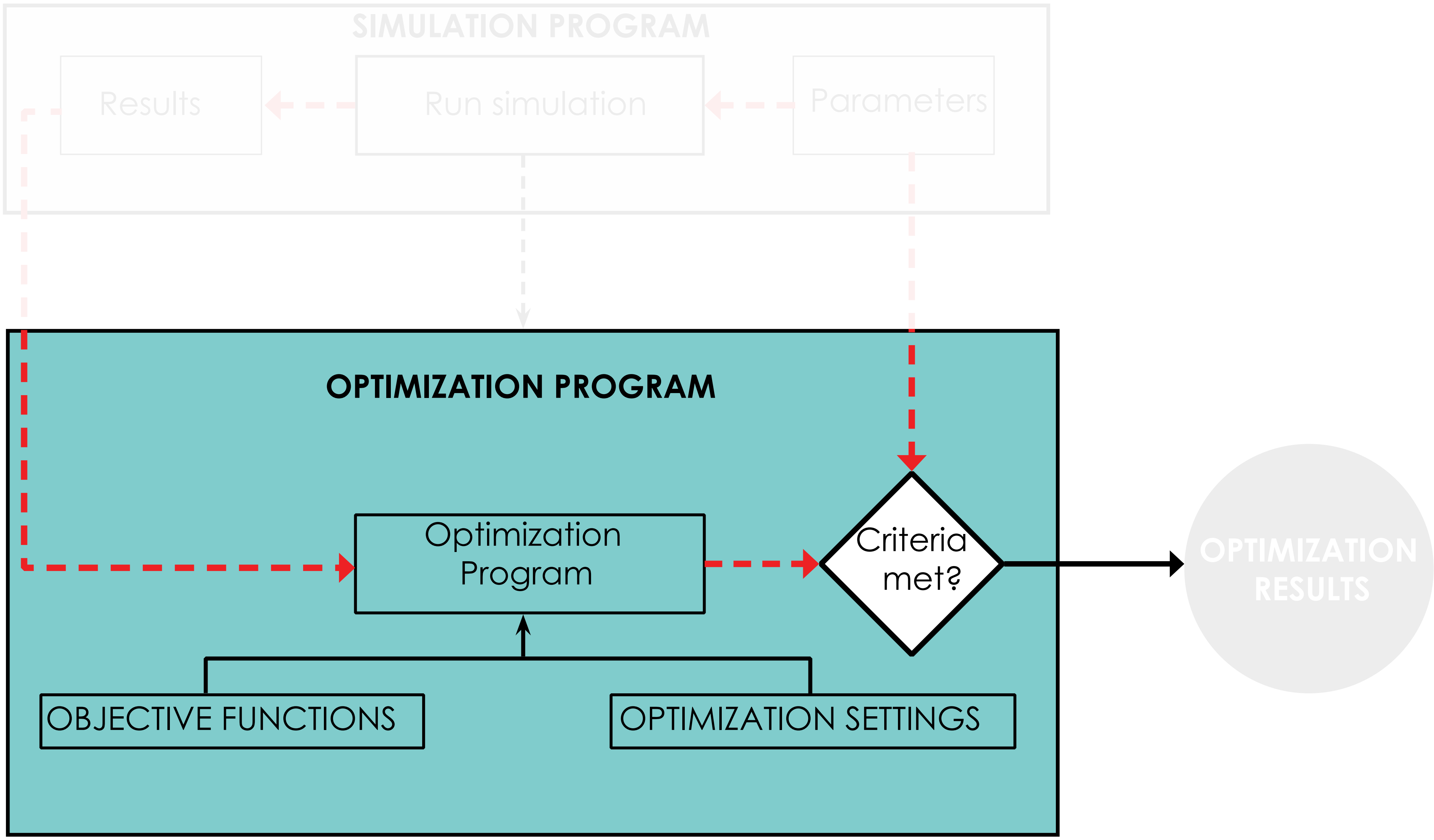


PROCESSING


SIMULATION PROGRAM
Results
Run simulation
Parameters
OPTIMIZATION PROGRAM
Optimization Program
Criteria met?
OBJECTIVE FUNCTIONS
OPTIMIZATION SETTINGS
OPTIMIZATION RESULTS

PROCESSING


1. PRE-PROCESSING
2. PROCESSING
3. POST-PROCESSING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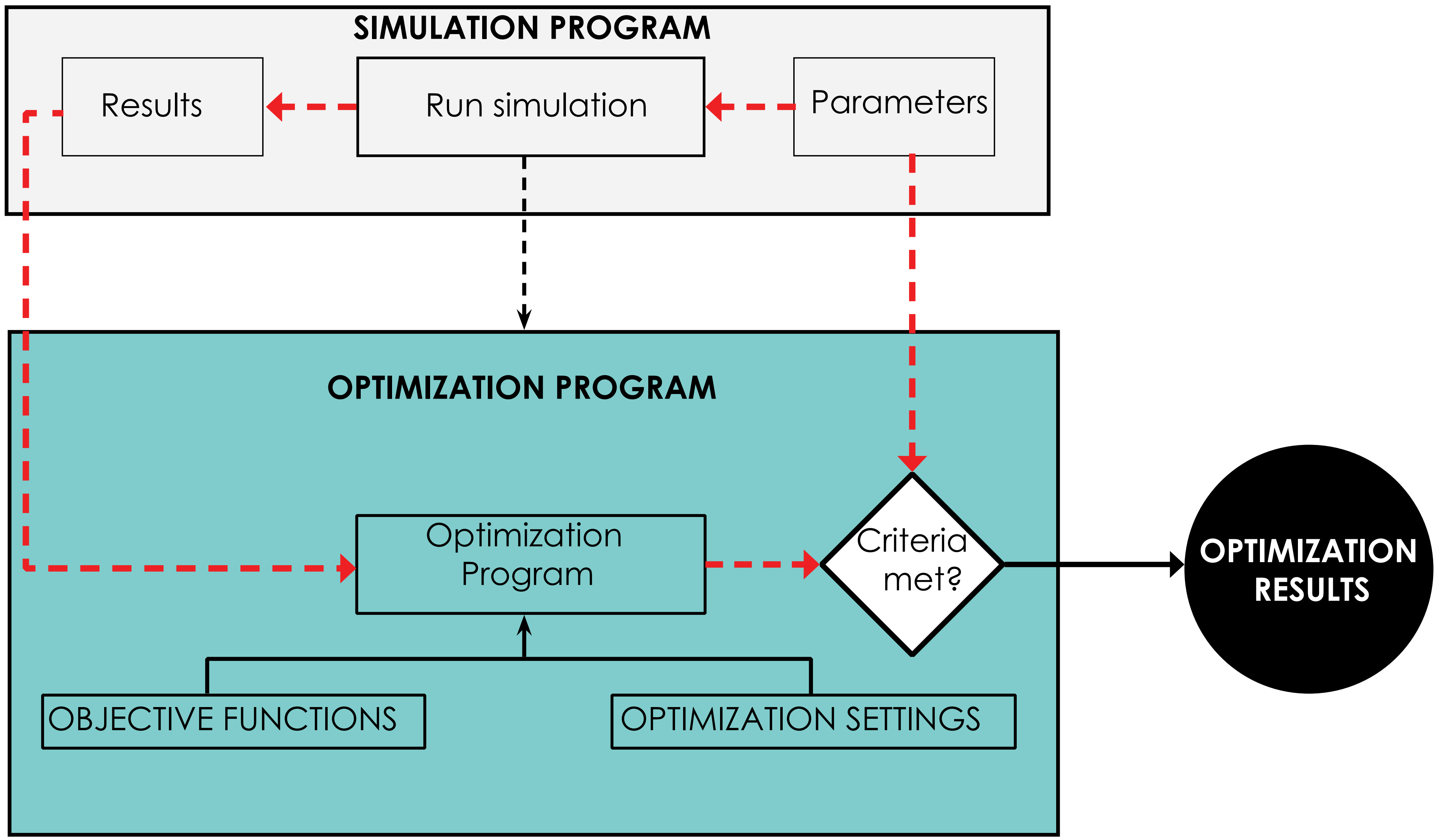
SIMULATION PROGRAM
Results
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Parameters
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Optimization Program
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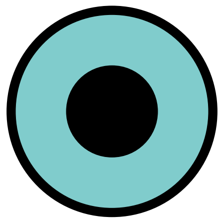
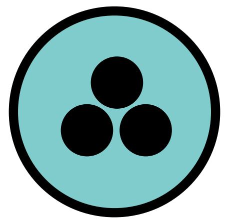
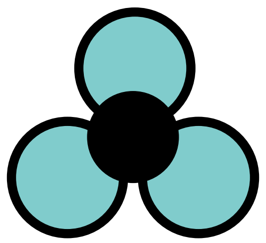
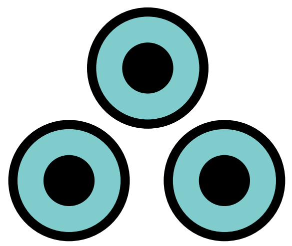
OPTIMIZATION RESULTS

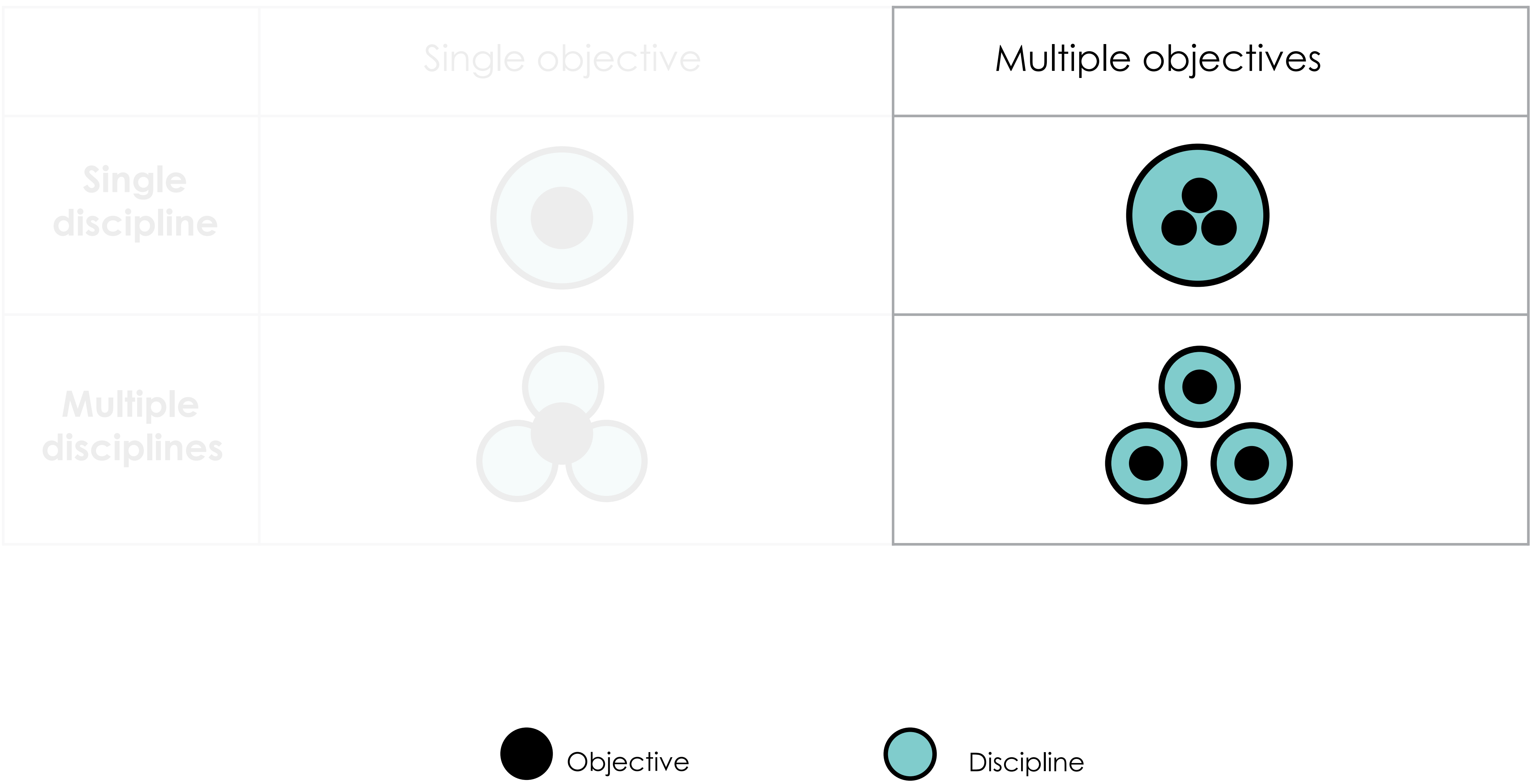
TYPES OF OPTIMIZATION

	Single objective	Multiple objectives
Single discipline		
Multiple disciplines		

Objective

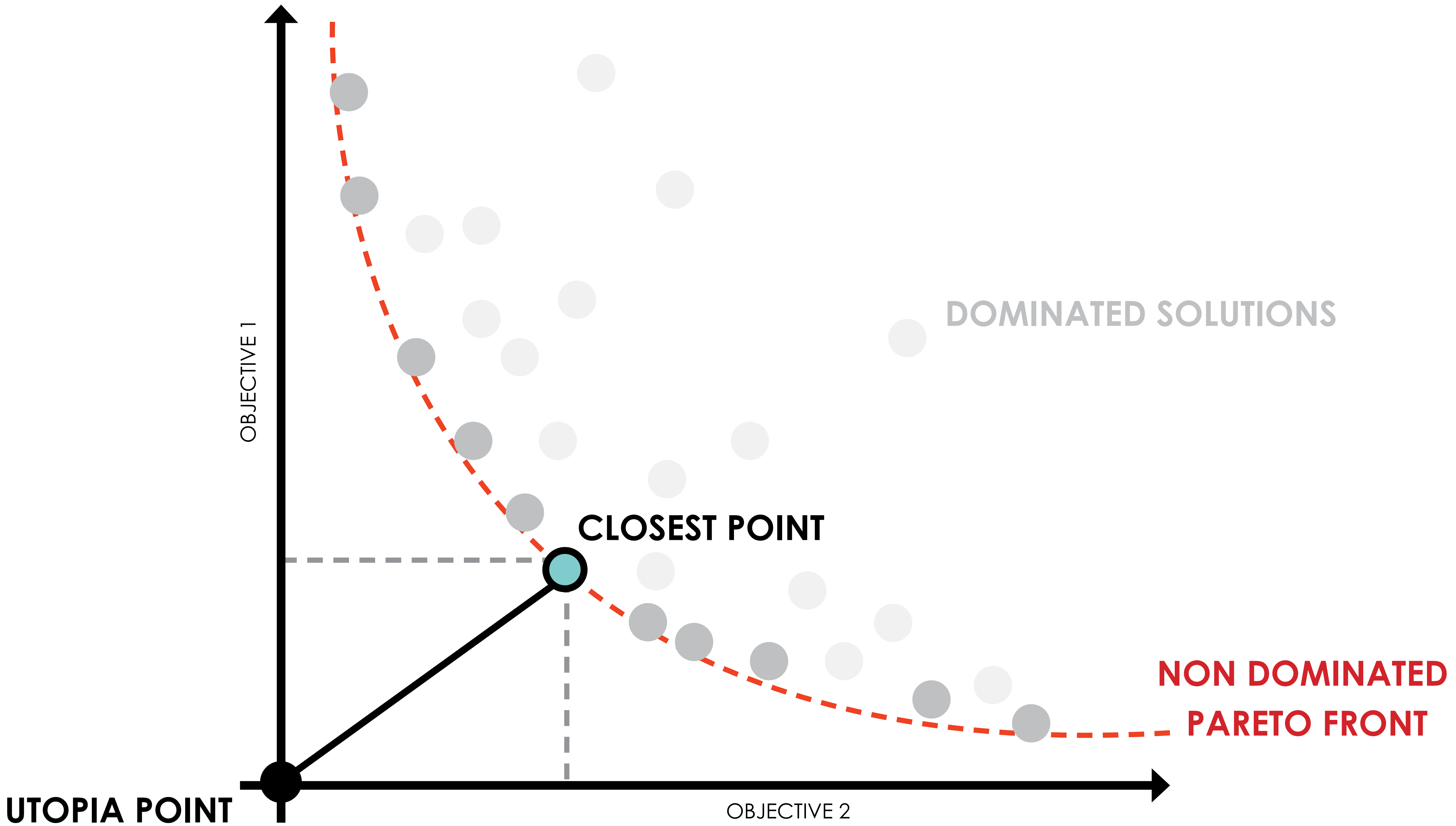
Discipline

TYPES OF OPTIMIZATION



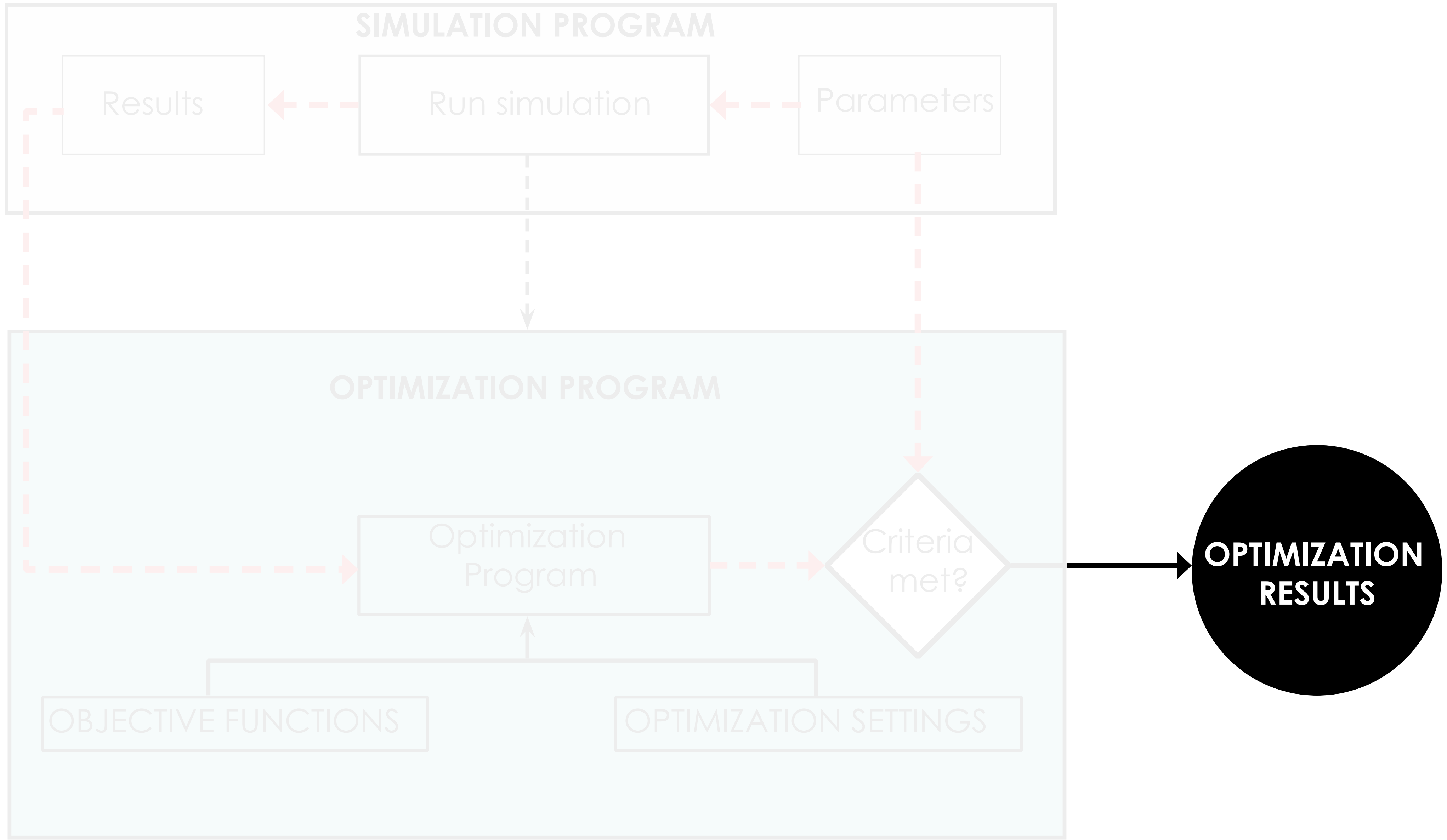
MULTI-OBJECTIVE OPTIMIZATION

1. PRE-PROCESSING → 2. PROCESSING → 3. POST-PROCESSING



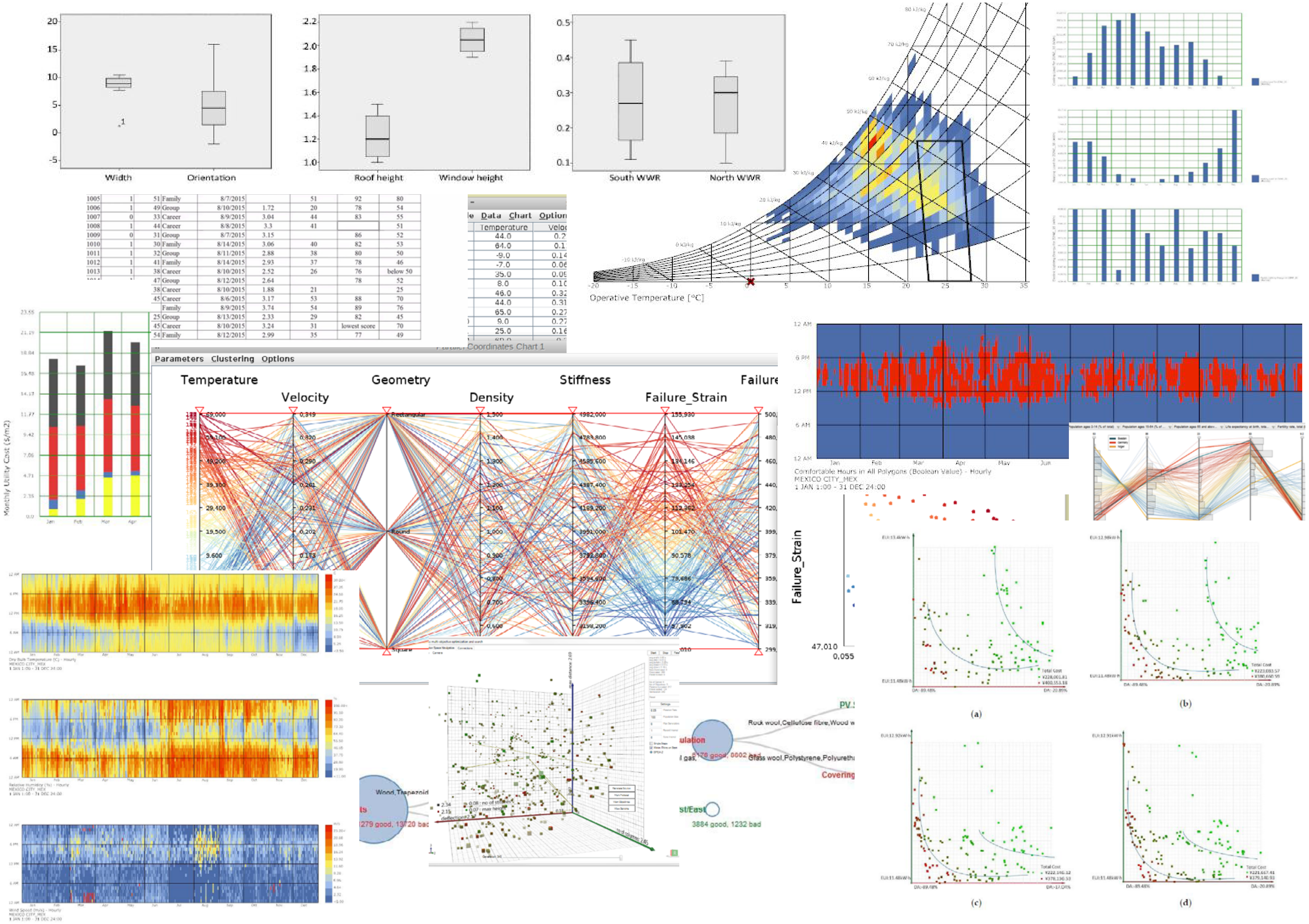
POST-PROCESSING

1. PRE-PROCESSING → 2. PROCESSING → 3. POST-PROCESSING



POST-PROCESSING

1. PRE-PROCESSING → 2. PROCESSING → **3. POST-PROCESSING**

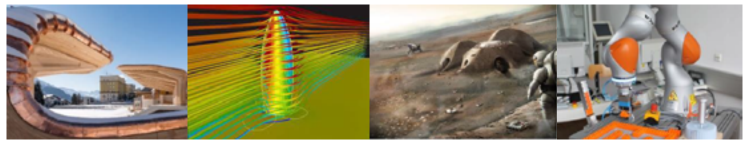


1

PERFORMANCE BASED DESIGN SPECIALIST

QUESTIONNAIRE (PERFORMANCE-BASED DESIGN SPECIALIST)
JAN DIERCKX
FOSTER AND PARTNERS - SPECIAL MODELLING GROUP

Foster + Partners



1. **What is your background?**

I did a double degree in civil engineering and architecture. I liked this because it combines the aesthetics of design with the efficiency of engineering. After that I did a year out in RWTH in Germany where I became very accustomed with compute aided tools and digital manufacturing. This lead to my postgraduate at the Bartlett in London which was very design oriented but backed by computational analysis.

2. **How do you use Computational design in your office?**

We use computational design for almost everything. The design philosophy of Foster + Partners is one of integrated design, where things don't only look beautiful but also are performative. We use a lot of solar, shading, view analysis to optimize facades which usually directly influence parametrically designed options.

3. **Which are the most common aspects or disciplines that you normally apply performance simulations and optimization strategies?**

The two most common aspects are structural efficiency and energy efficiency. We look at making the best possible use out of the materials we choose and vary geometry and buildup to make this possible

4. **What kind of software do you use for energy and cost simulation and which one for optimization purposes?**

We use a multitude of tools to achieve an optimal design and are always looking to expand and improve our knowledge. Our team uses a lot of Grasshopper and Dynamo which we usually augment with our own custom tools.

5. **Why do you think Performance-based generative design (Quantitative /numerical assessment of a design) and design optimization procedures are still a not that common practice in most of the architectural firms?**

Architecture and especially construction is a slow-moving field, not adjusting as quick as product and industrial design. Although many of the new generation of architects has some knowledge of performance-based design, it will take some time for this to become mainstream. For now it is limited to very large projects in big practices, where there is scope to hire specialist, and budget to look into optimization.

6. **How do you see the future of the architect from a technological point of view?**

I feel an architect will increasingly be enabled to make informed decisions to design in a more performative way. Creativity will always come from the human mind, but computers can assist a great deal in helping us to see things from a different perspective and open up solutions we might not have thought of ourselves

3

PERFORMANCE BASED DESIGN SPECIALIST

WALTER WOODINGTON
SENIOR ENGINEER
THORNTON TOMASETTI

Thornton Tomasetti

1. **What is your background?**

BS-Civil Engineering (concentration on structures)
MS-Building Engineering (TU Delft, interest in special structures and façade structures)
Professional-Glass (stairs, structural fins, facades). Cable and membranes (shading structures, bicycle wheel stadia) Grid shells(steel, domes and shells, small and large). EFTE cushion facades and structures. Façade engineering (mullions, system selection, glass sizing). Forensic (Glass breakages). Field inspections (anchorages, splices, etc.) Pneumatic/inflatable structures.

2. **How do you use Computational design in your office?**

The office is quite large an uses computational design to varying degrees between groups and projects. Generally: Parametric design is used to aid the architect in formal and structural exploration as well as a way to produce drawings, this involves vary many computer programs (grasshopper, dynamo, Catia, excel and others) At the early stages of design computational design is used as a way to open up formal/geometric options to architect, at mid stages these tools are used to evaluate design options and narrow the design space, at later stages these tools are used to adjust and improve the design, towards the end of a project these tools are used to finalize engineering design and eventually produce drawings.

3. **Which are the most common aspects or disciplines that you normally apply performance simulations and optimization?**

These concepts are used in very many different degrees based on topic. For thermal and energy aspects the results of simulations are used more generally to assess massing and façade properties. These optimizations can lead to glass frit pattern variation to reduce solar heat gain or glare. Commonly optimization is done for lateral design of tall buildings, for example setting drift targets can lead to the design of a core to the level of wall thickness, outrigger location, and guidance on core penetration percentages. For grid shells, tensile structures, and other structurally driven forms simulation/optimization could be called "form finding" which we apply at very early stages of a project to set certain criteria (such as rise/span ratio and boundary conditions) which must be architecturally suitable but however we also perform this for inflatable structures and bending structures(see images above)

4. **What kind of software do you use for structural design, energy and costs simulations and which one for optimization procedures?**

MS Excel works very well for everything, tying into it with python and other scripts allows us to impose optimization and other techniques into most other software. Within my group in the office we typically use grasshopper to narrow down formal aspects with architects early on. Then we move on to SOFiSTiK for more complicated form finding/force finding, and preliminary sizing, global buckling checks and eigen mode analysis are also checked here for confirmation with the wind consultant, to understand the structure from a stiffness standpoint, from there we move on to SAP, EASY, Strand7 and other software to validate our previous analysis, check against code, and to proceed with detail design.

1

TECHNOLOGY DEVELOPER

QUESTIONNAIRE (TECHNOLOGY DEVELOPER)
MINGBO PENG
COLIBRI & DESIGN EXPLORER DEVELOPER

1. **What is your background?**

I studied Architecture in Bachelor and Master, and my second Master is environmental building design.

2. **Which kind of algorithms do you normally use for optimization problems related to Buildings design?**

I don't use any algorithm specifically in my daily work. What I do the most is parameter sensitivity test, and this is what Colibri and Design Explorer mainly do. They are designed to assist the design process, instead of providing the answer.

3. **Which are the most common aspects or disciplines that you apply performance simulations and optimization procedures?**

I use annual daylight simulation (sometime use point-in-time daylight simulation when designer is hard to understand the annual matric), point-in-time glare study, along with cooling and heating peak load for hvac sizing.

4. **What kind of software do you use for energy and cost simulation and which one for optimization purposes?**

For the energy, I use EnergyPlus along with Honeybee and OpenStudio. I don't do any cost simulation, that is usually done by our façade team.

I wouldn't say I do any optimization work, most of my work is exploring study and sensitivity test as I mentioned above.

5. **Why do you think Performance-based generative design (Quantitative /numerical assessment of a design) and design optimization procedures are still a not that common practice in most of the architectural firms?**

Well, first I think the performance based design is not common yet, but it is moving toward it. Second, what we can say about performance-based design is mainly focusing on daylight and energy, which are two aspects currently feasible to do alone with architecture design process. Designing a building is not only about daylight and energy, there are more others consideration that cannot be easily quantified. Just as same as "AI" world, AI can do everything except the art, which is the part that still require human to be involved. Third, even though we want to generate a building only focusing on energy, there are still too many parameters to test without cloud computing ability. But this one will be generally available in next five years, I believe.

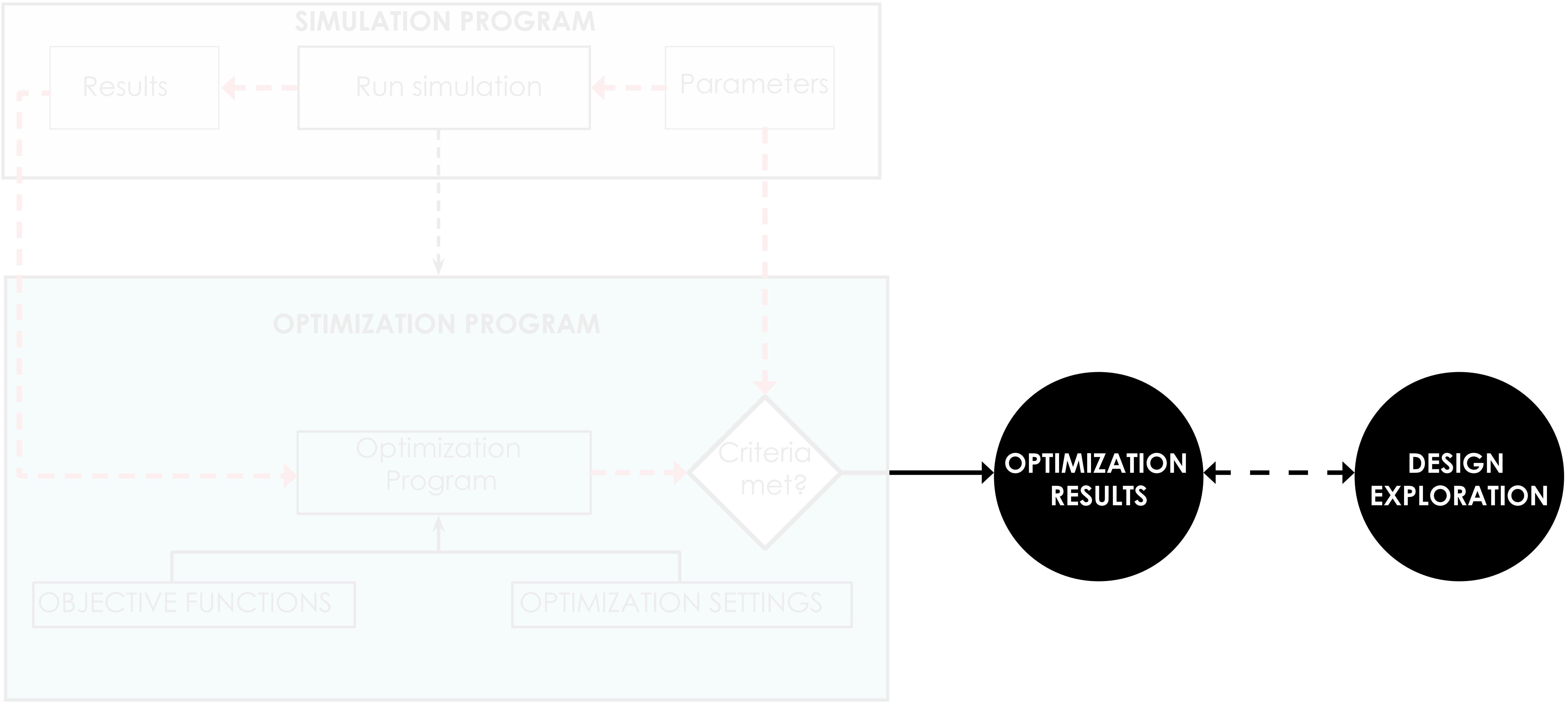
6. **What do you think about the phrase "the designer as a tool builder"**

I totally agree with it, or "the designer should be a tool builder", which I believe is similar to "everyone should learn a computer langrage". It is a different thinking process than "doing one thing", instead, it requires designer to abstract the common rules from "dong one thing" and make this process or "tool" reusable or adaptive.

7. **Do you think that in a near future Artificial intelligence and Machine learning will replace the designers or trigger a jobless future?**

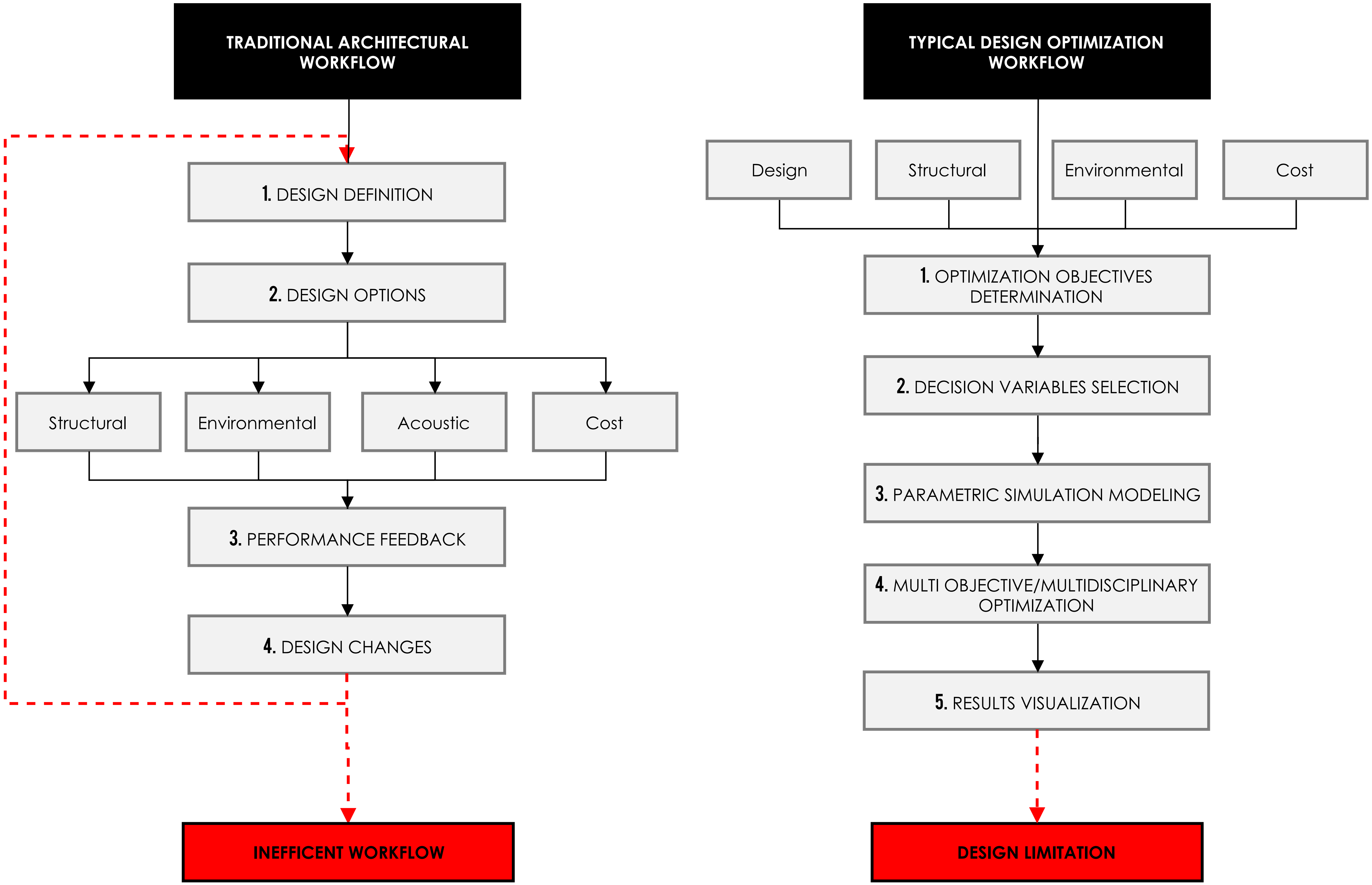
Mentioned above in 5.

POST-PROCESSING

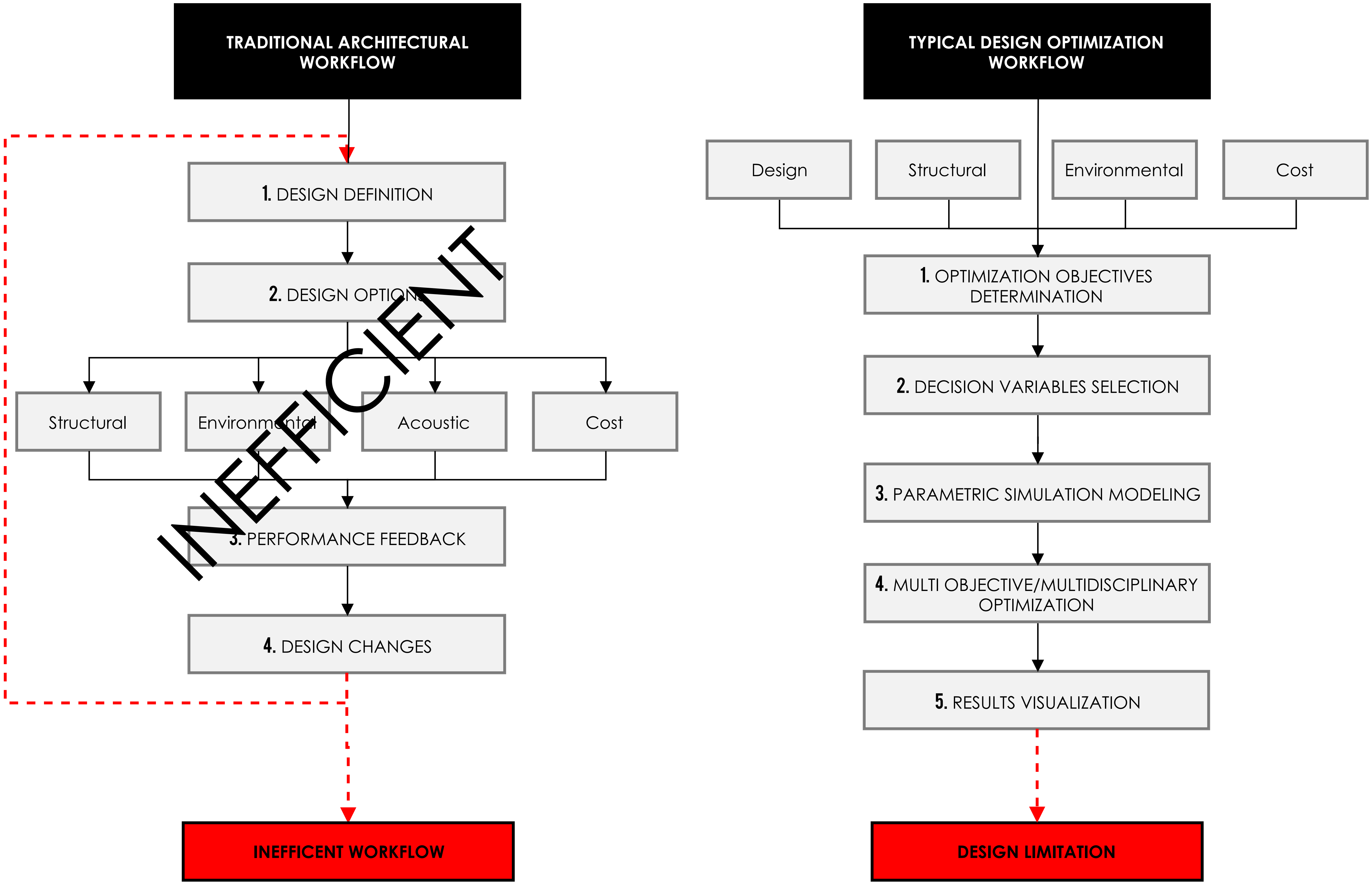


WORKFLOW DEFINITION

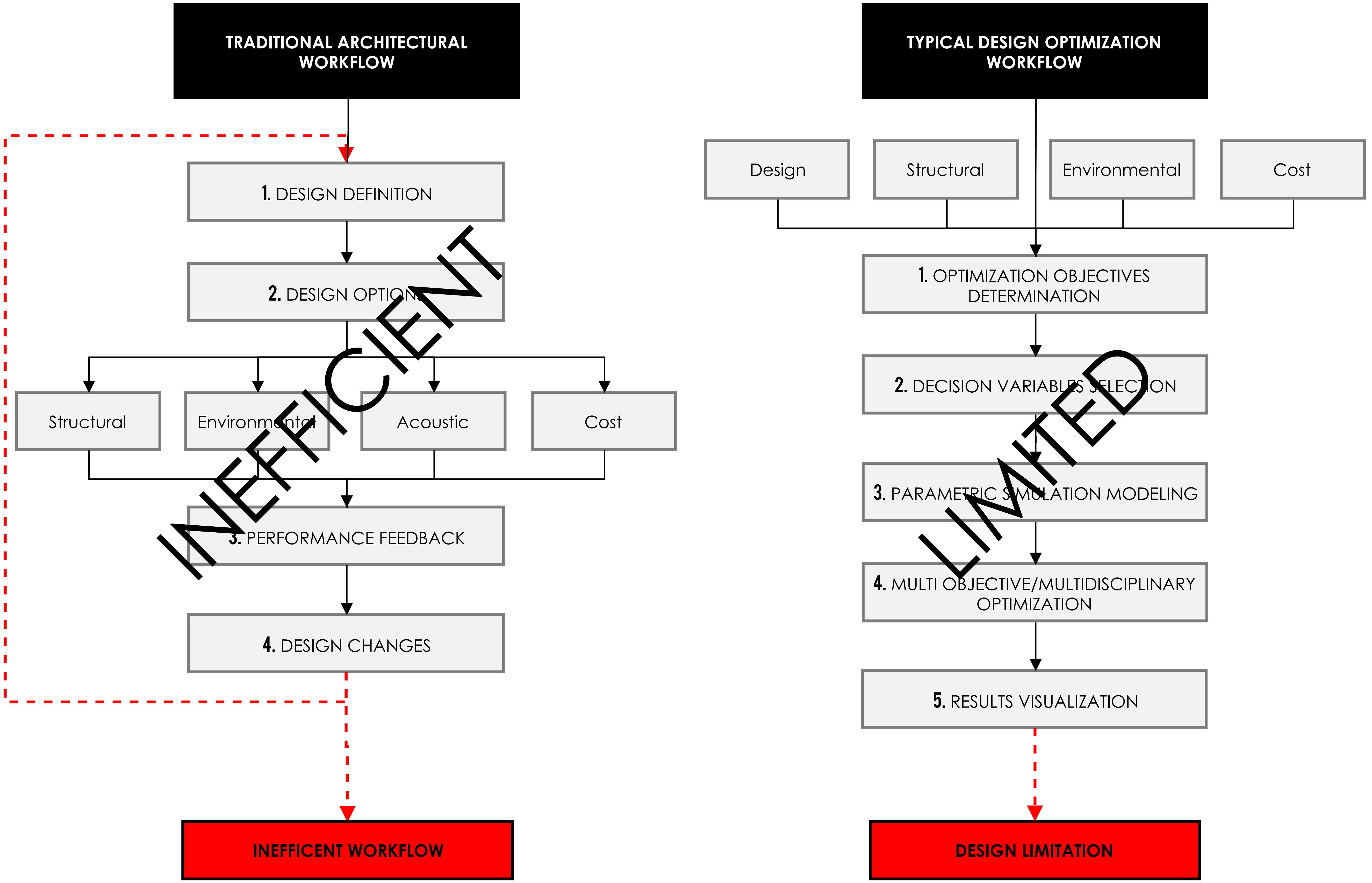
CONVENTIONAL WORKFLOWS



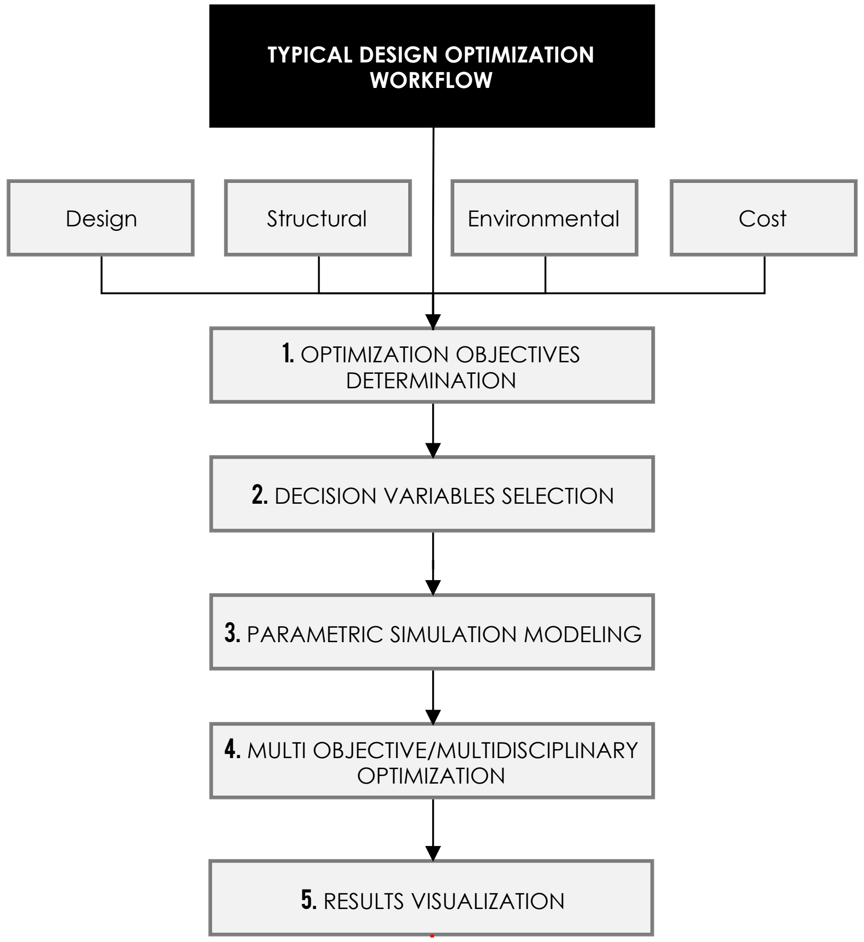
CONVENTIONAL WORKFLOWS



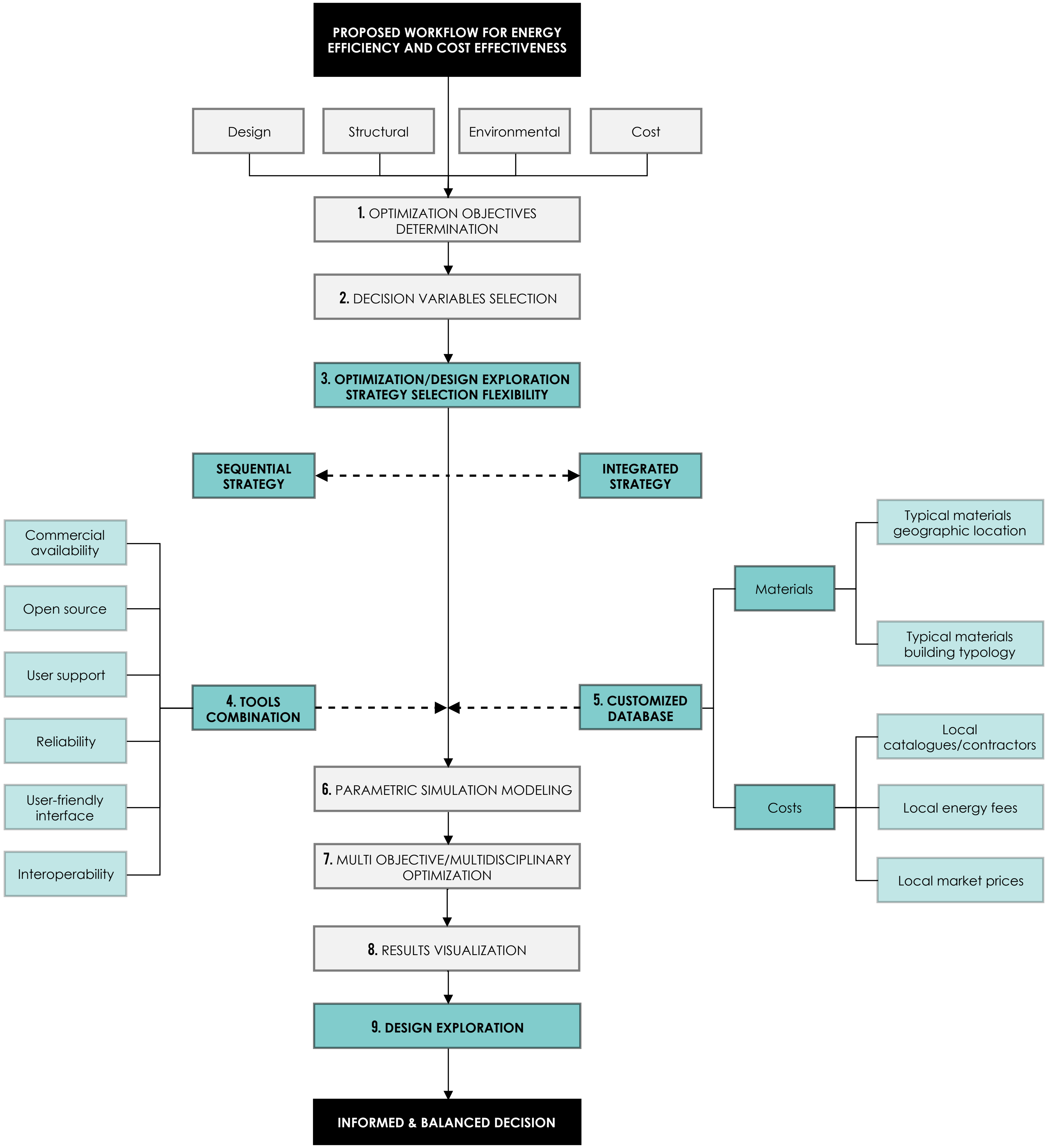
CONVENTIONAL WORKFLOWS



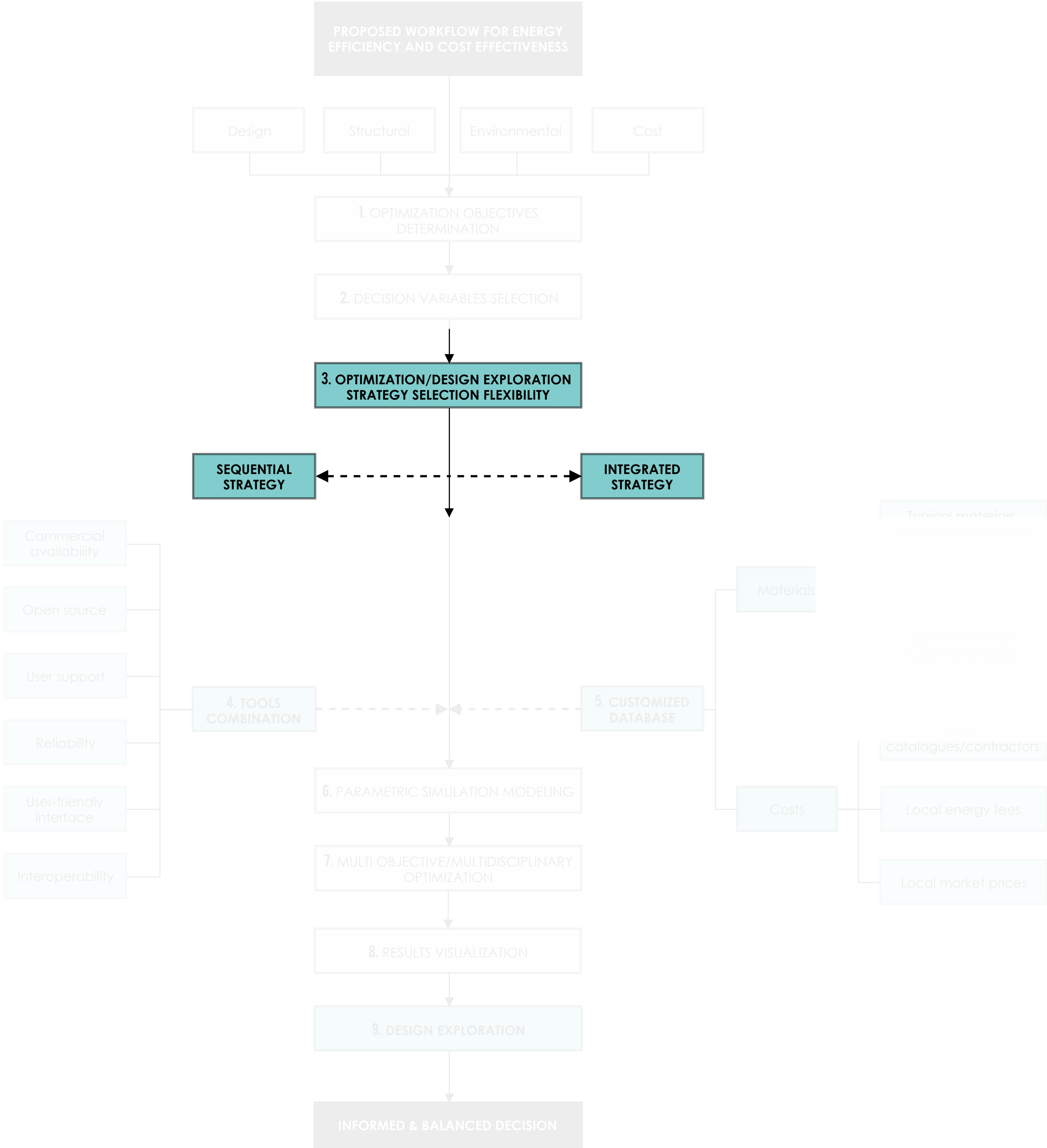
PROPOSED WORKFLOW



PROPOSED WORKFLOW



PROPOSED WORKFLOW



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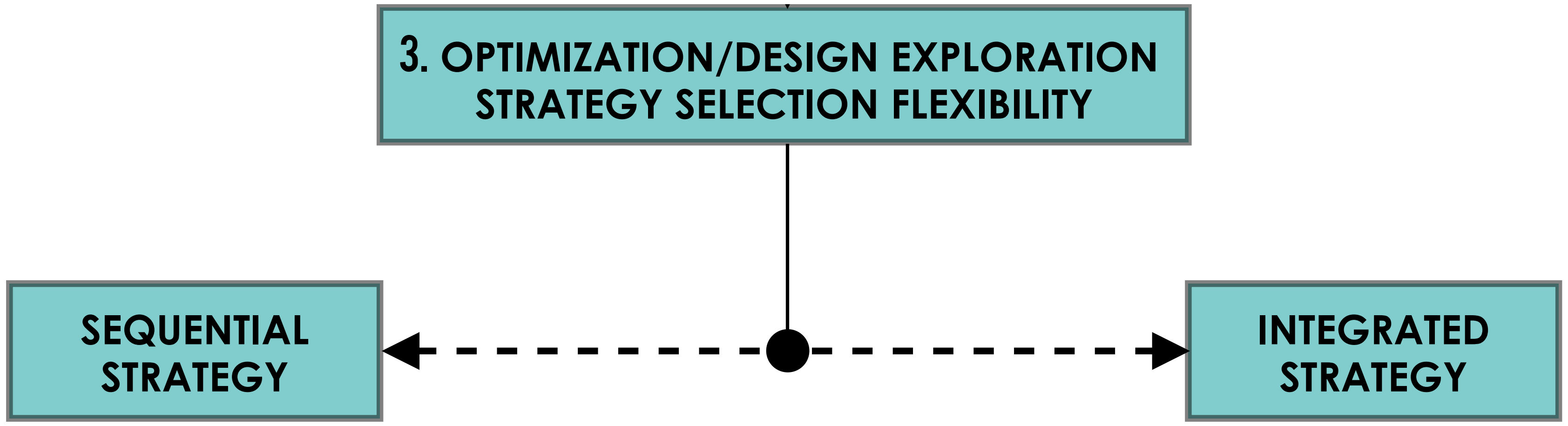
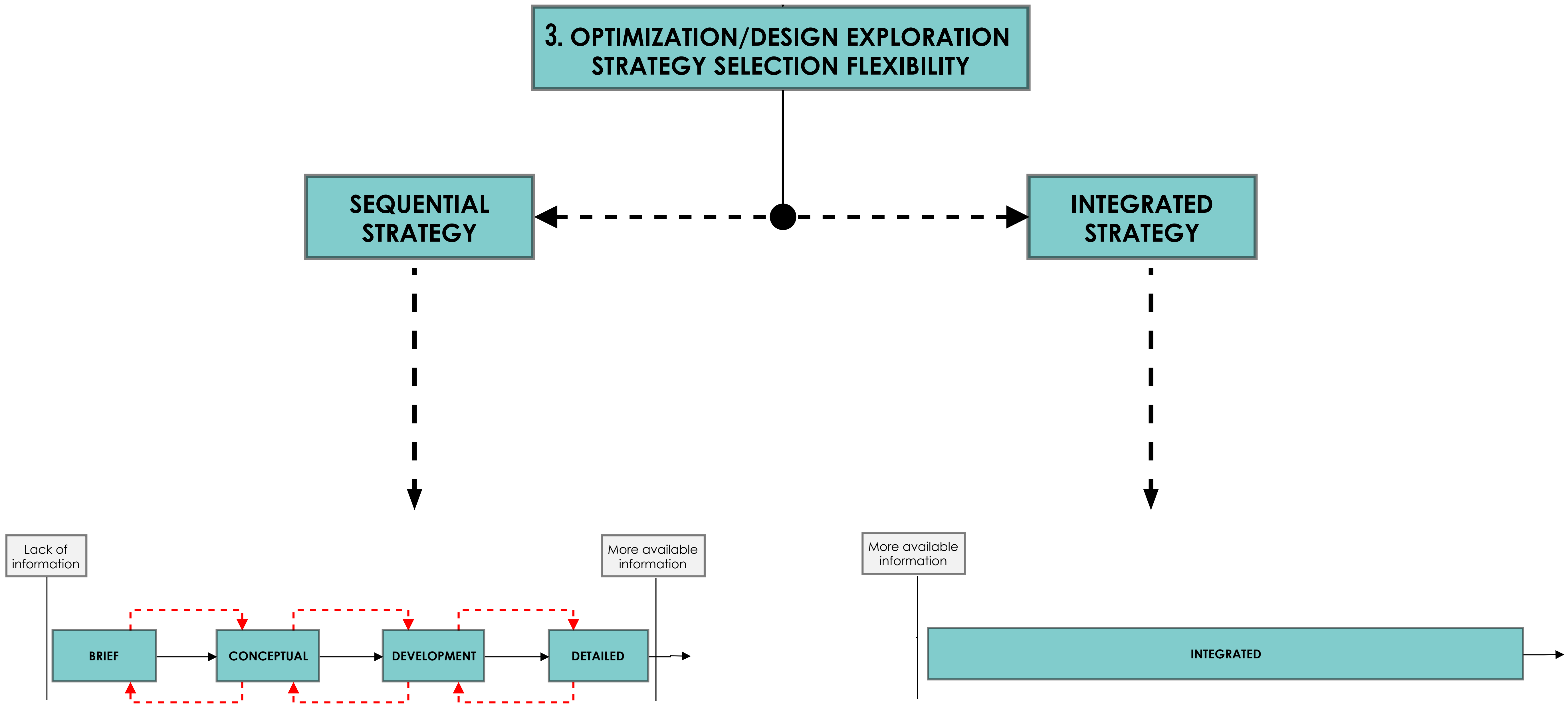
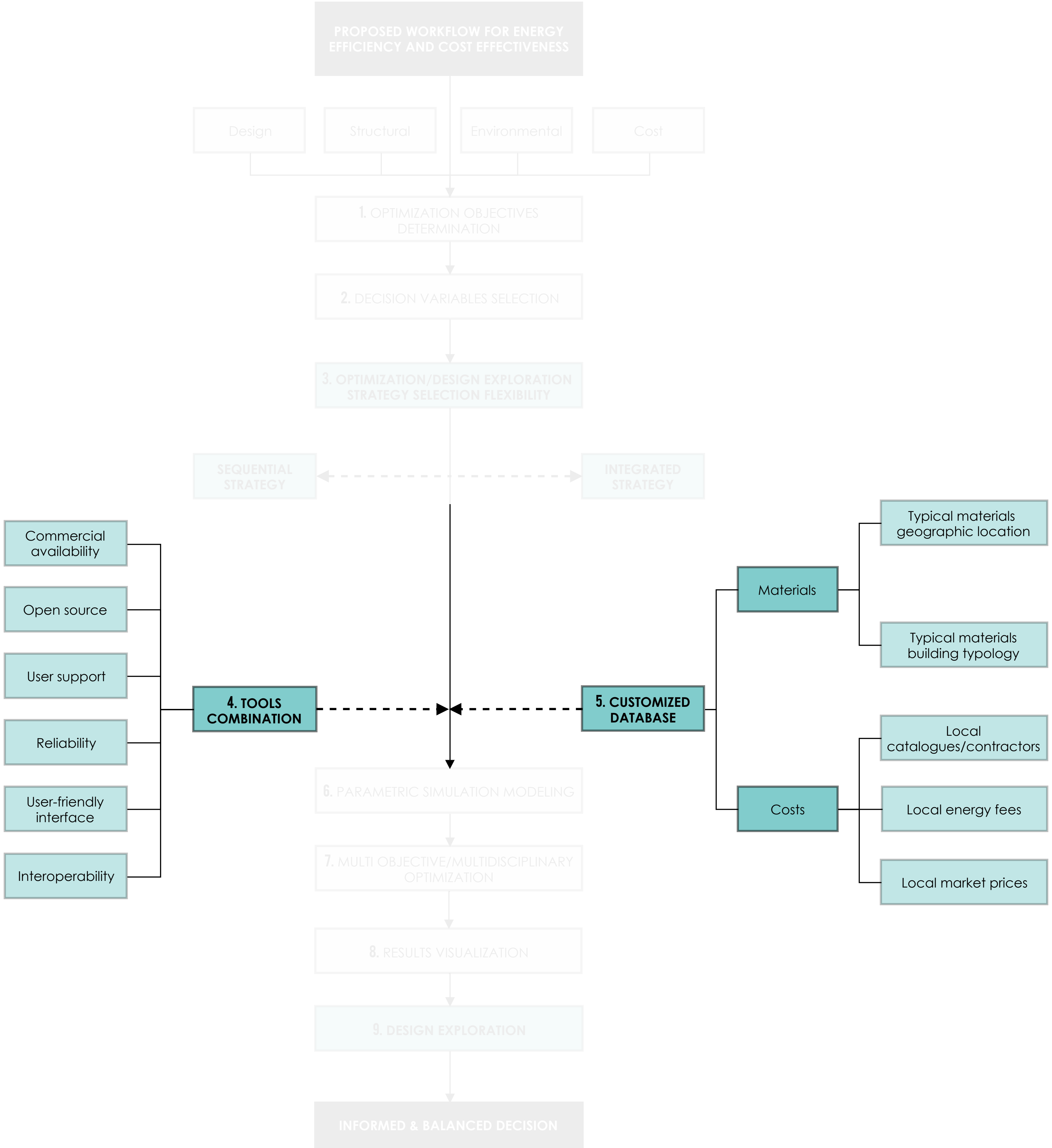


PROPOSED WORKFLOW



PROPOSED WORKFLOW



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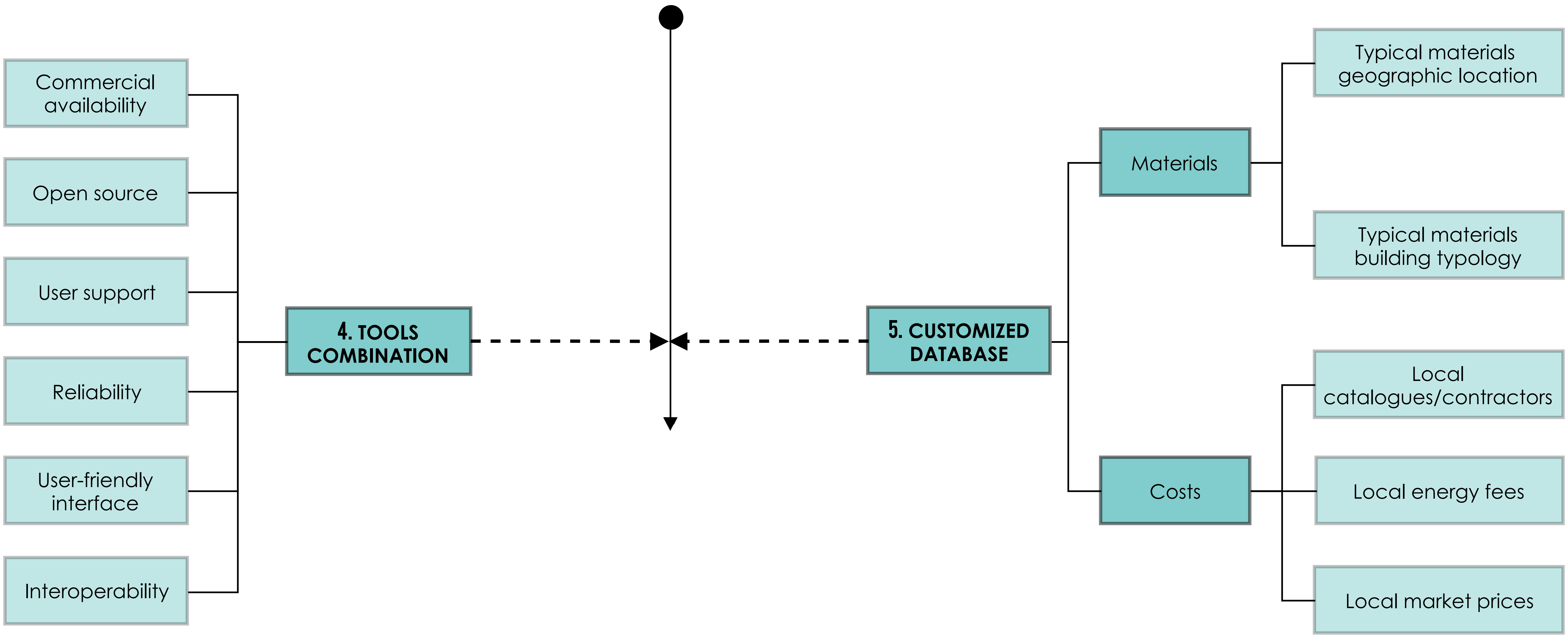
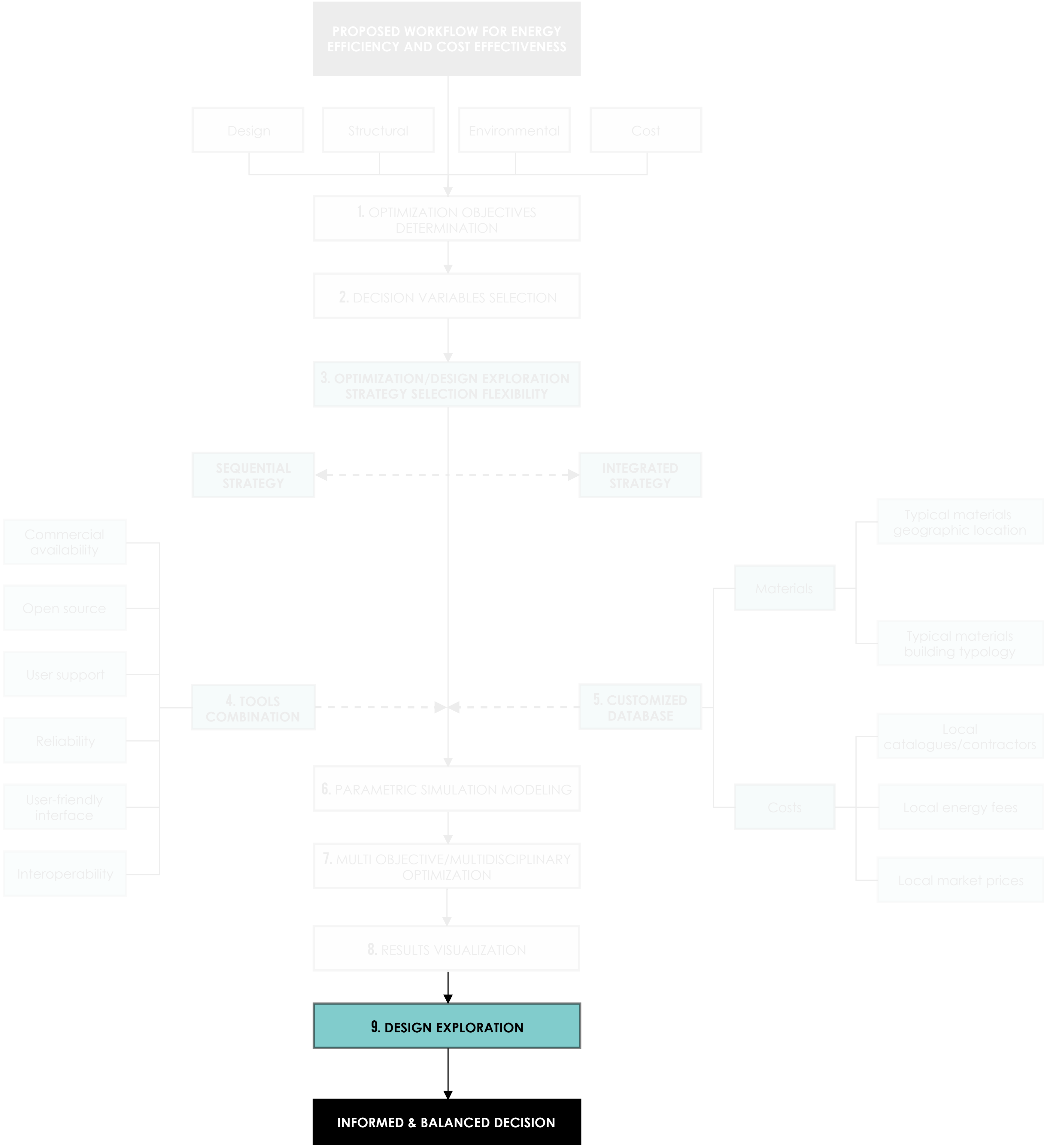
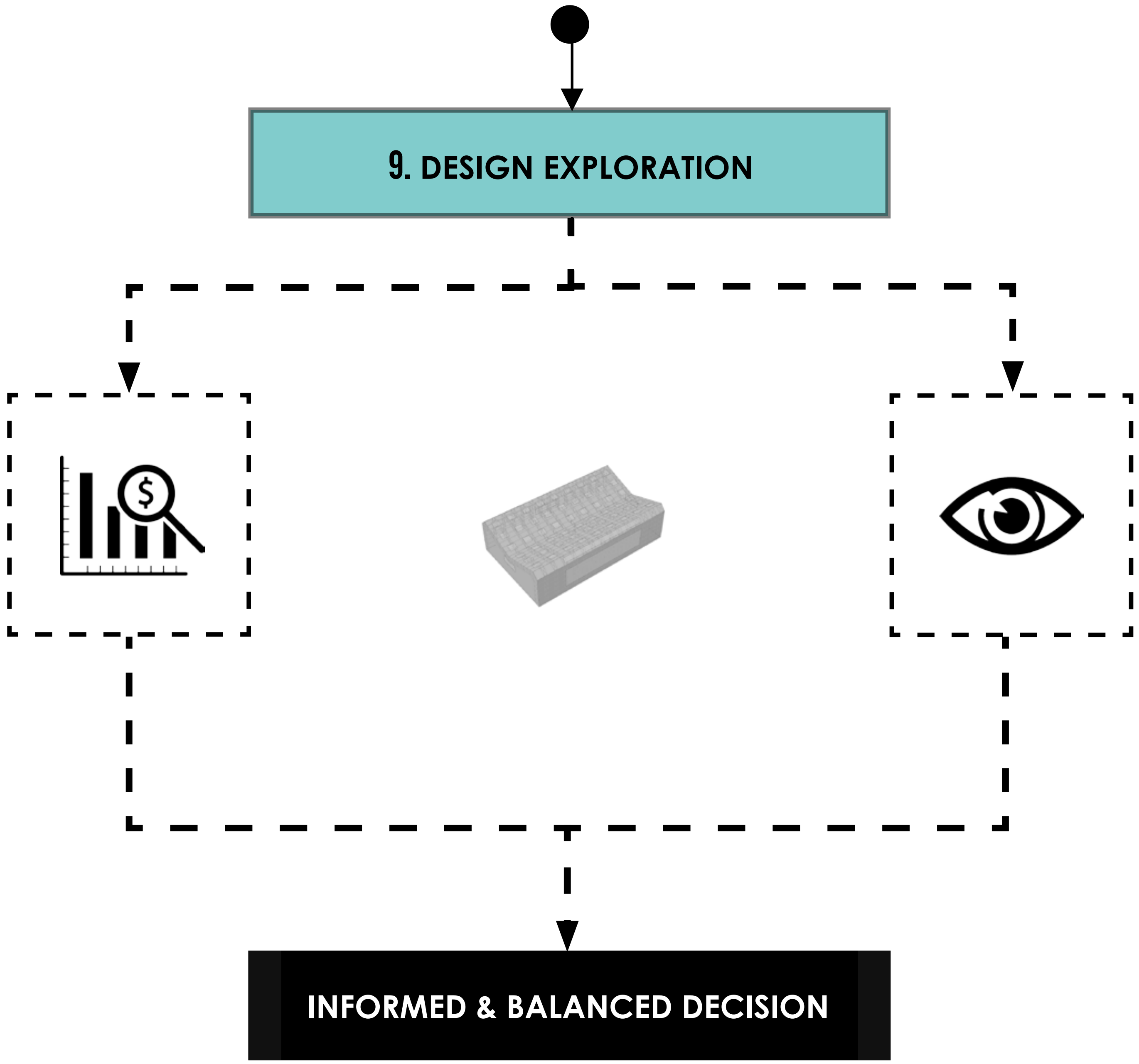


PROPOSED WORKFLOW

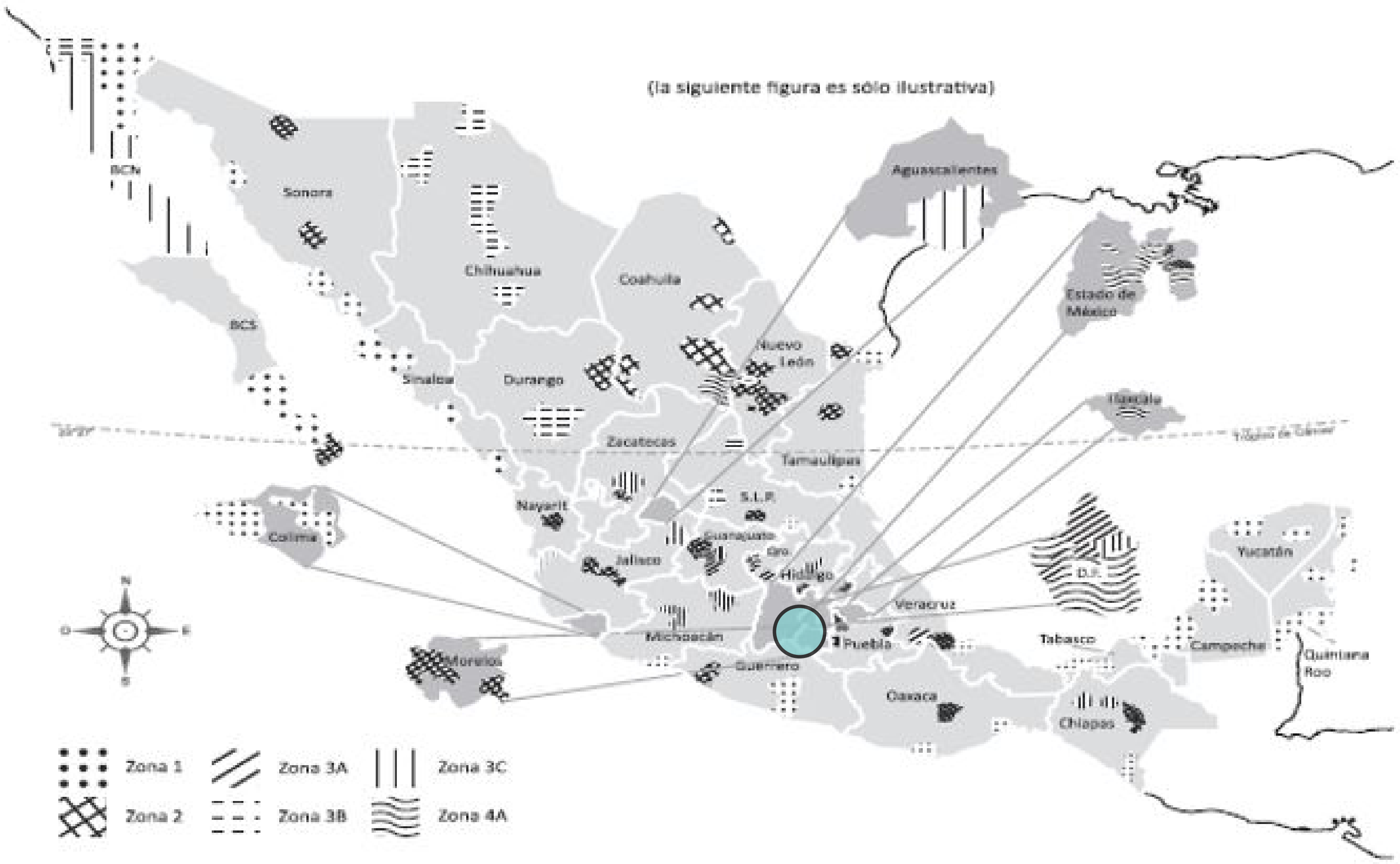


PROPOSED WORKFLOW



CASE STUDY

CONTEXT

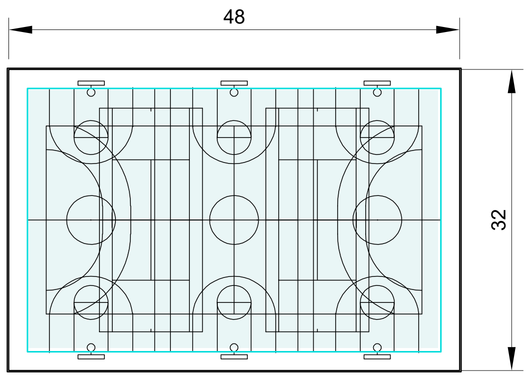


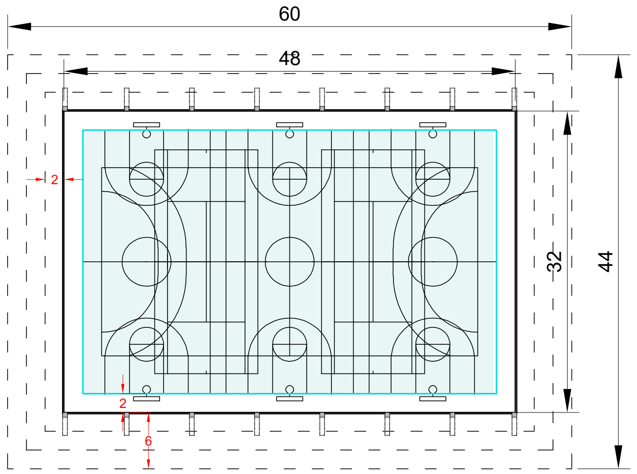
CUITLÁHUAC PARK, IZTAPALAPA, MEXICO CITY

CONTEXT

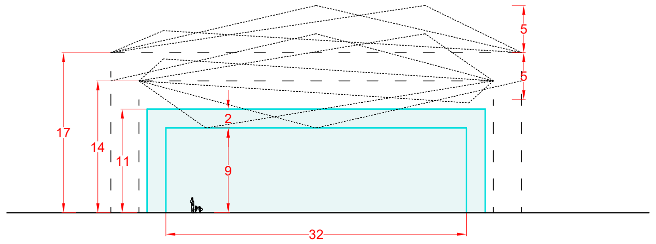
General	
MEX_MEXICO_CITY_IWEC	
Source	IWEC
Country	MEXICO
Filename	MEX_MEXICO CITY_IWEC.epw
Details	
Latitude (*)	19.43
Longitude (*)	-99.06
WMO station identifier	766790
ASHRAE climate zone	3B
Summer	
Summer start month	apr
Summer end month	jun
Extreme hot week, starting	may-27
Typical hot week, starting	may-20
Cooling degree-days (Base 10°C) (Degree days	-
Winter	
Winter start month	oct
Winter end month	dec
Extreme cold week, starting	dec- 3
Typical cold week, starting	nov-12
Heating degree-days (Base 18°C) (Degree days	-

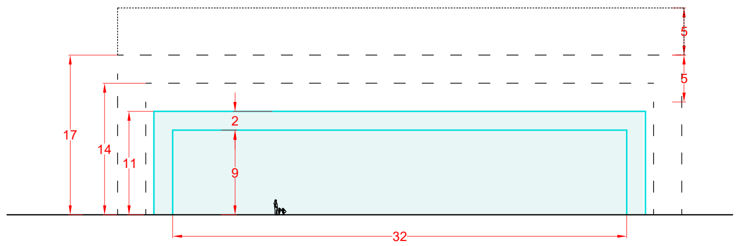
REQUIREMENTS



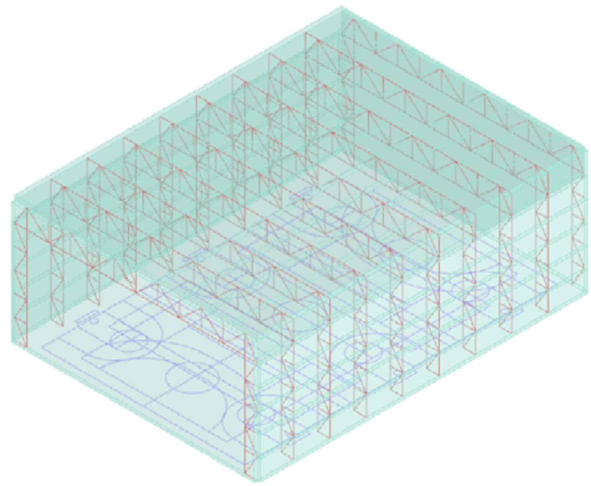


Floorplans

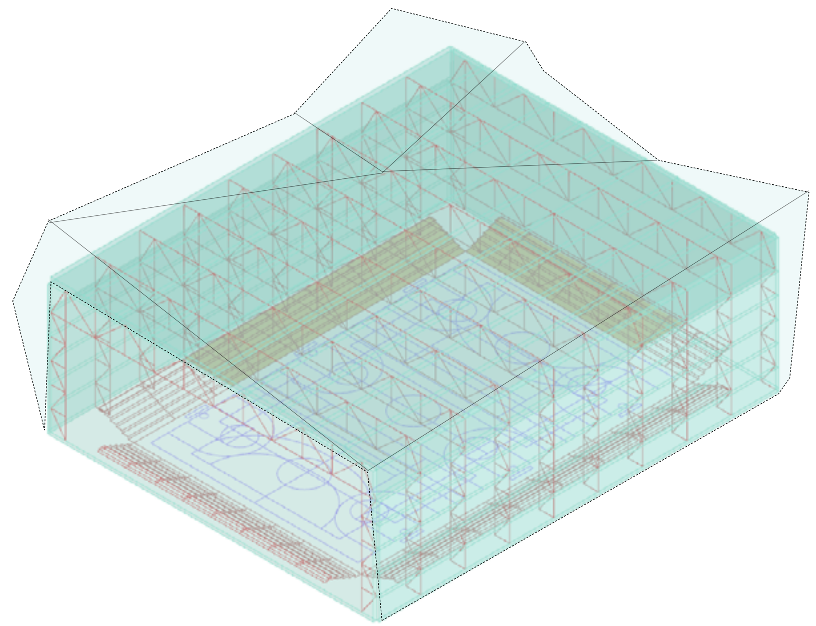




Elevations



Isometric without spectators space



Isometric with possible spectators space

Situation 1 (Without spectators)

Area : 1,536 m2

Volume : 16,896 m3

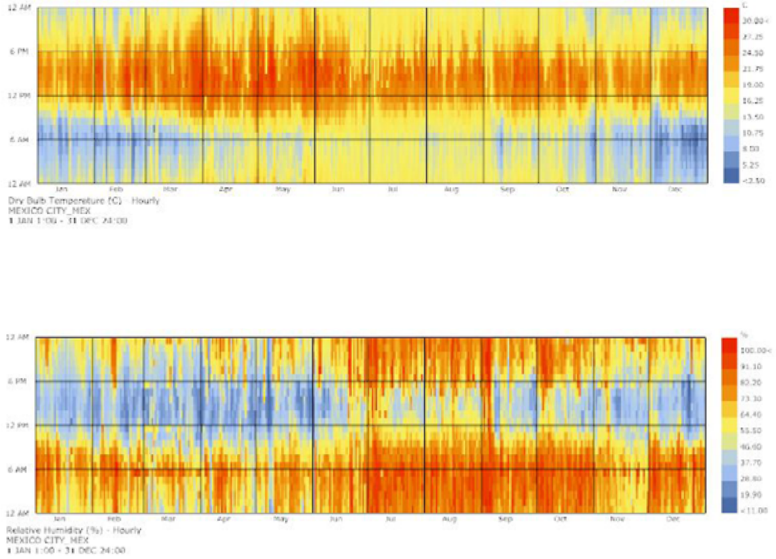
Situation 2 (With possible spectators)

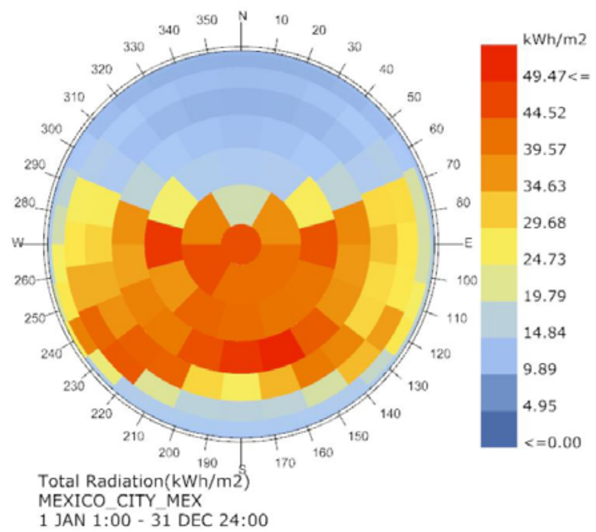
Area: 2,640 m2

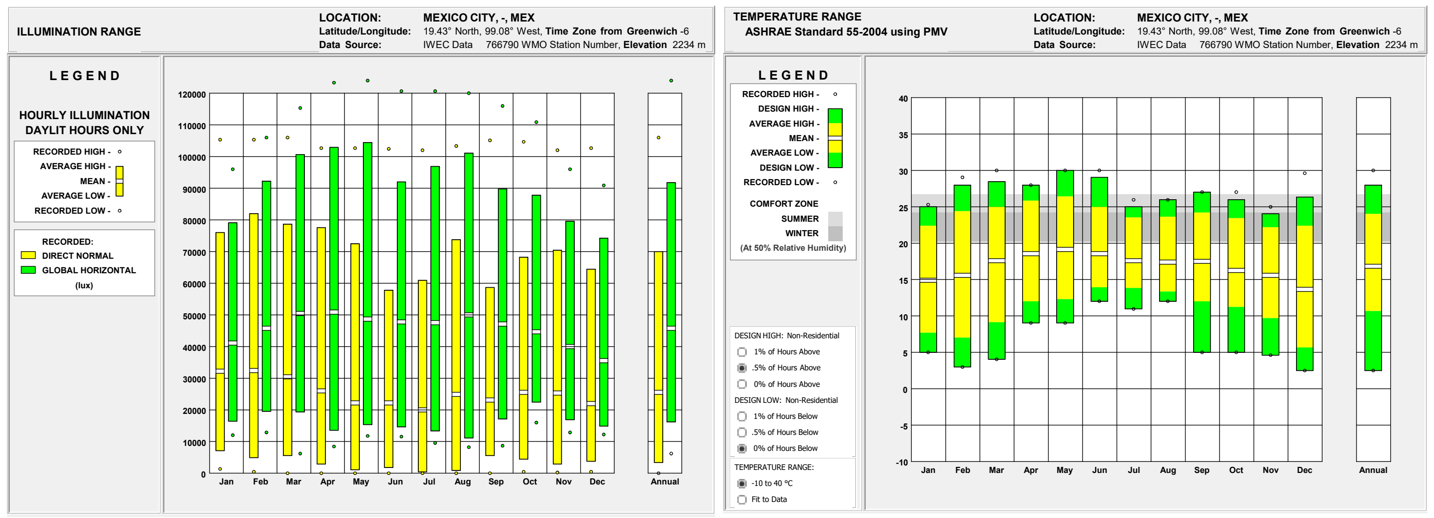
Volume: 44,880 m3

Program:
-3 Basketball courts
-2 Volleyball courts
-1 Soccer space
-1 Circulation space
-1 Steps space

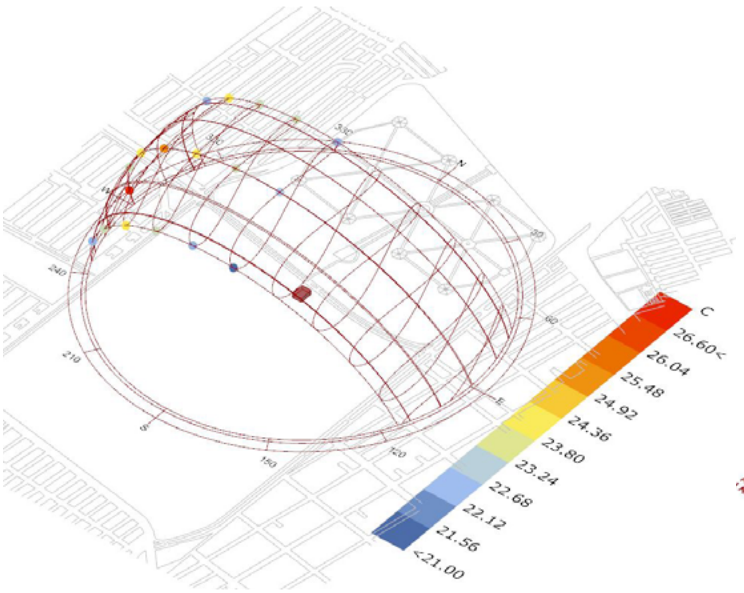
CLIMATE ANALYSIS

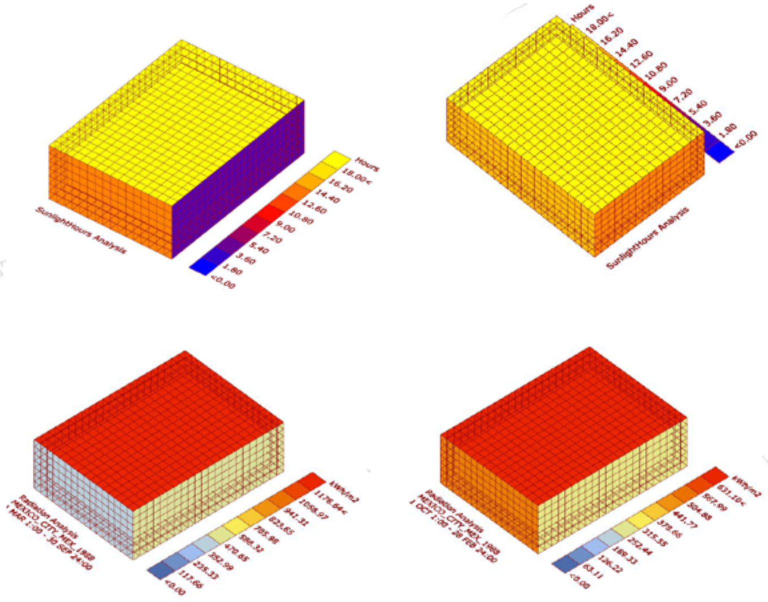


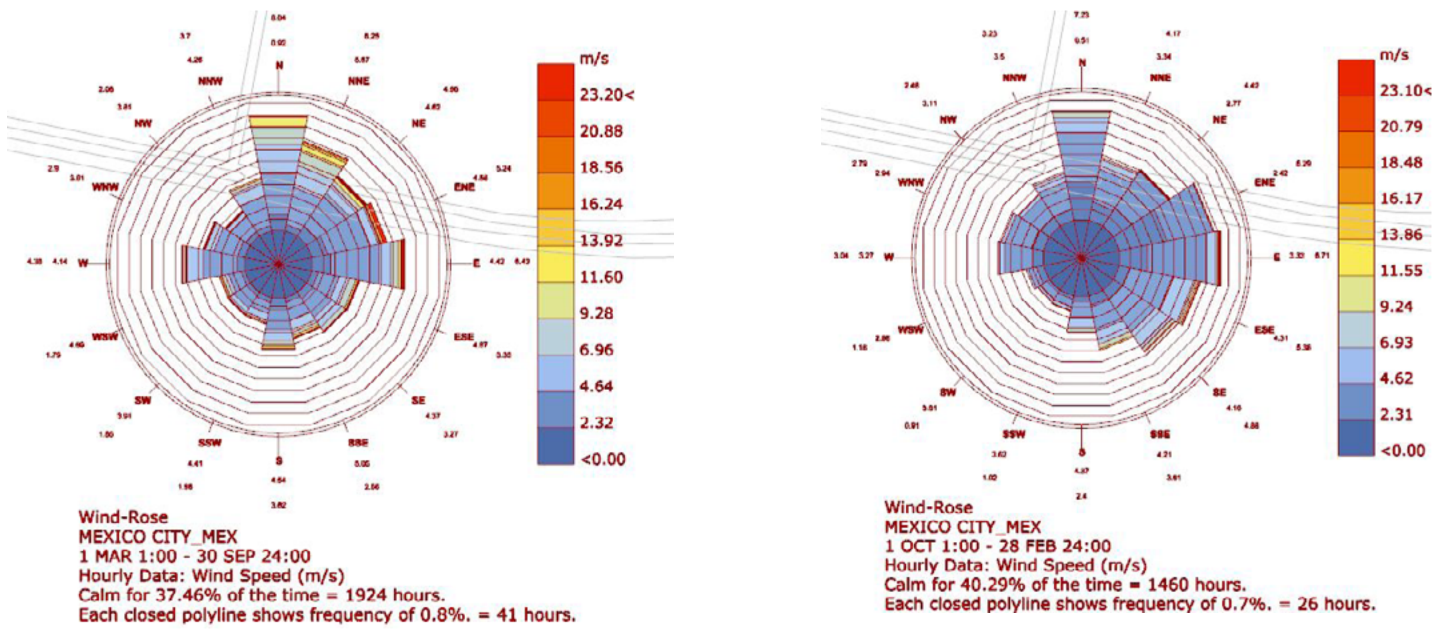




TEMPERATURE & ILLUMINATION RANGES







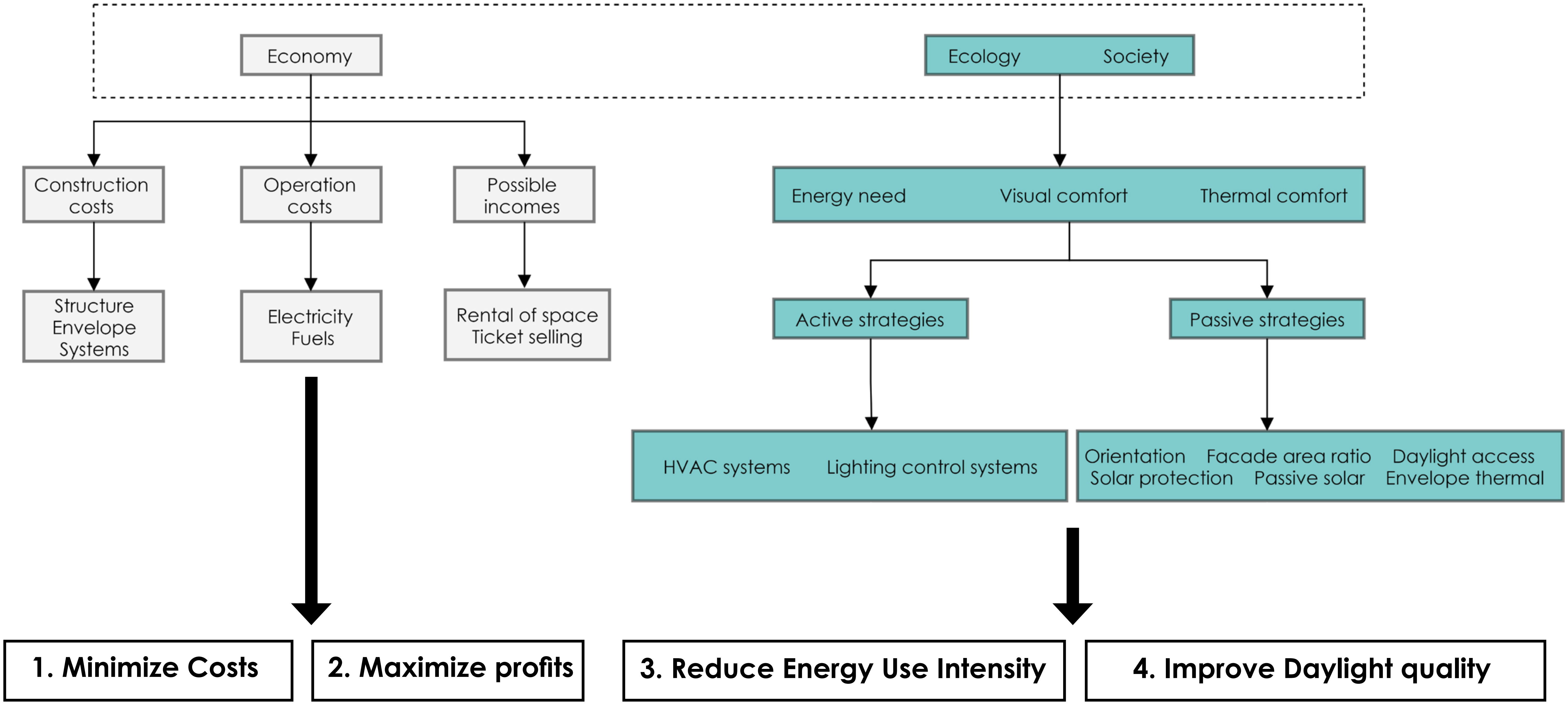
SUNPATH ANALYSIS

RADIATION ANALYSIS

WIND ROSE ANALYSIS

DESIGN OBJECTIVES

PERFORMANCE EVALUATION CRITERIA



DESIGN OBJECTIVES

1. Minimize Costs

2. Maximize profits

3. Reduce Energy Use Intensity

4. Improve Daylight quality

DESIGN VARIABLES

- Building depth
- Building width
- Building height
- Height of the peak
- Position of the peak
- Lateral connection thickness
- Divisions of the beam

- Beam depth
- Column depth
- Chord diameter
- Chord thickness
- Web diameter
- Web thickness
- Lateral connection diameter
- Divisions of the colum
- Number of frames

- WWR Ration (walls)
- WWR Ration (Roof)
- Opaque material - wall
- Opaque material - roof
- Window material
- Orientation
- Number of sshadings

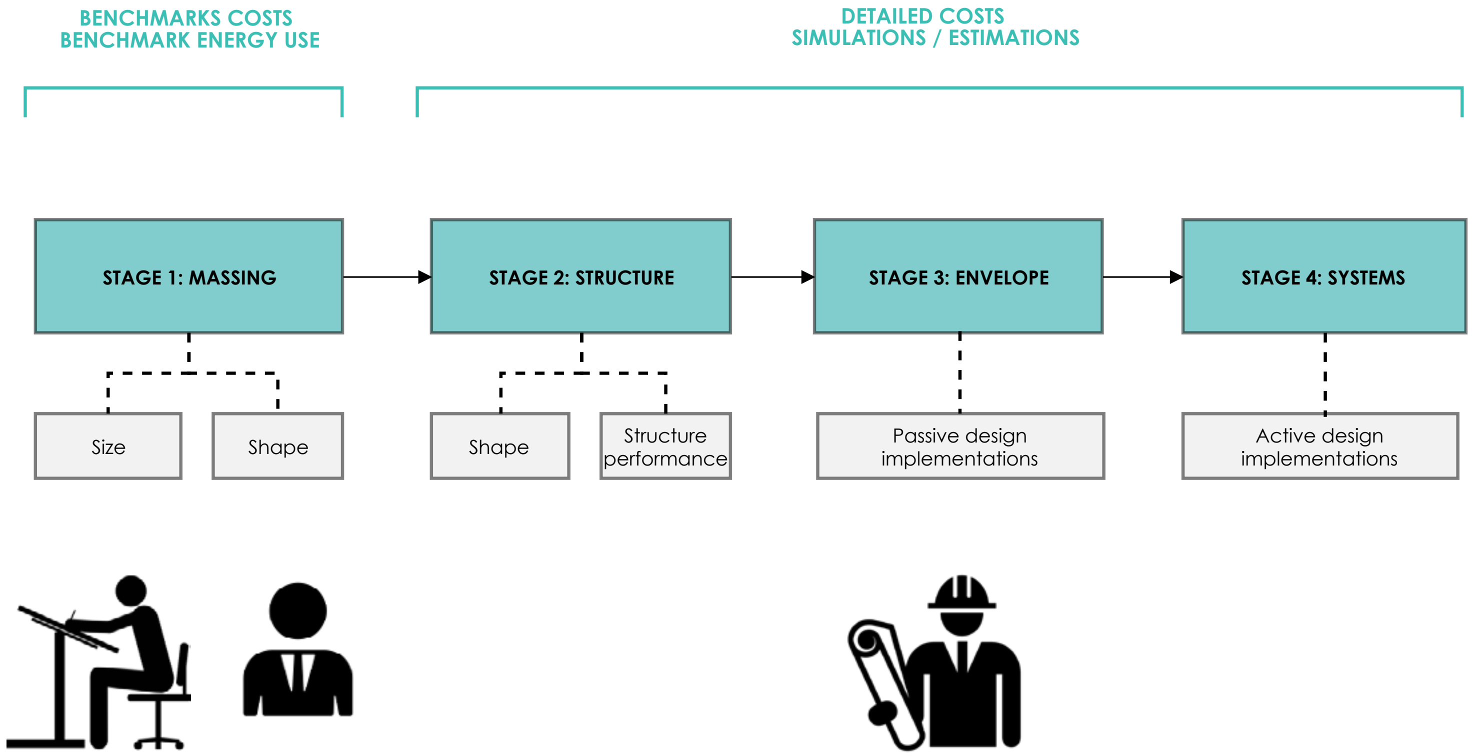
- HVAC systems
- Lighting systems

DESIGN VARIABLES

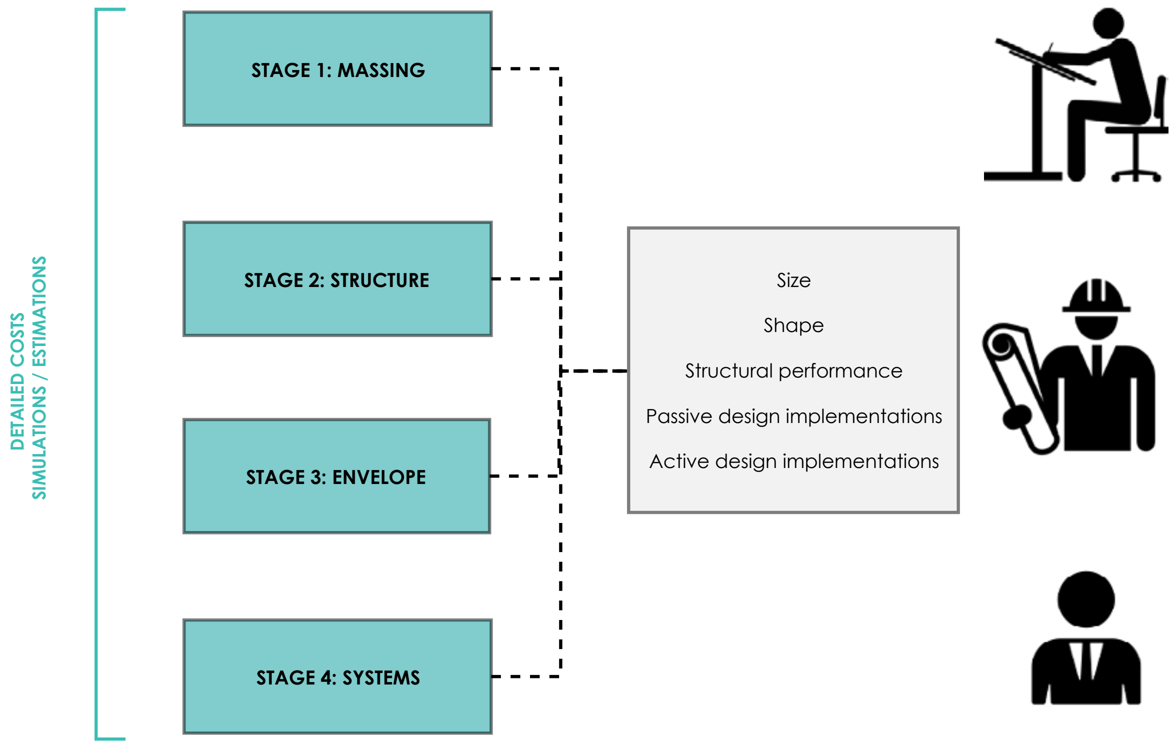
SHAPE	STRUCTURE	ENVELOPE	SYSTEMS
Building depth	Beam depth	WWR Ration (walls)	HVAC systems
Building width	Column depth	WWR Ration (Roof)	Lighting systems
Building height	Chord diameter	Opaque material - wall	
Height of the peak	Chord thickness	Opaque material - roof	
Position of the peak	Web diameter	Window material	
Lateral connection thickness	Web thickness	Orientation	
Divisions of the beam	Lateral connection diameter	Number of sshadings	
	Divisions of the colum		
	Number of frames		

DESIGN STRATEGY

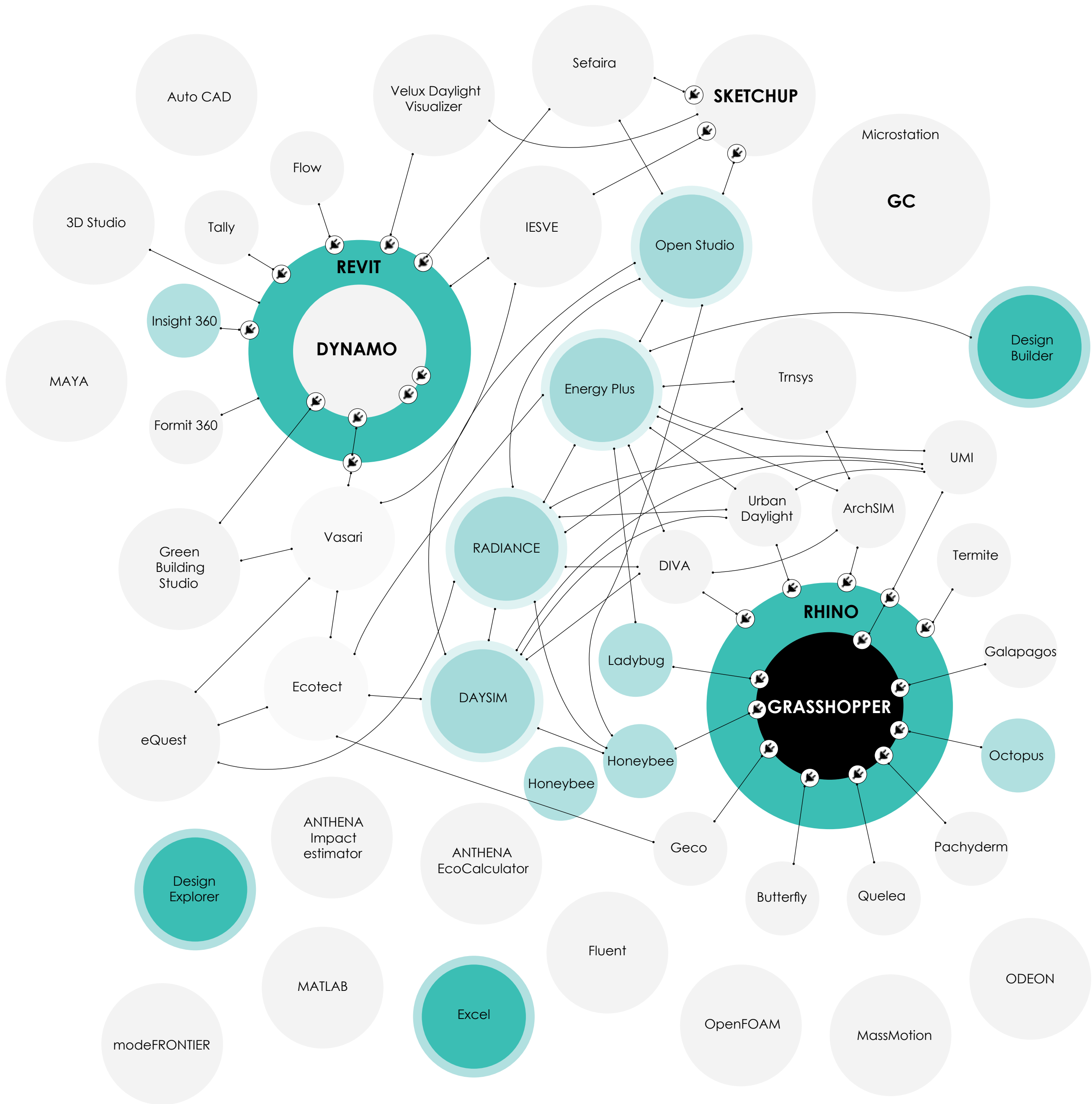
SEQUENTIAL



INTEGRATED

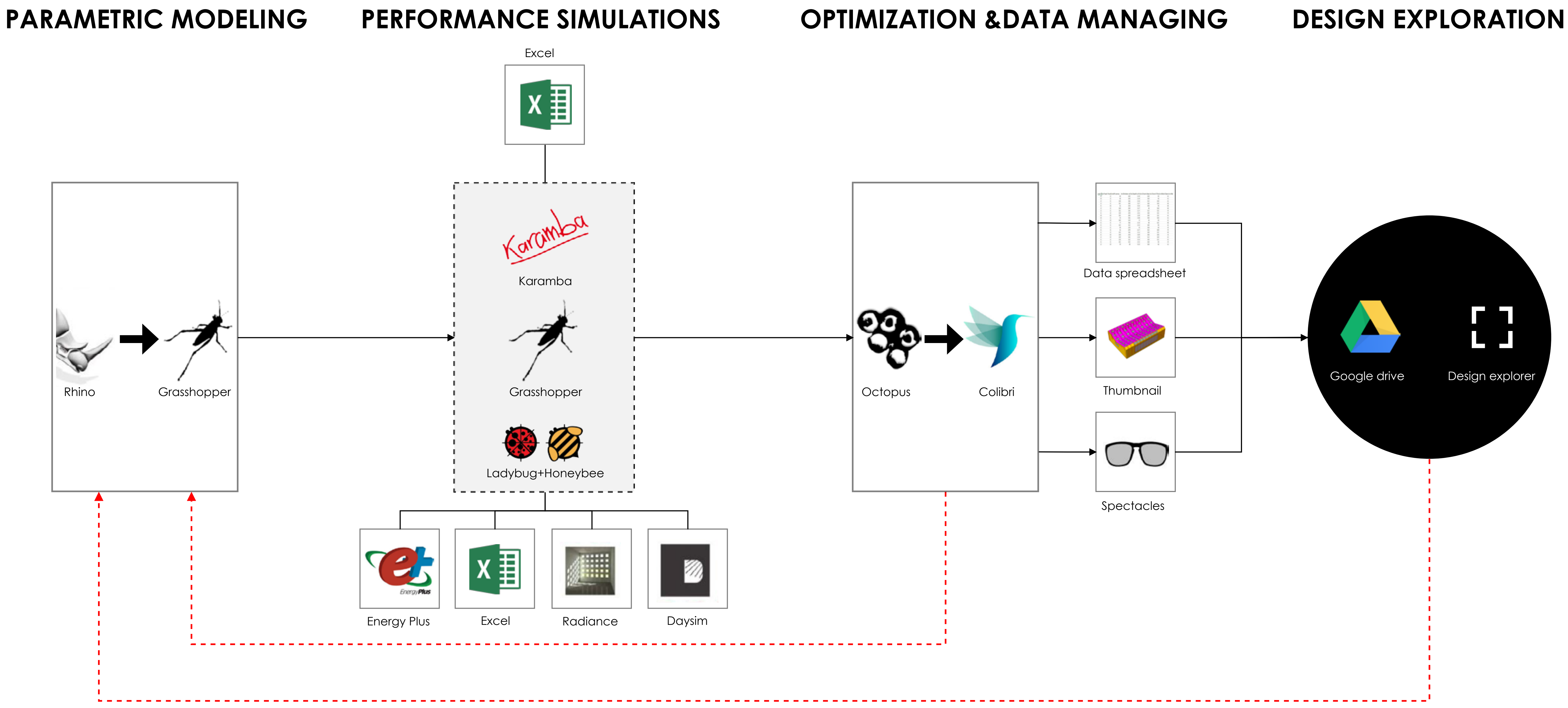


TOOLS COMBINATION

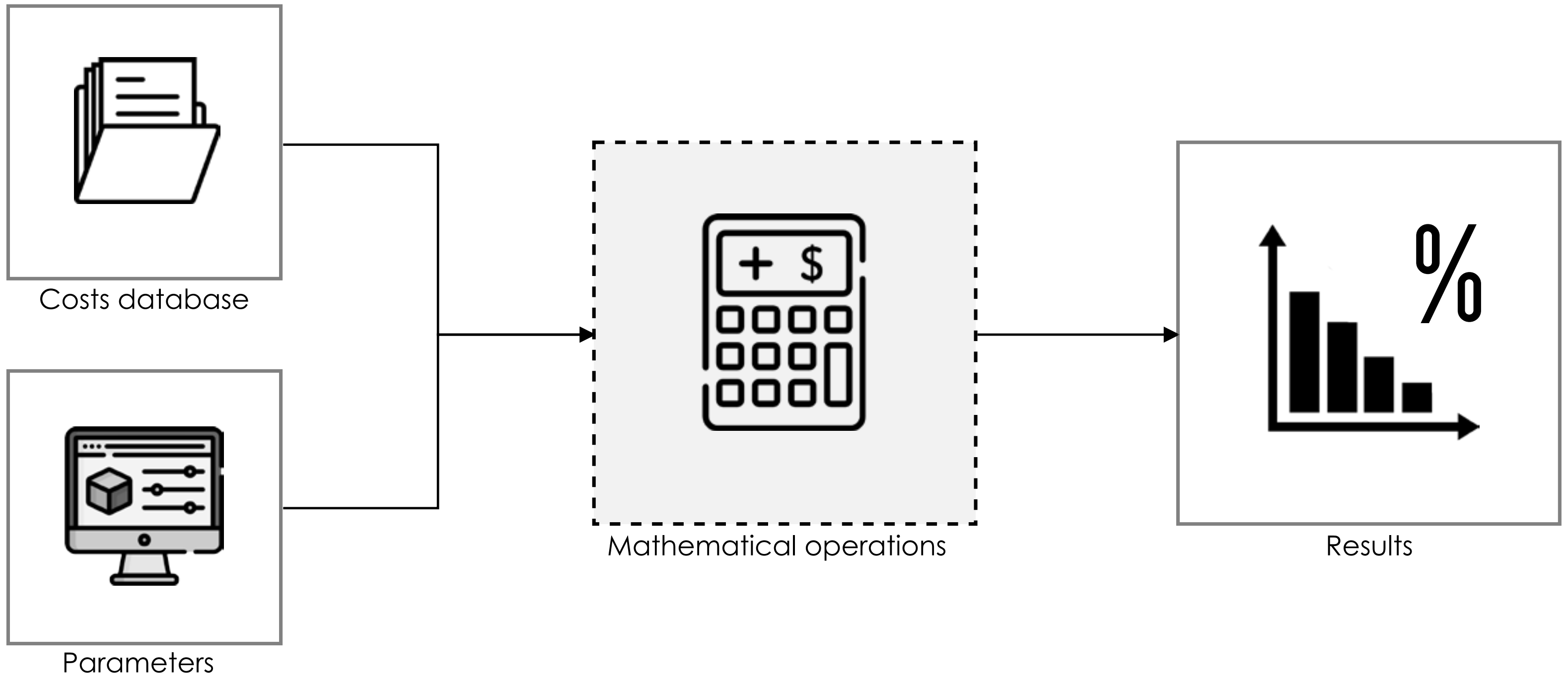


Modeling Parametric mod- Plugins Engines External software

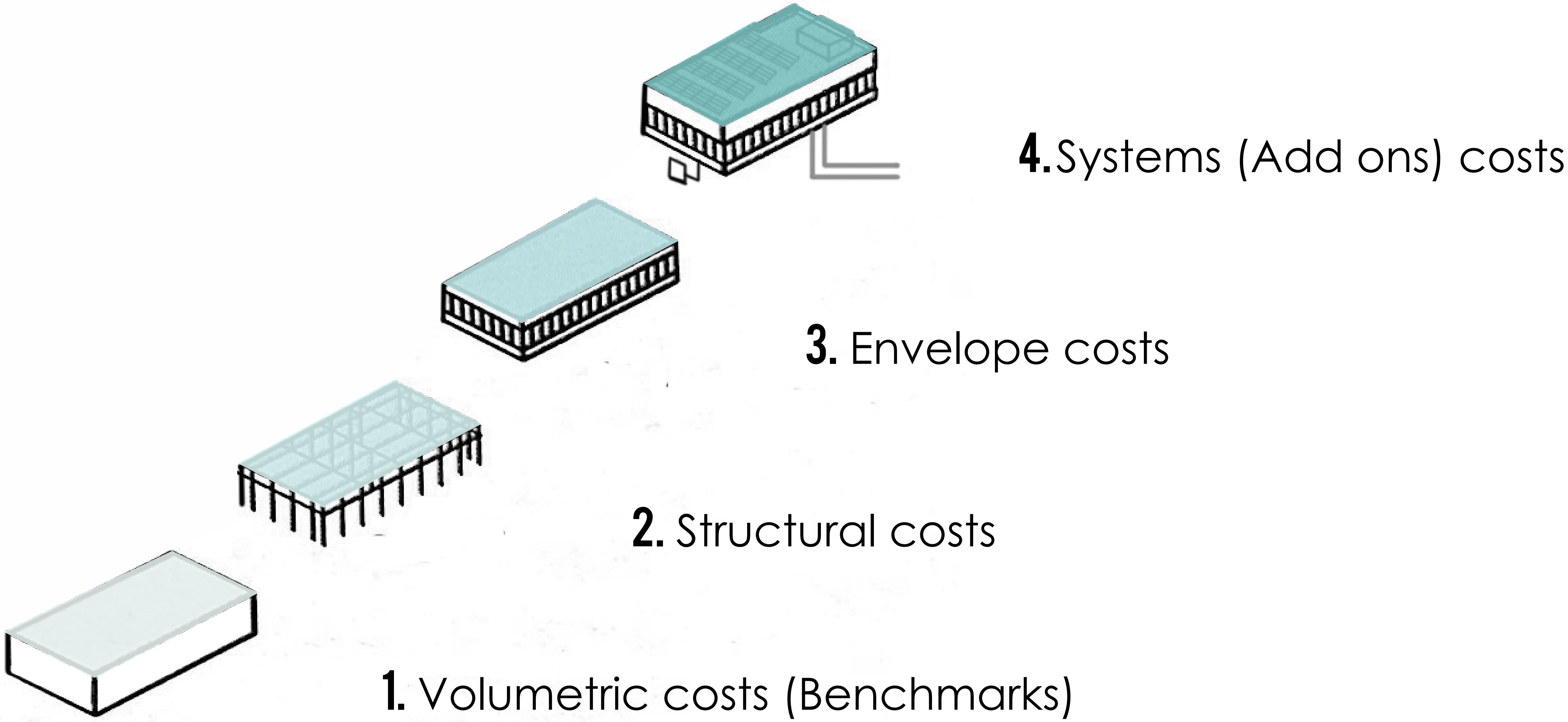
TOOLS COMBINATION



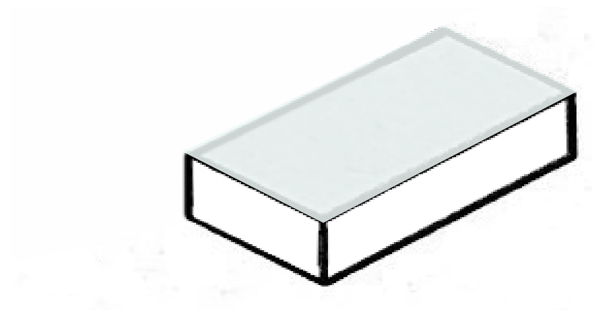
COSTS DATABASE

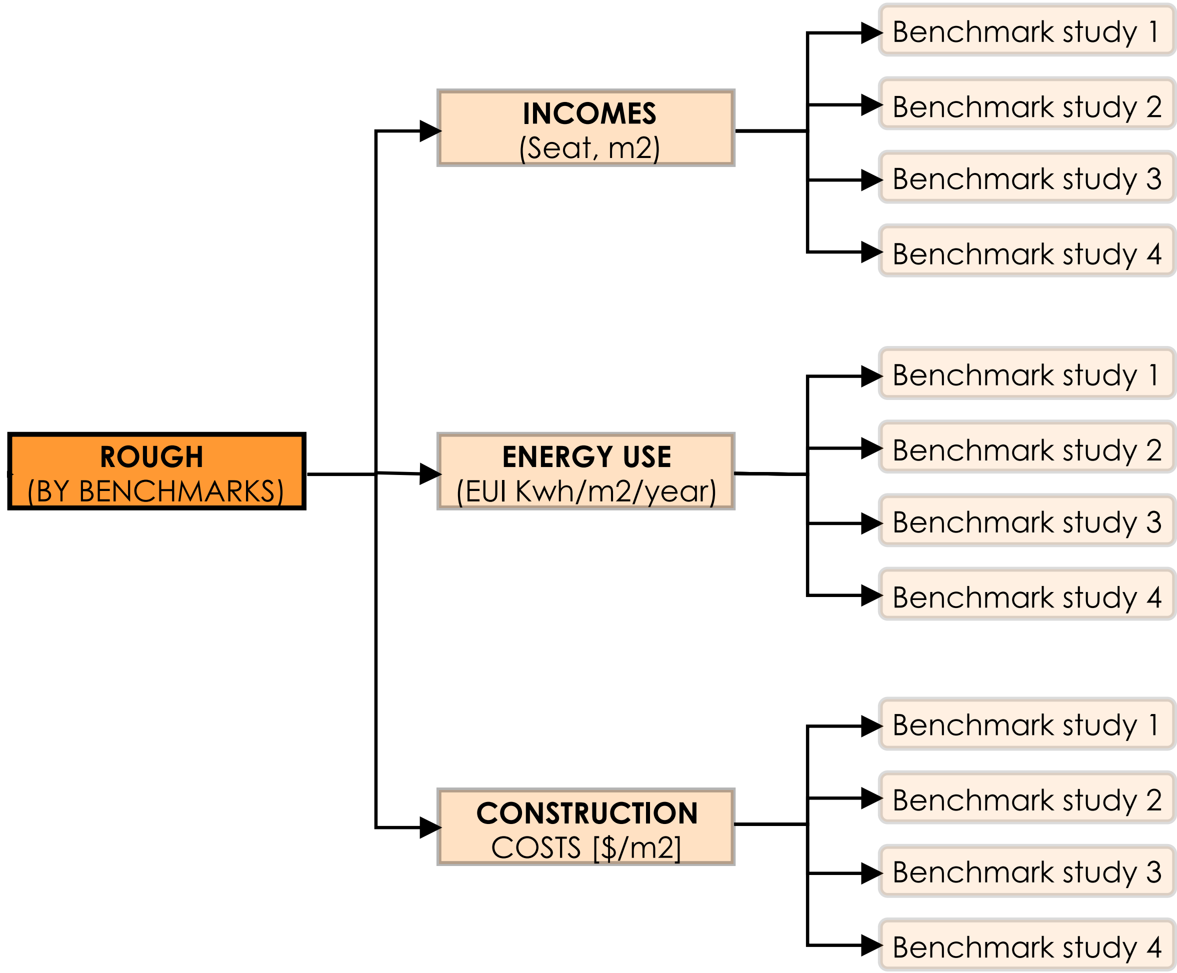


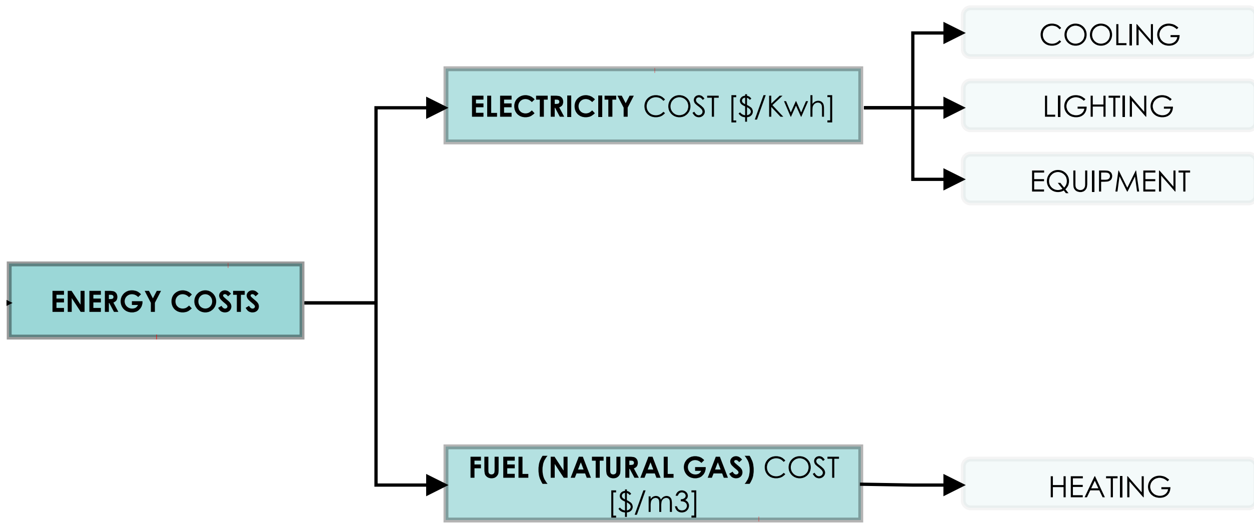
COSTS DATABASE



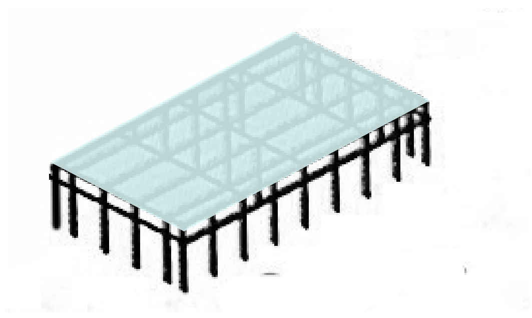
COSTS DATABASE

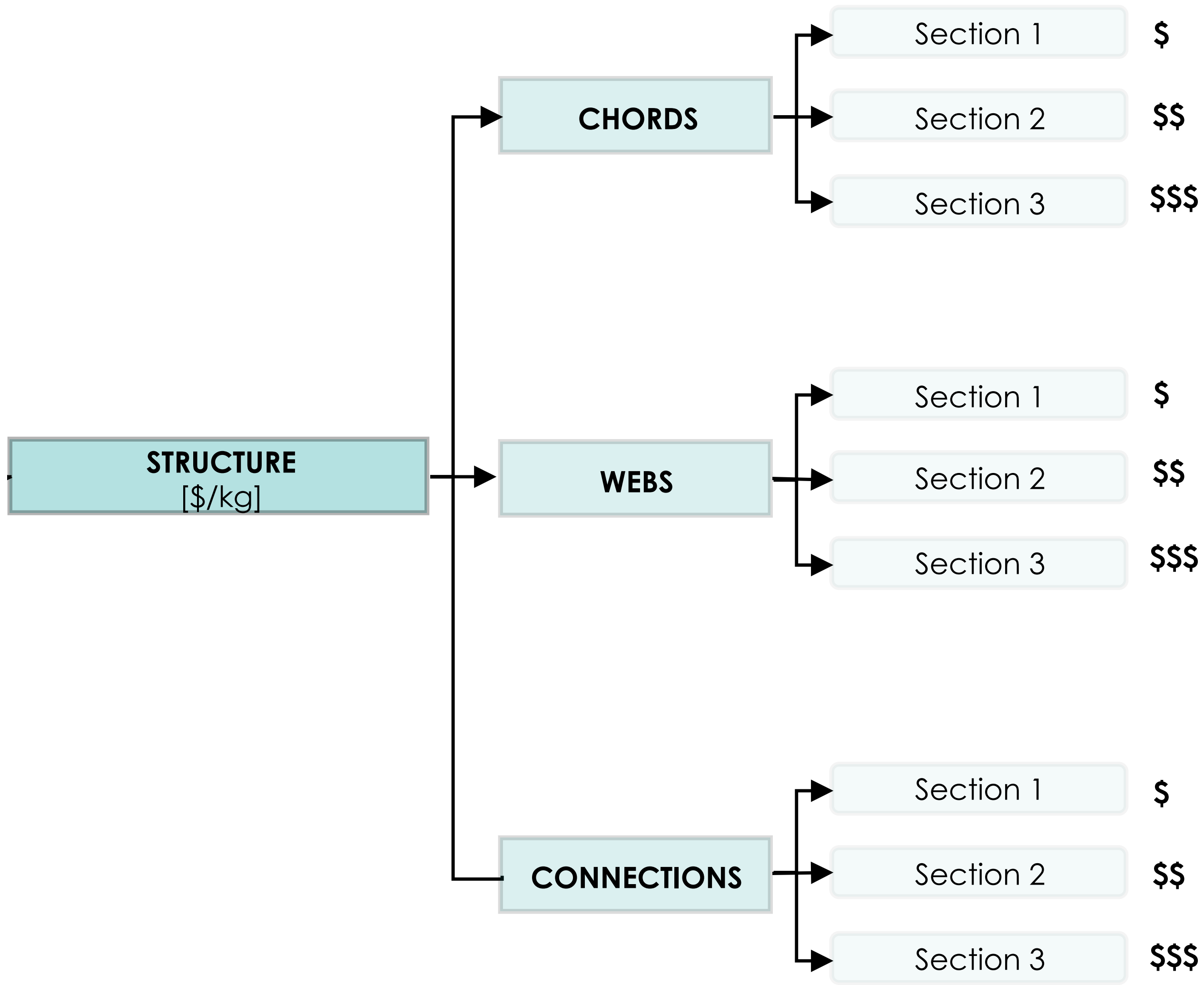






COSTS DATABASE





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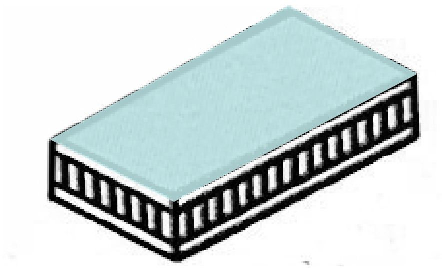

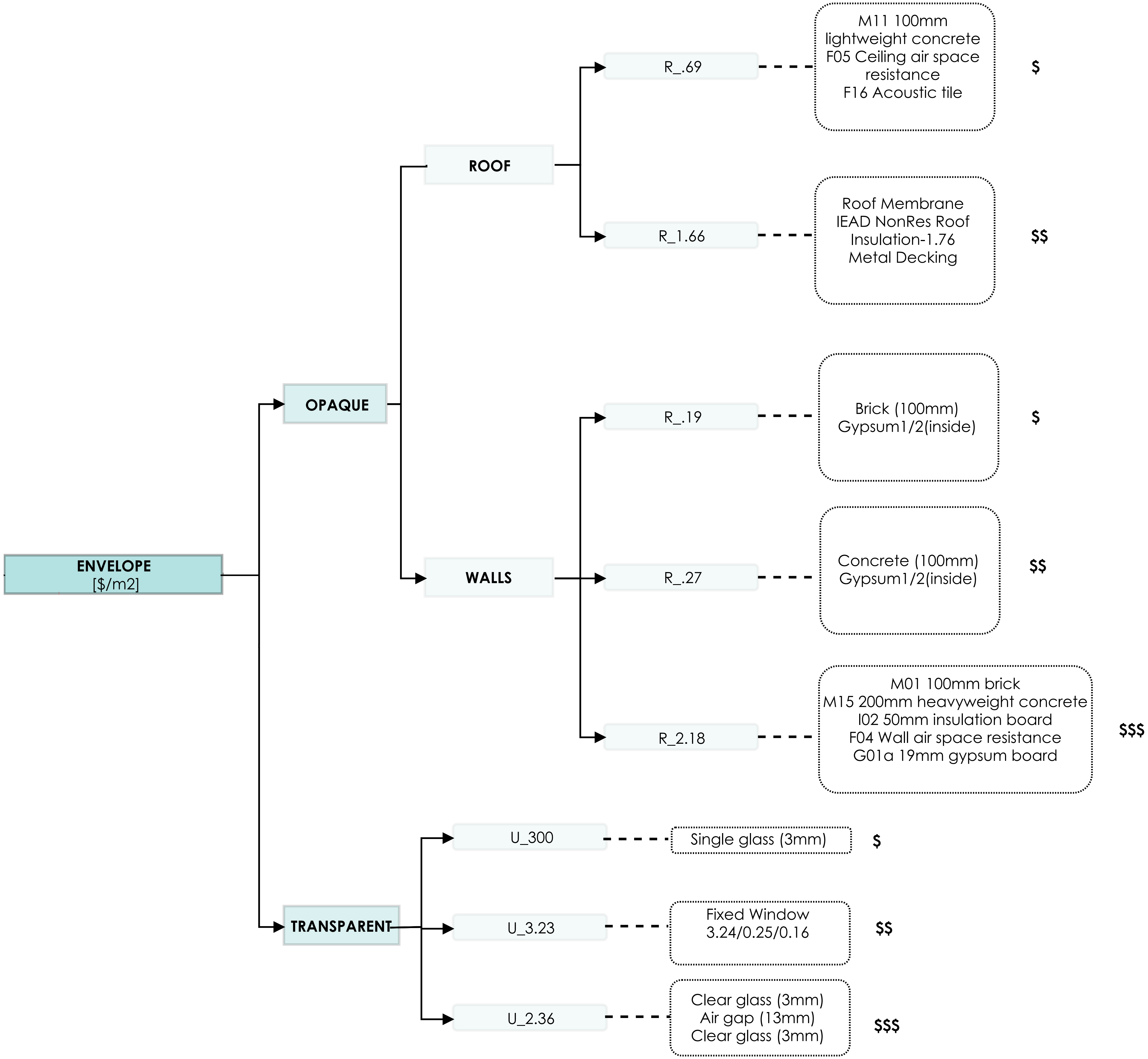

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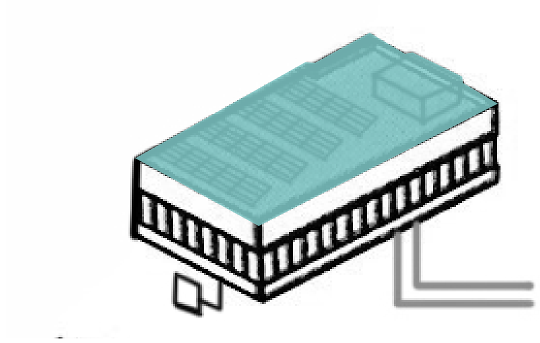
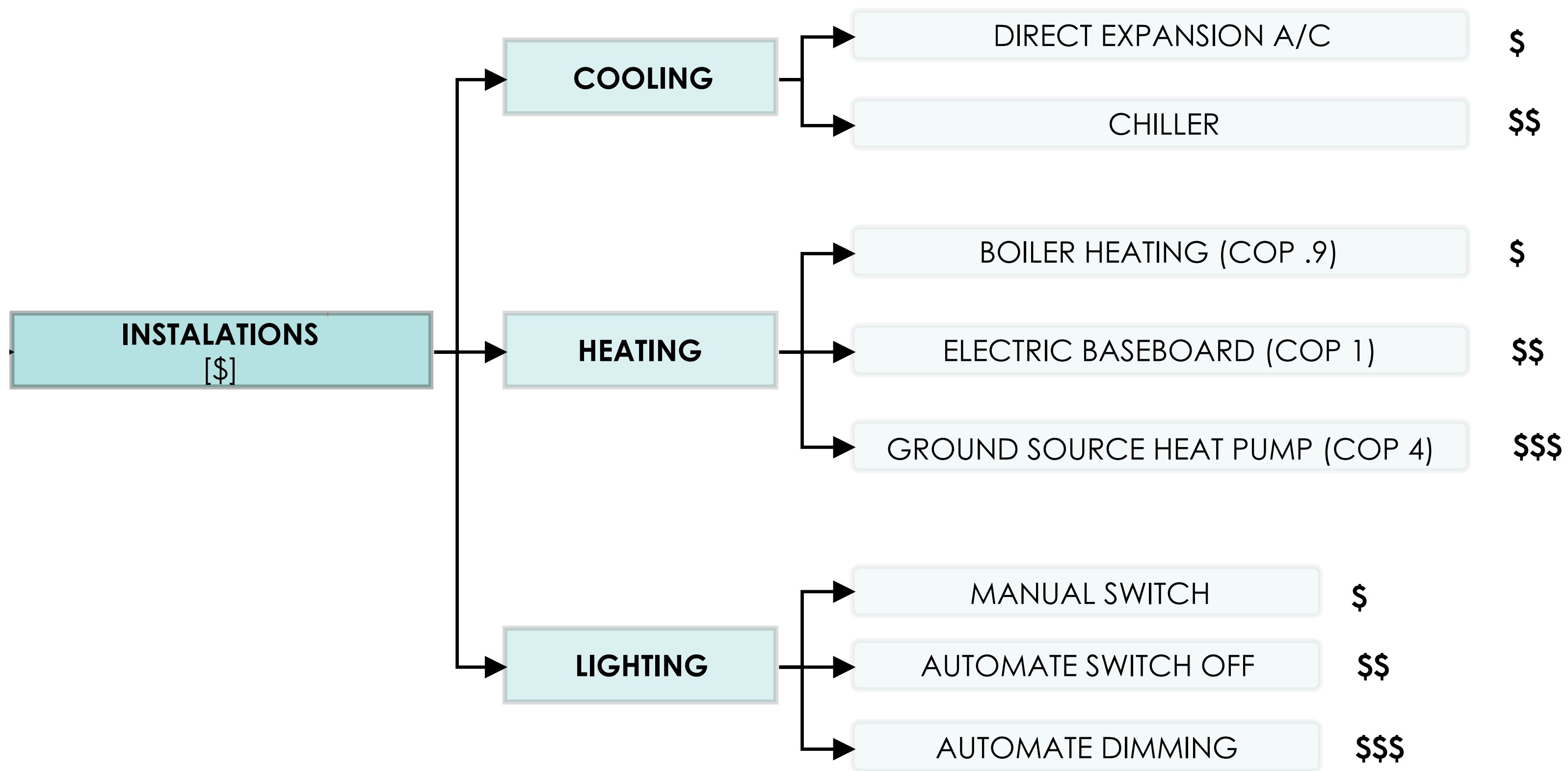
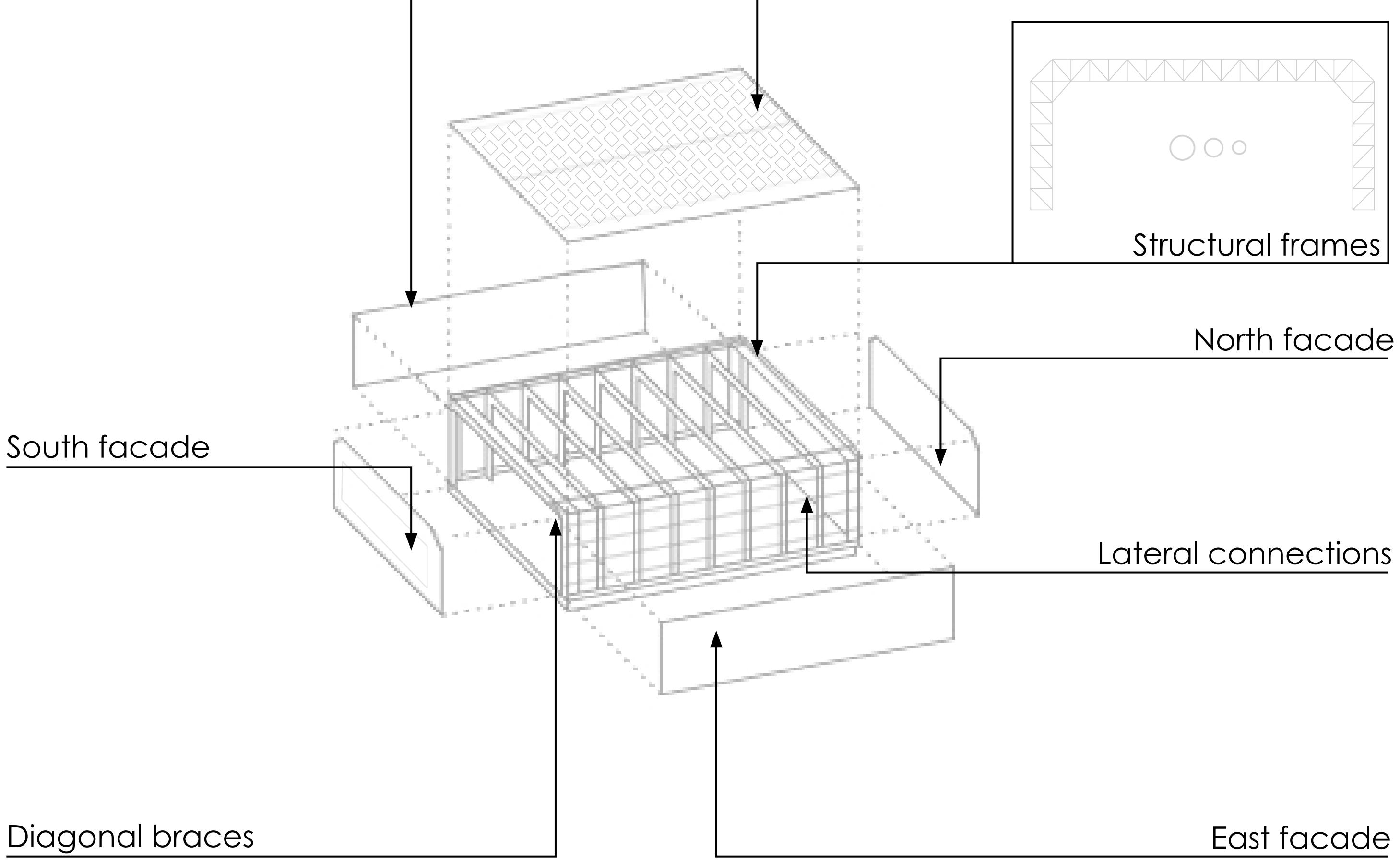
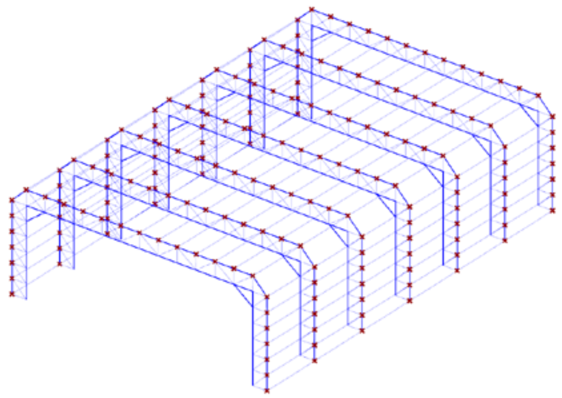
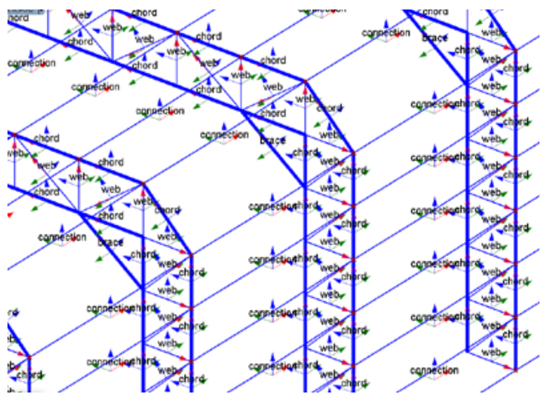


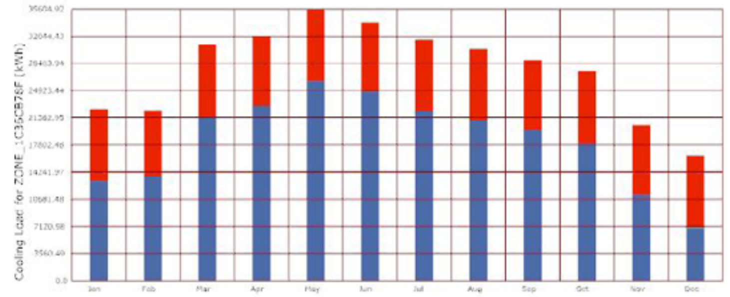


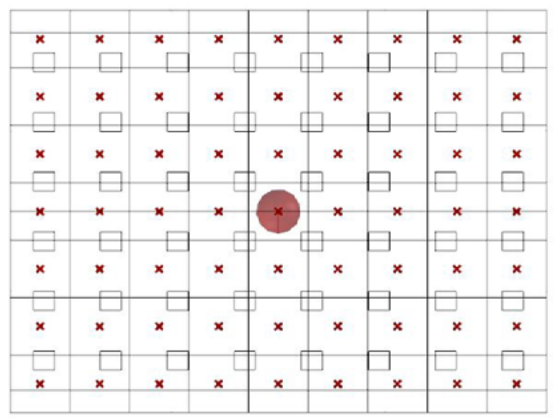
PARAMETRIC SIMULATION MODELING



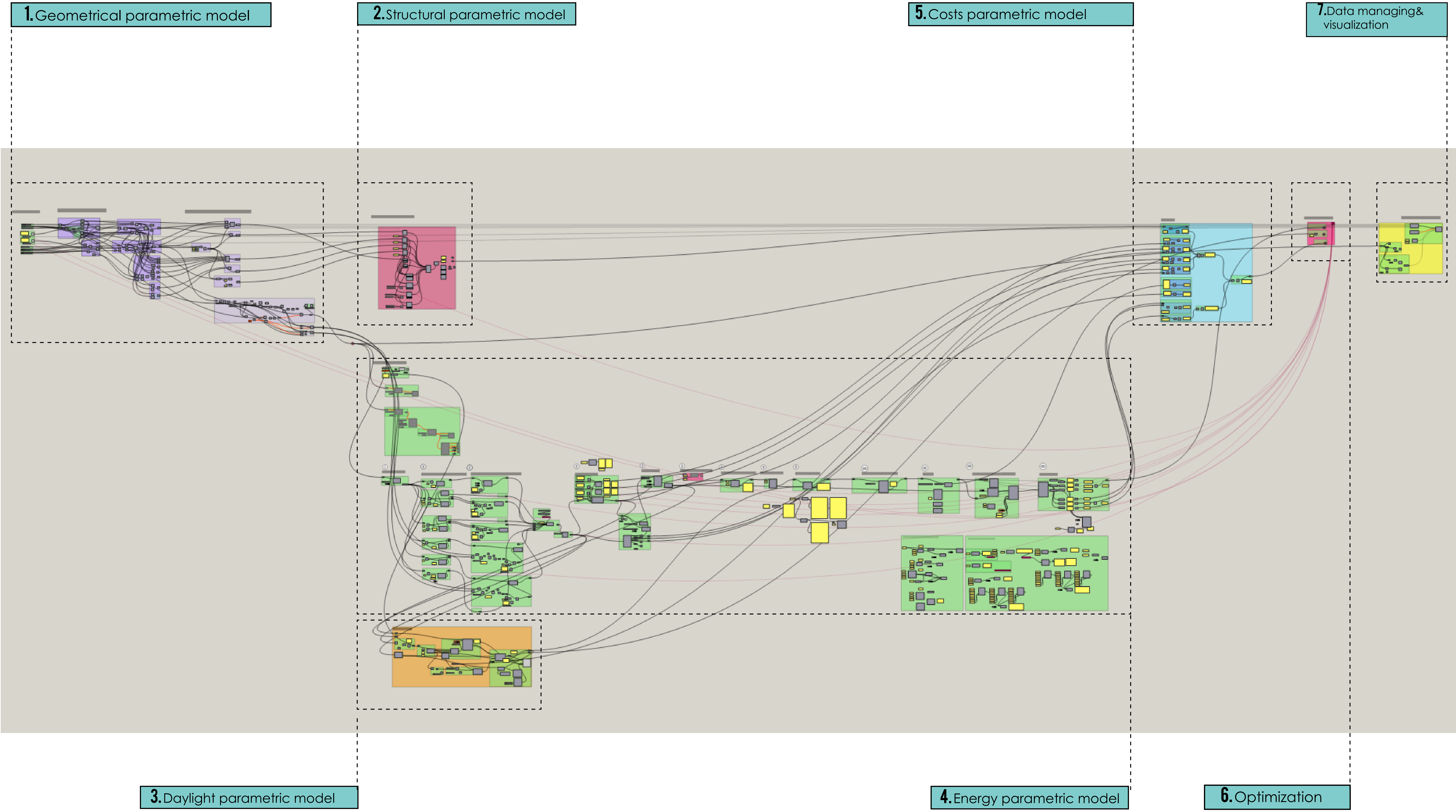




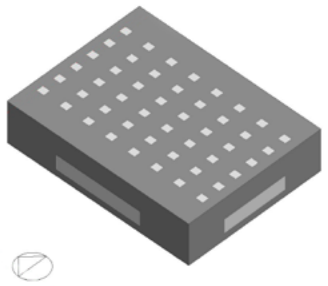
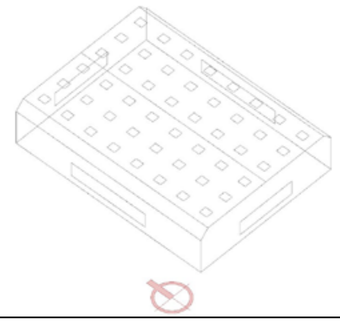




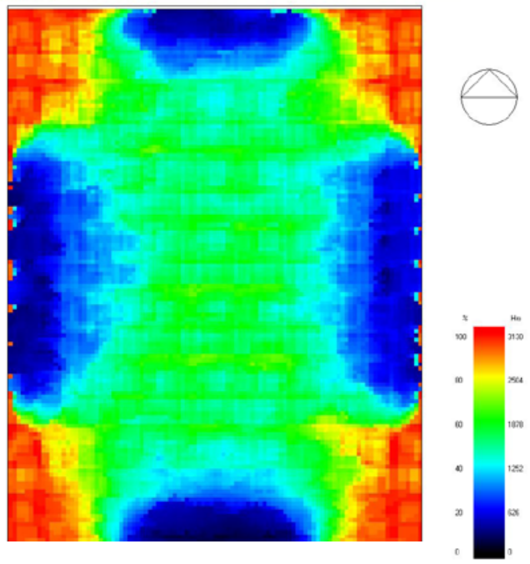
PARAMETRIC SIMULATION MODELING

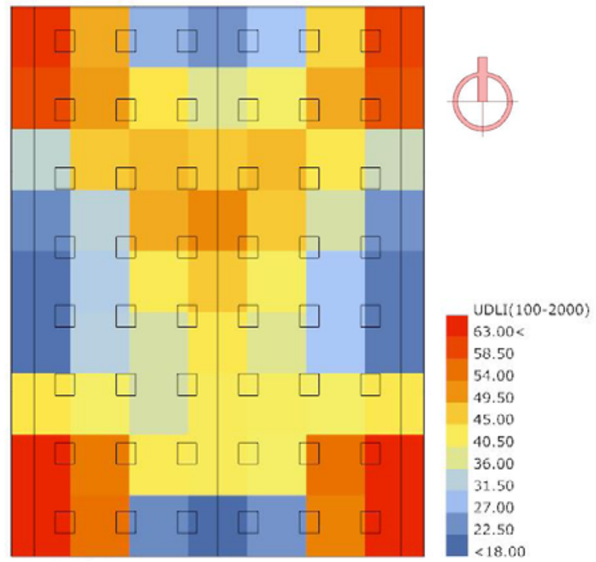


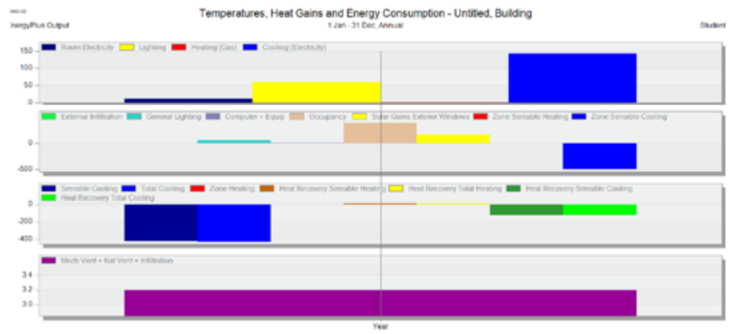
CALIBRATION / INTER COMPARISON

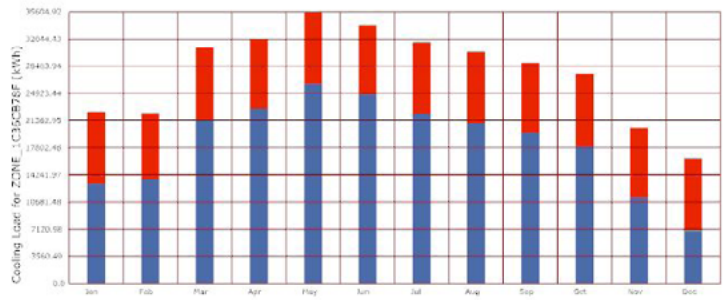
	HONEYBEE MODEL	DESIGN BUILDER MODEL
		
General		
Location (weather file)	Mexico City.iwec	Mexico City.iwec
Orientation	N-S	N-S
Geometry		
Height	11m	11m
Widht	36m	36m
Depth	48m	48m
WWR Skylight	10%	10%
WWR (All walls)	40%	40%
Materials		
Floor	500mm Ins. 200mm Heavy weight concrete	500mm Ins. 200mm Heavy weight concrete
Roof	100MM lightweight concrete, f05 ceiling air space resistance , f16 acoustic tile	100MM lightweight concrete, f05 ceiling air space resistance , f16 acoustic tile
Walls	100mm concrete 1/2" Gypsum	100mm concrete 1/2" Gypsum
Windows	3mm clear glas-13mm ai gap r-3mm clear glass	3mm clear glas-13mm ai gap r-3mm clear glass
Activity		
Occupancy schedule	6am-9pm (Monday-Sunday)	6am-9pm (Monday-Sunday)
Occupancy density	50m2/person	.02ppl/m2
Heating setpoint	28°C	28°C
Heating setback	8°C	8°C
Cooling setpoint	22°C	22°C
Cooling setback	28°C	28°C
Metabolic rate	120W	120W
Equipment	2W/m2	2W/m2
Lighting density	11W/m2	11W/m2
HVAC		
Infriltration rate	.000257 m3/s/m2	.085 Ach
Infiltration schedule	Always on	Always on
Mech vent. Per person	.001524m3/s	15.24 ls/person
HVAC System	Ideal Loads-fuel natural gas/electricity from grid	Ideal Loads-fuel natural gas/electricity from grid
Supply temperatures	Heating 35°C / Cooling 12°C	Heating 35°C / Cooling 12°C
Heat recovery	Yes (.7)	Yes (.7)
Economizer	None	None
Results		
Area	1728m2	1728m2
Volume	18816m3	19008
Wall area	3060m2	3573m2
Window area	395.52m2	450m2
Annual Cooling demand	42.70 kWh/year	45.09 kWh/year
Annual Heating demand	0.011 kWh/year	0.015 kWh/year
Annual Lighting demand	64.24 kWh/year	60.22 kWh/year
Total Annual energy demand	102.935 kWh/m2/year	106.395 kWh/m2/year

EUI **102.93 kWh/m2/y** **106.39 kWh/m2/y**

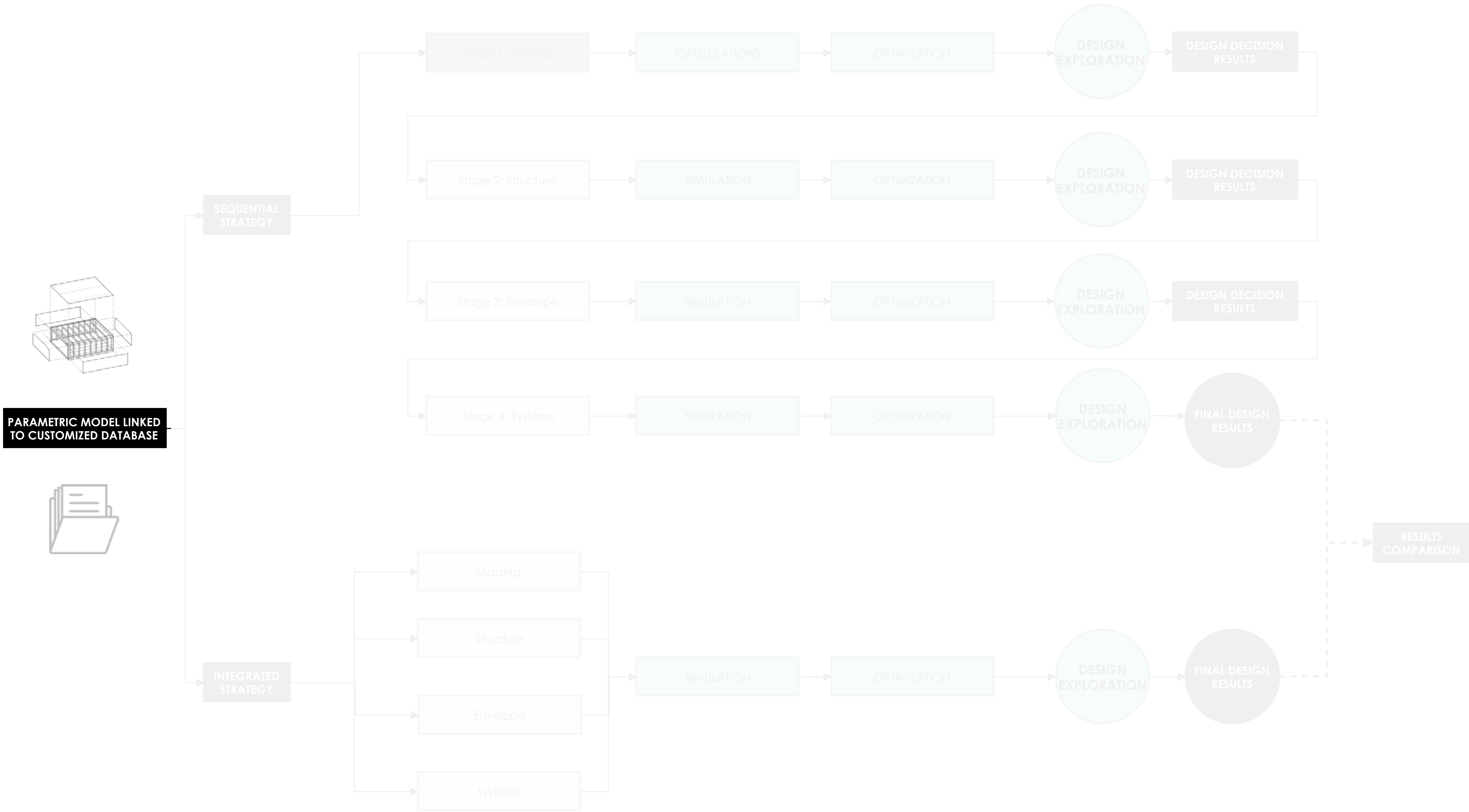




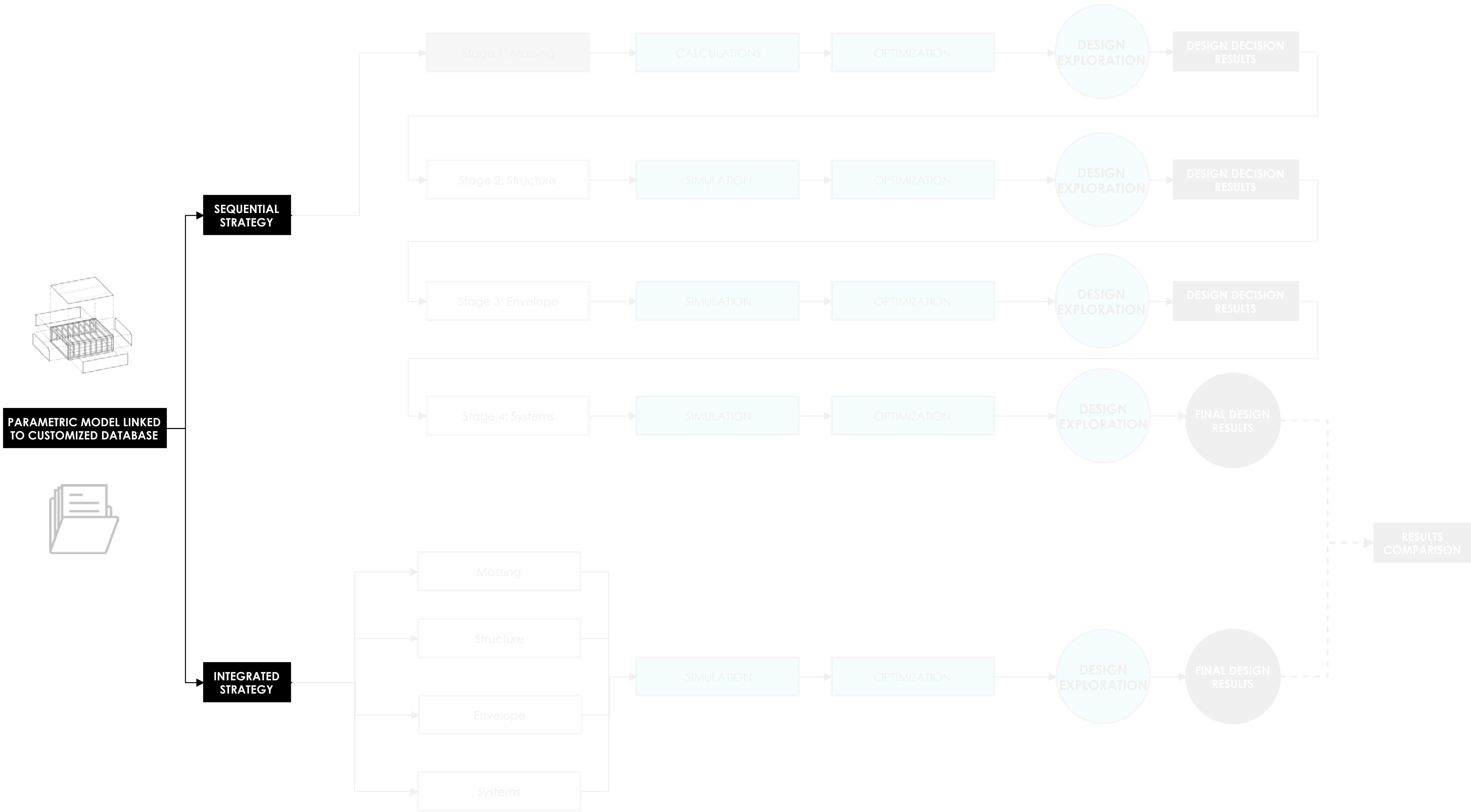




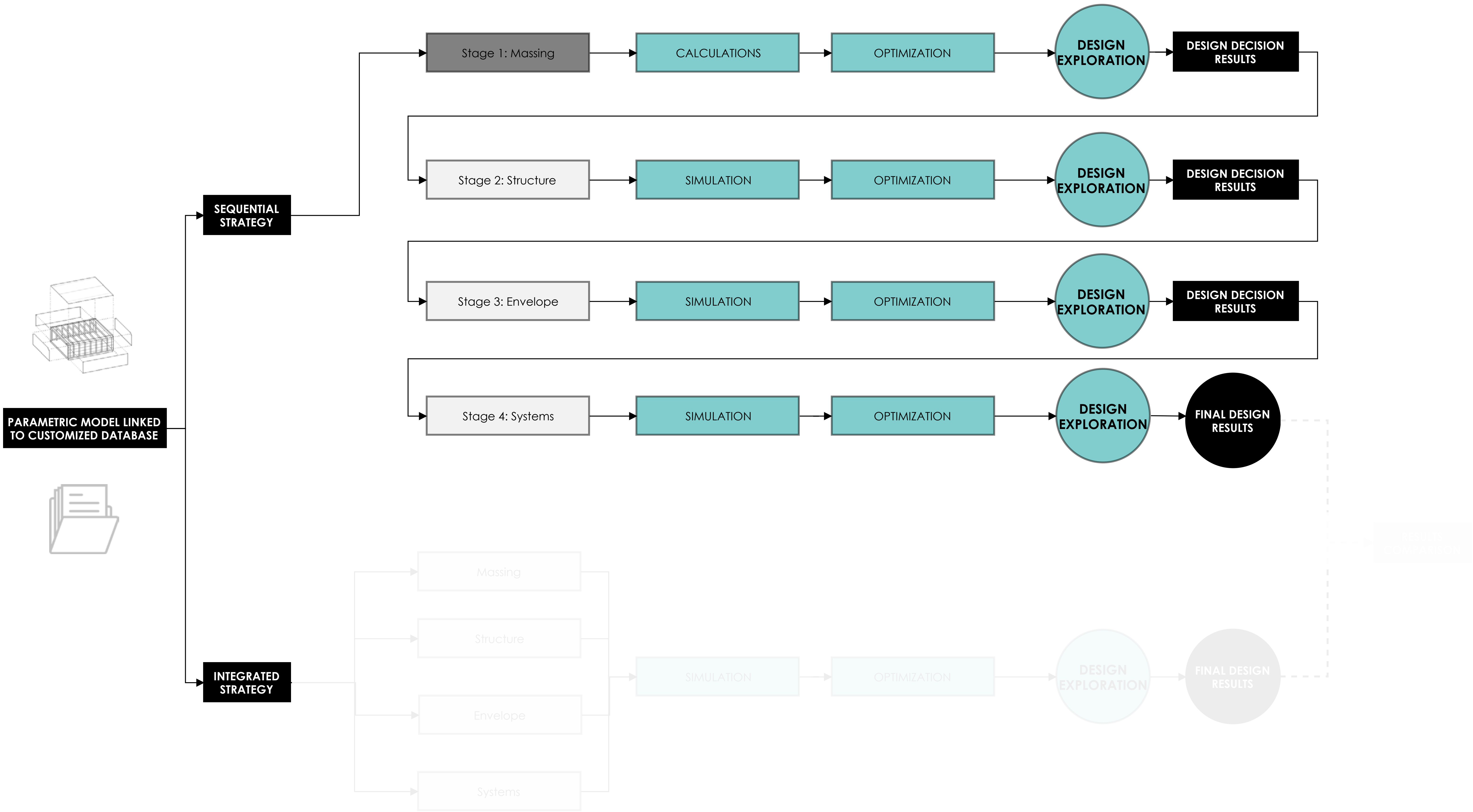
IMPLEMENTATION



IMPLEMENTATION



IMPLEMENTATION



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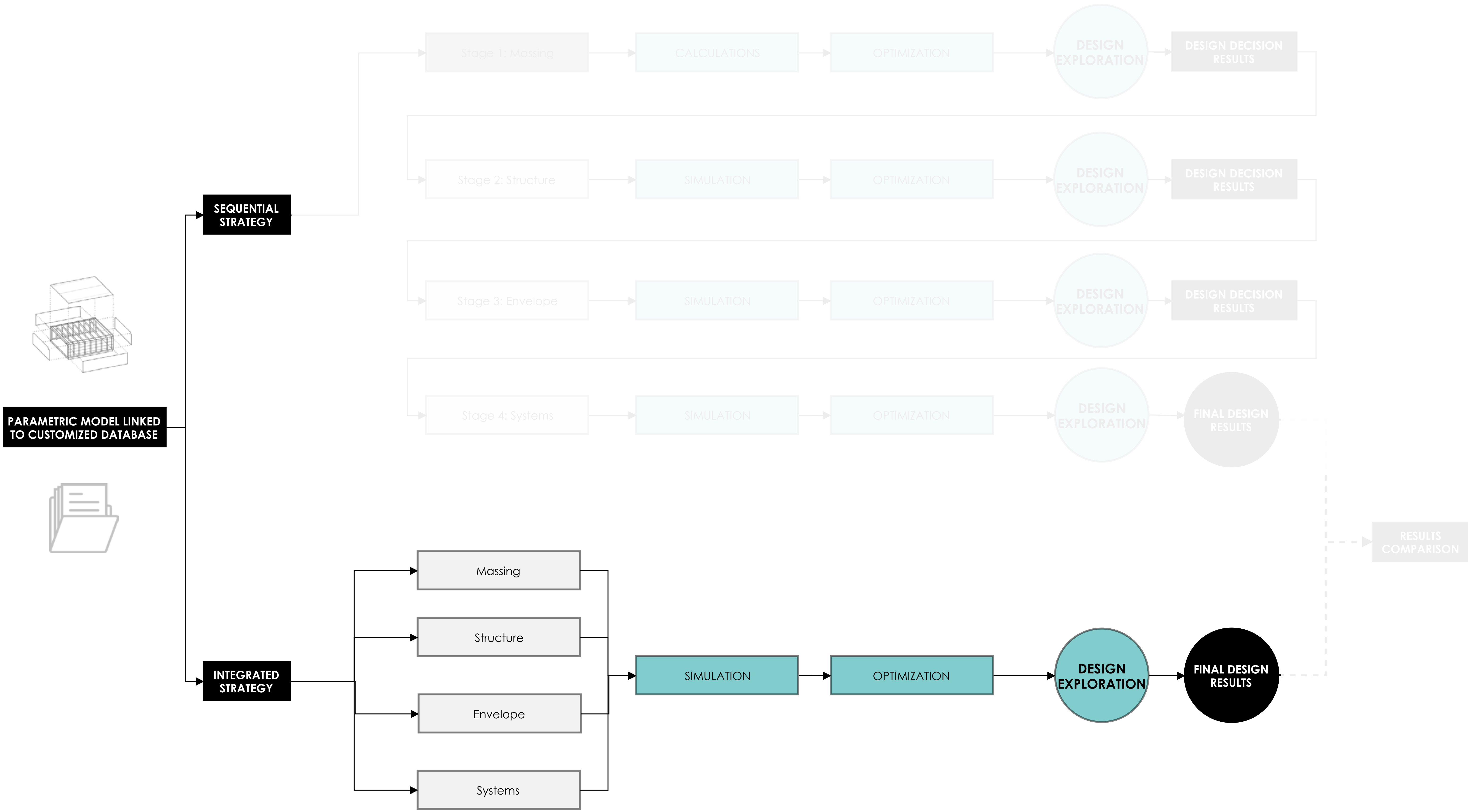
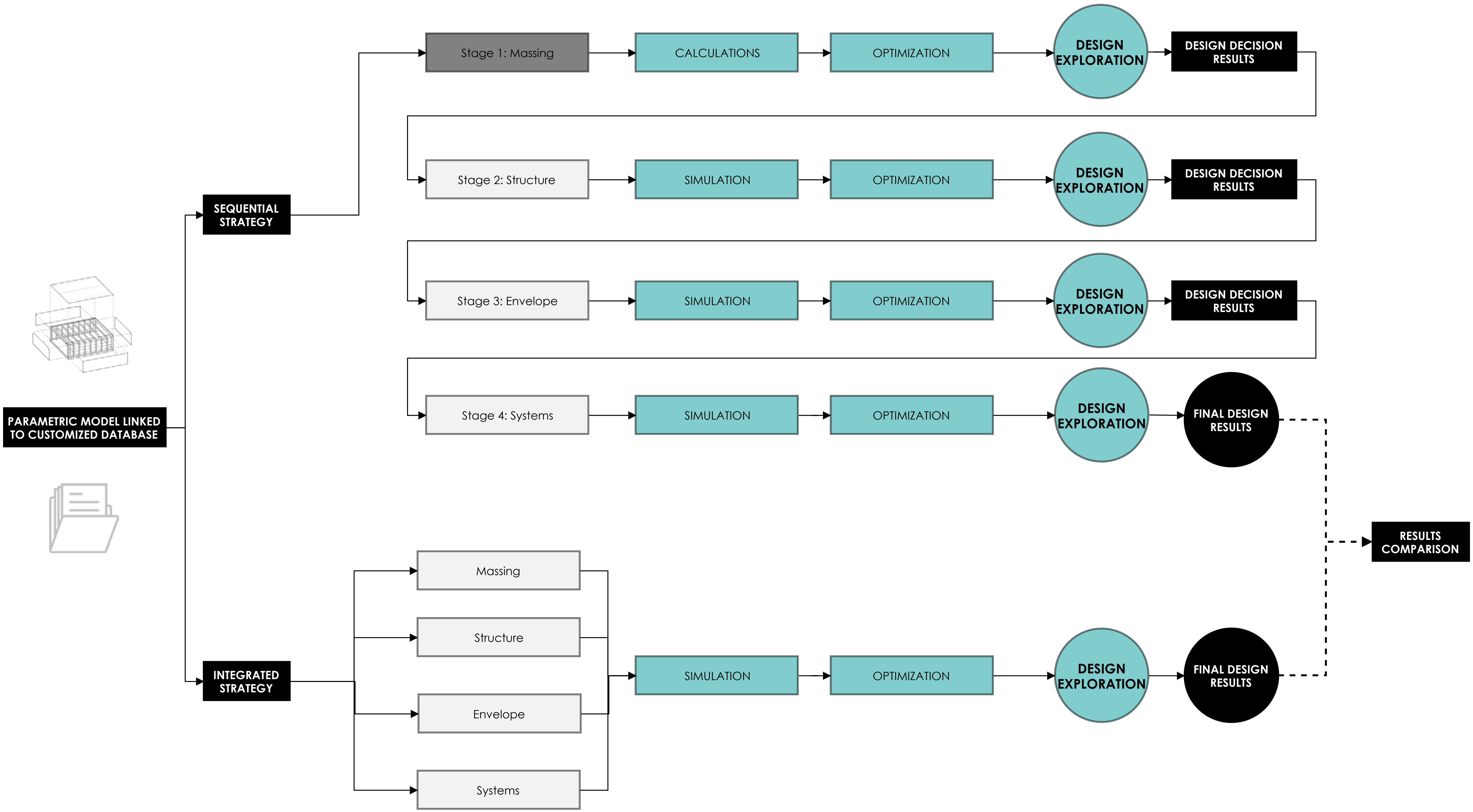
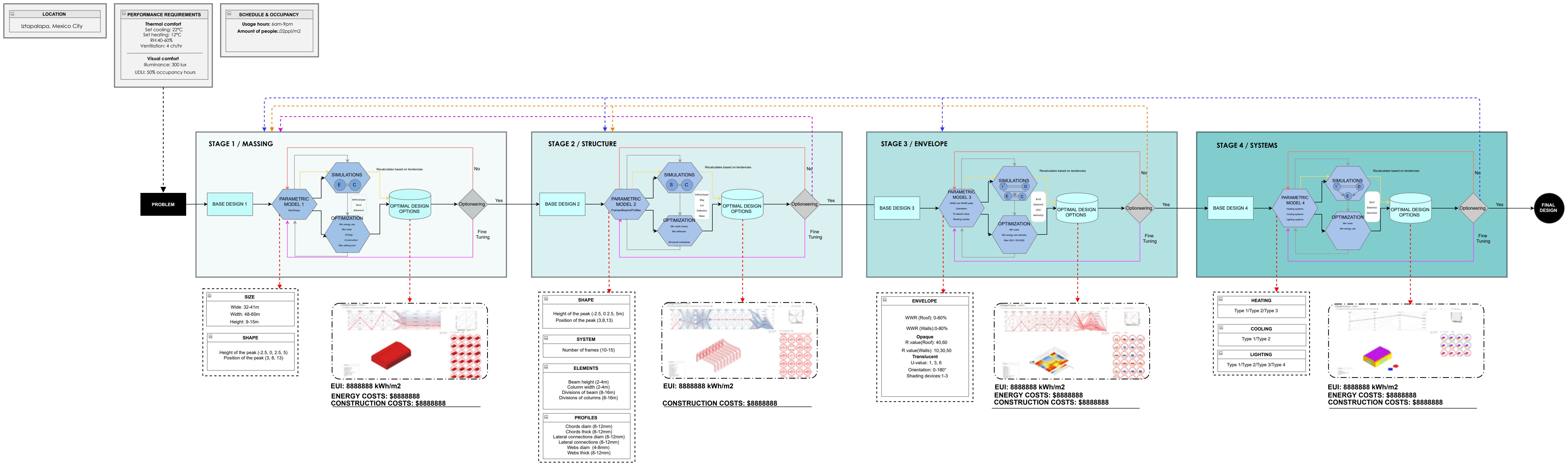


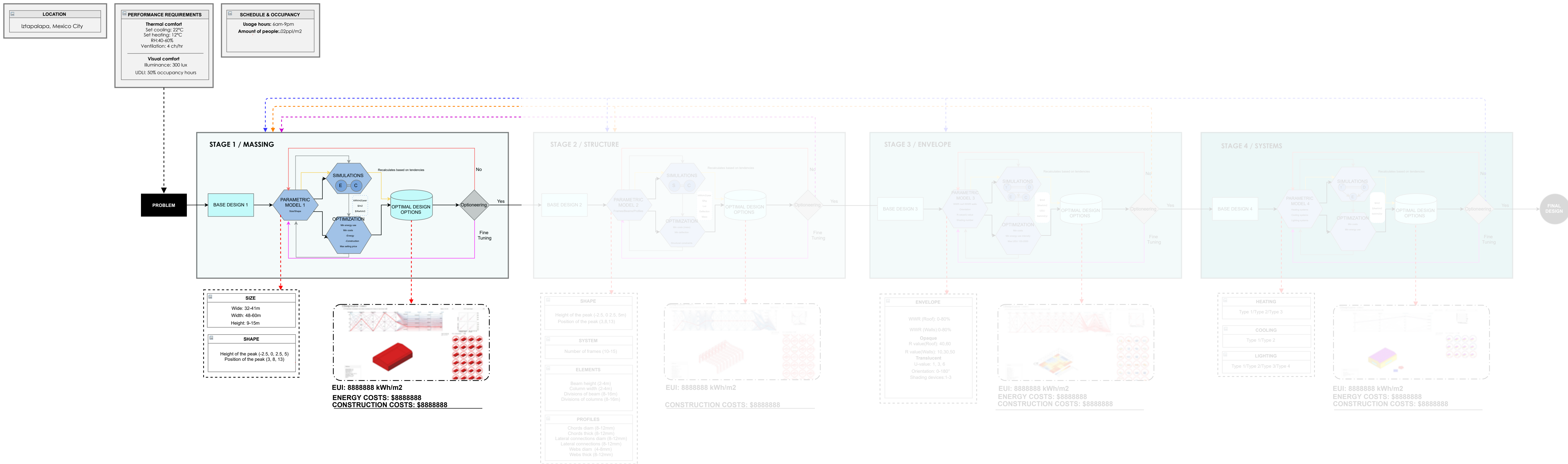
IMPLEMENTATION



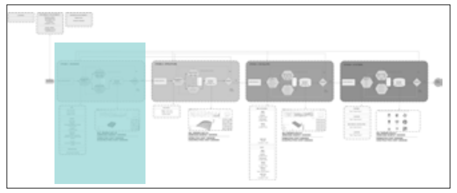
SEQUENTIAL STRATEGY

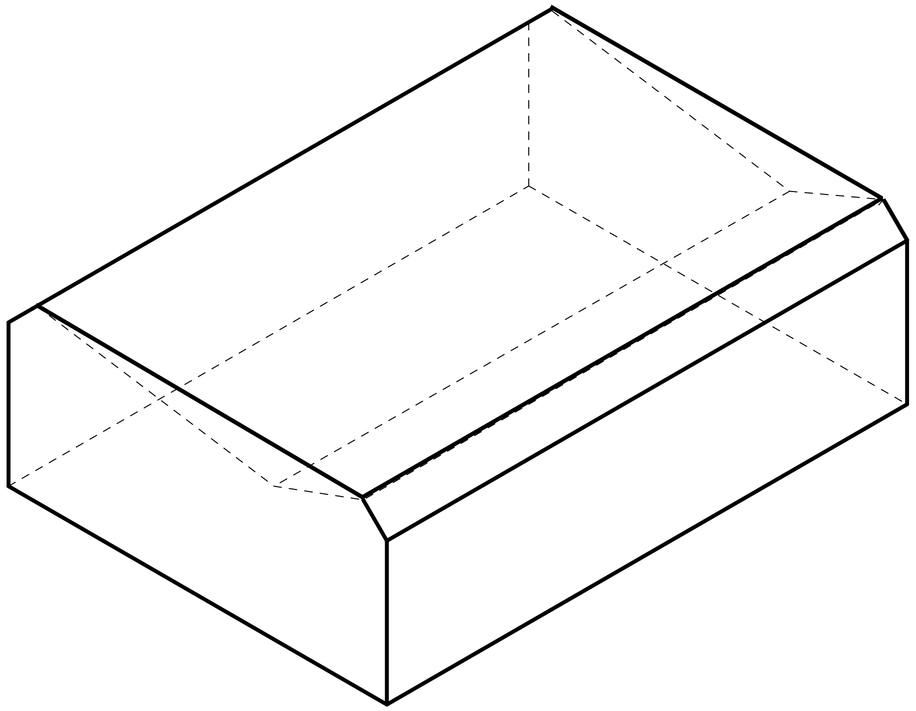


STAGE 1: MASSING

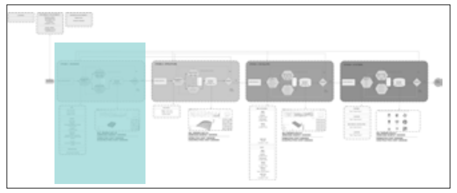


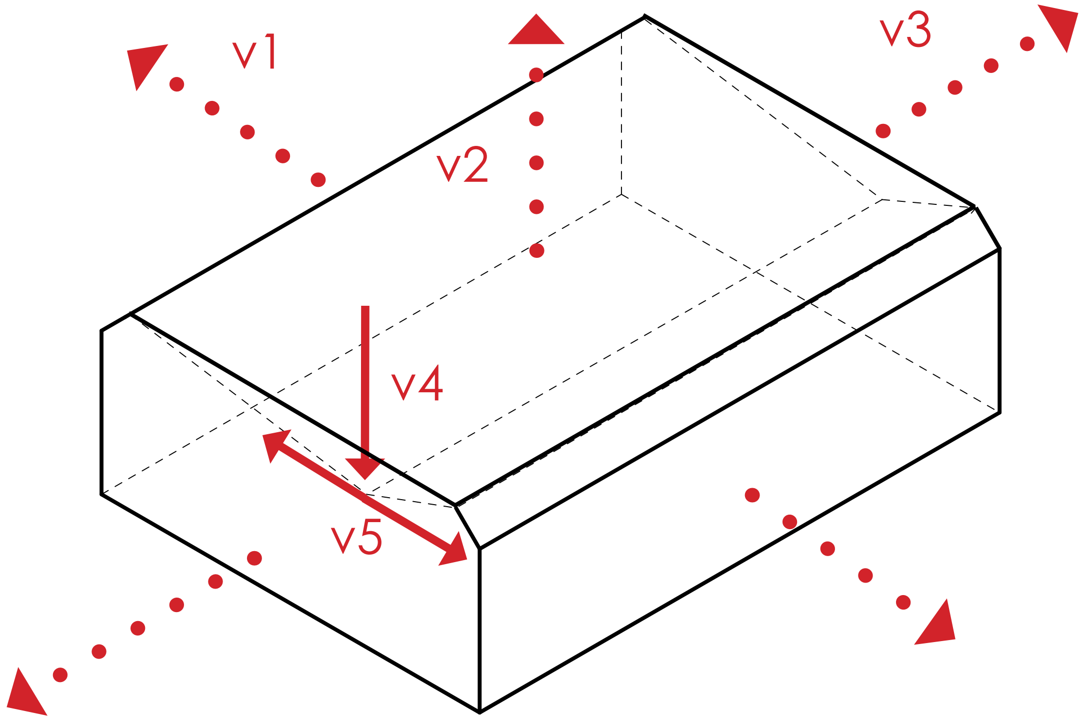
STAGE 1: MASSING

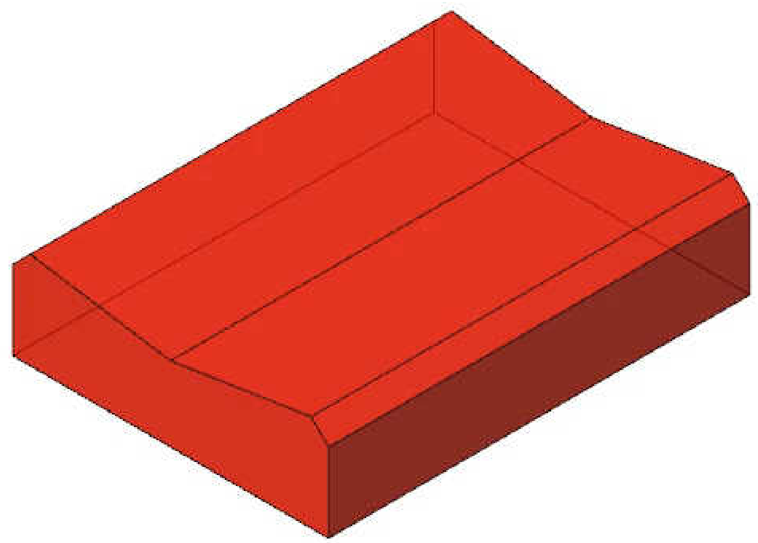


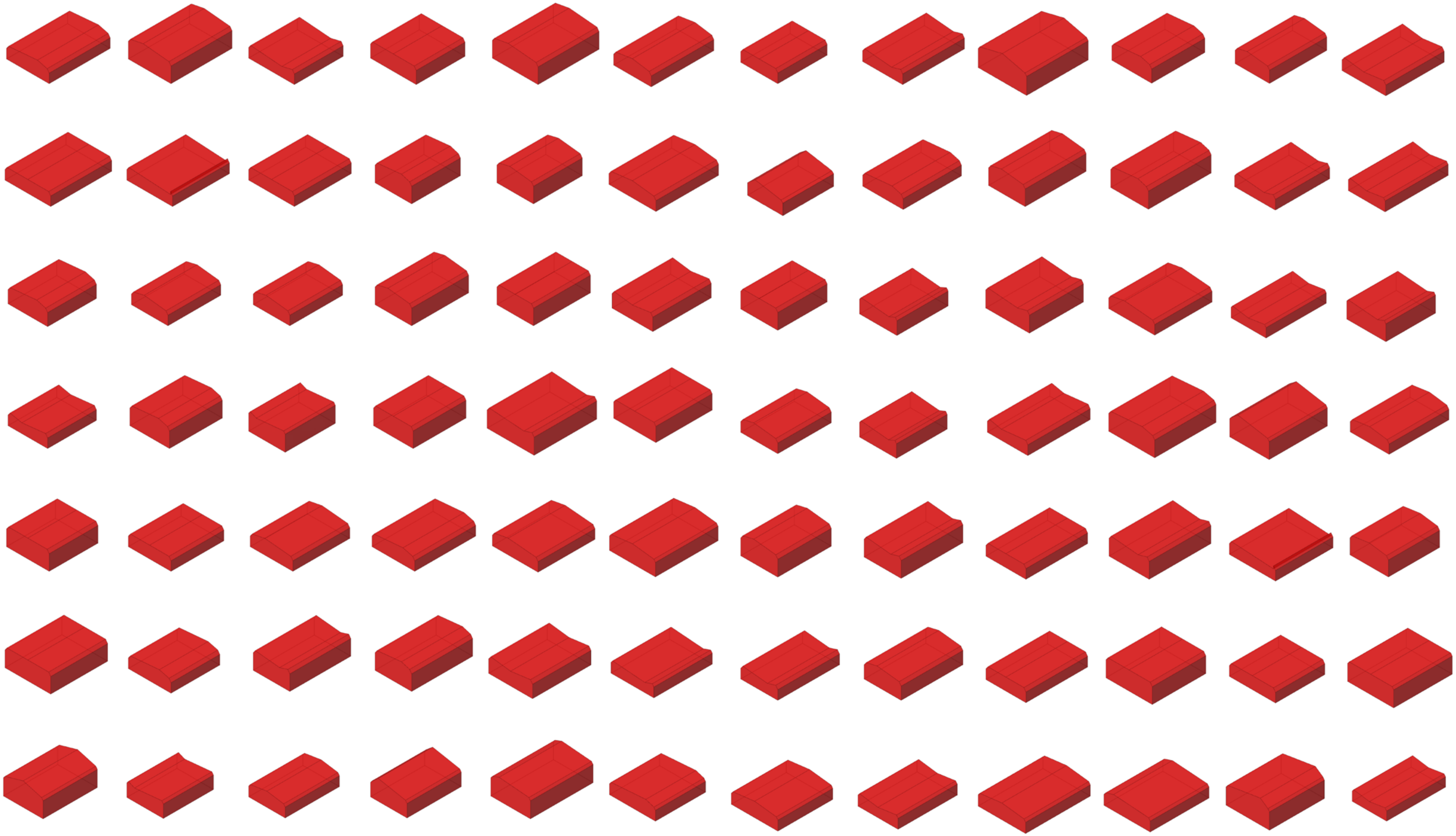


STAGE 1: MASSING

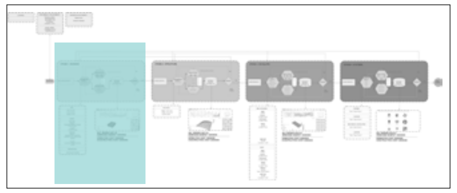


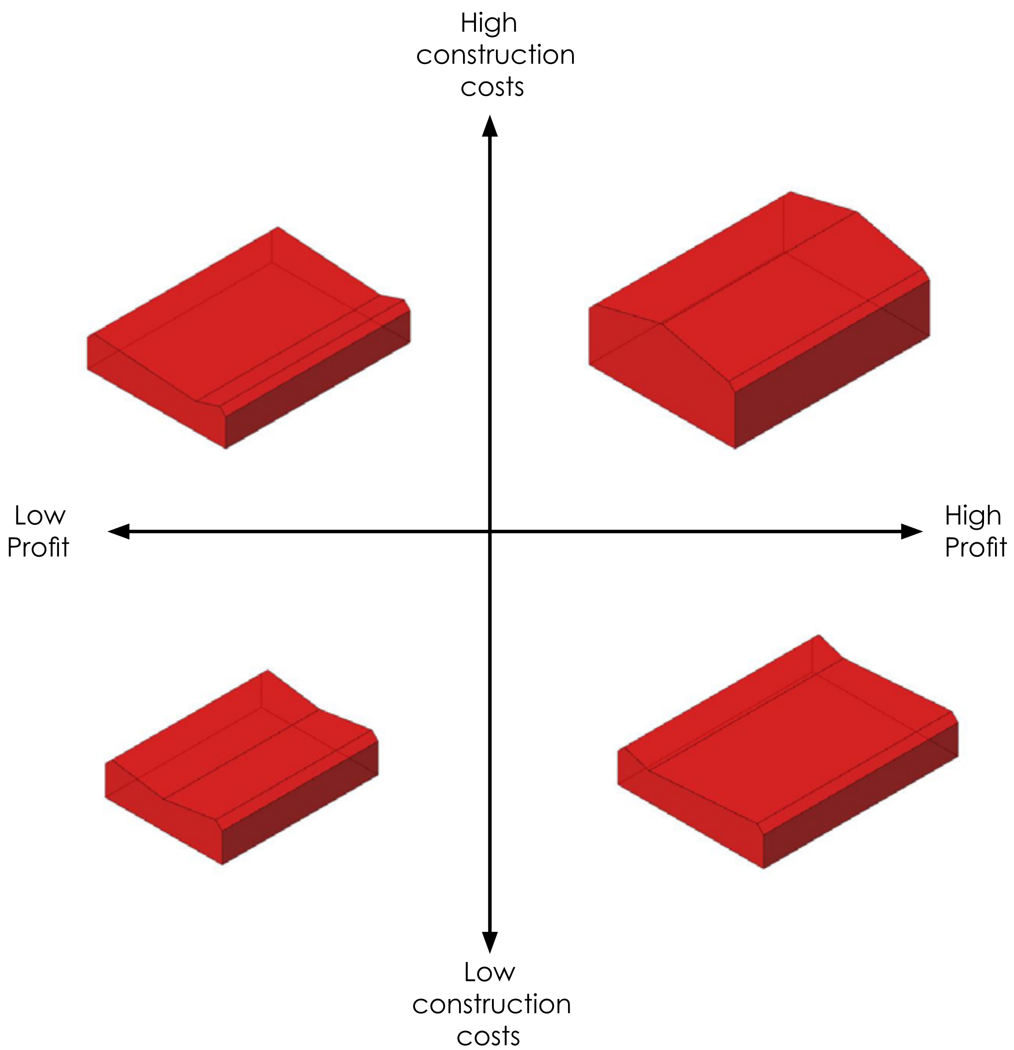


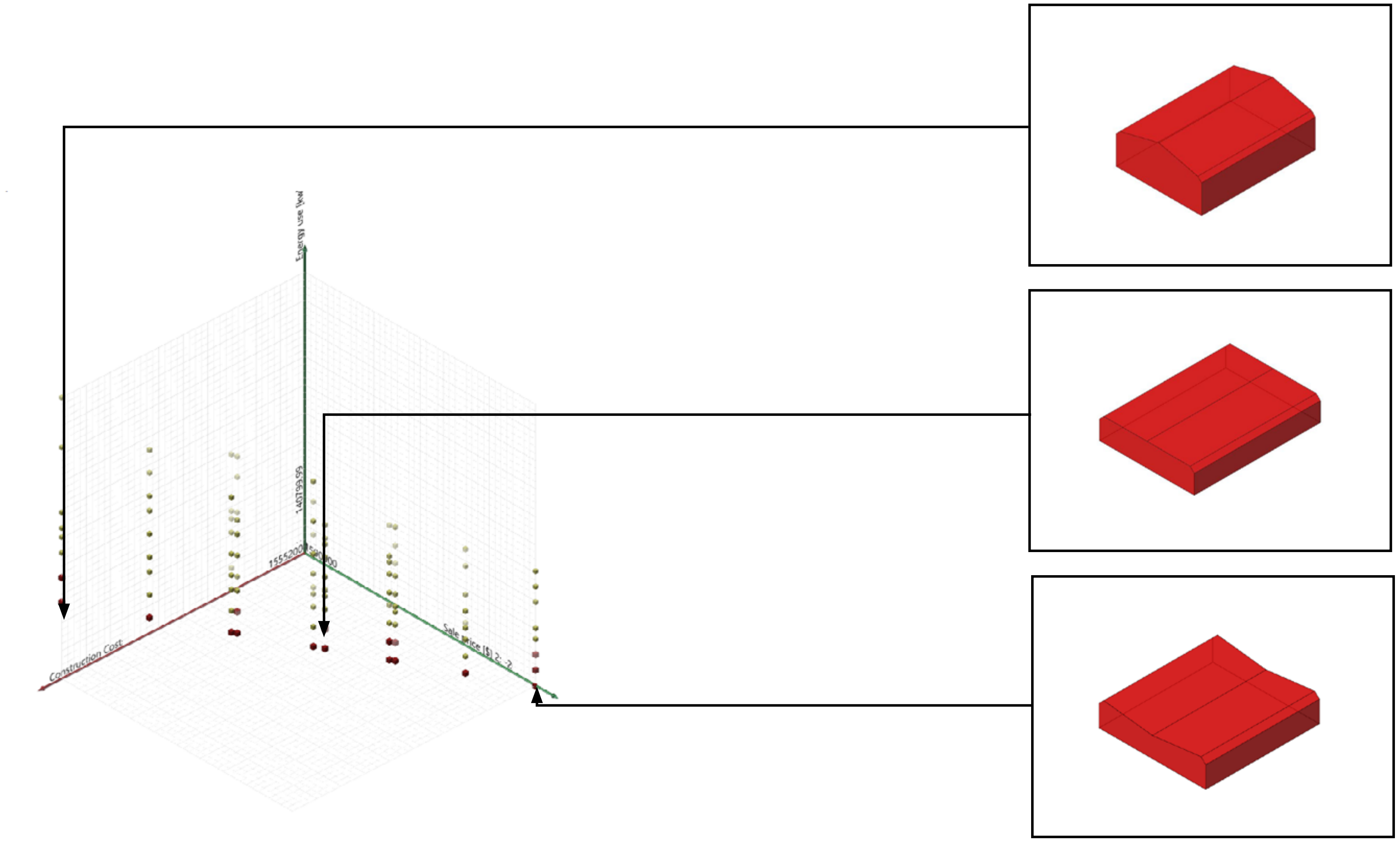


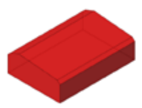


STAGE 1: MASSING

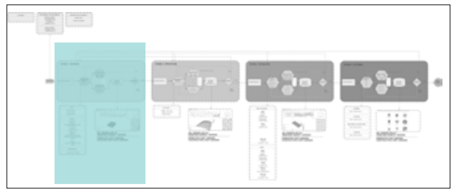


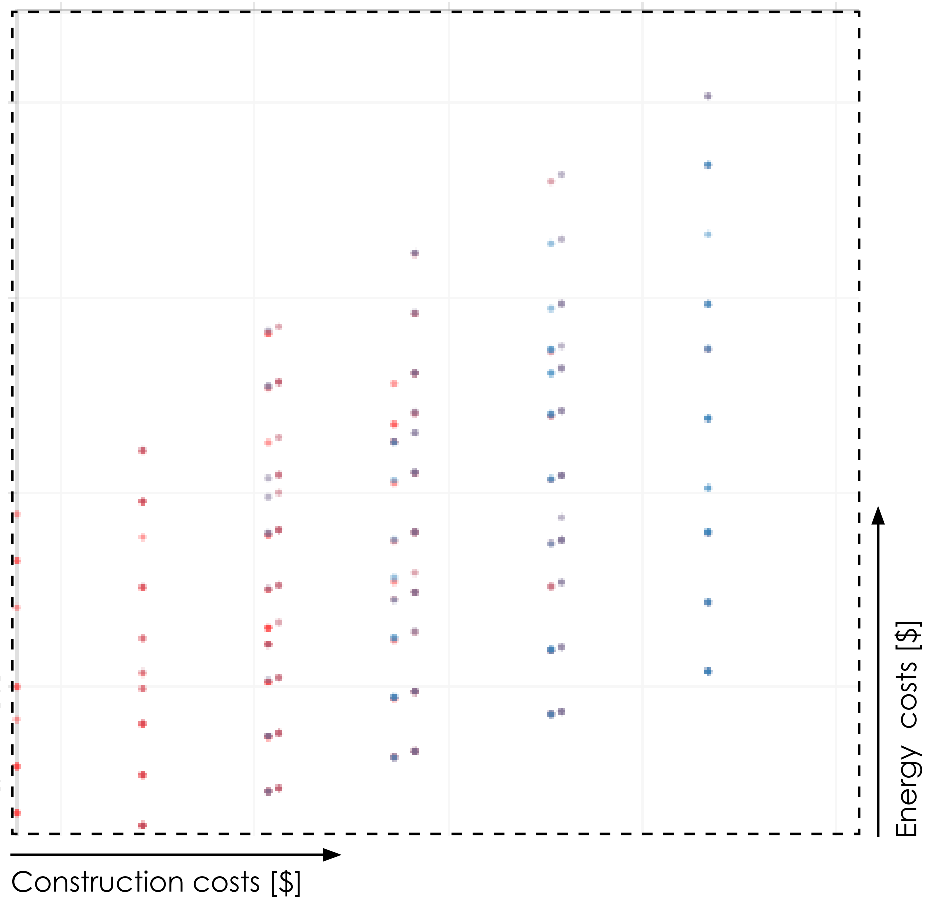


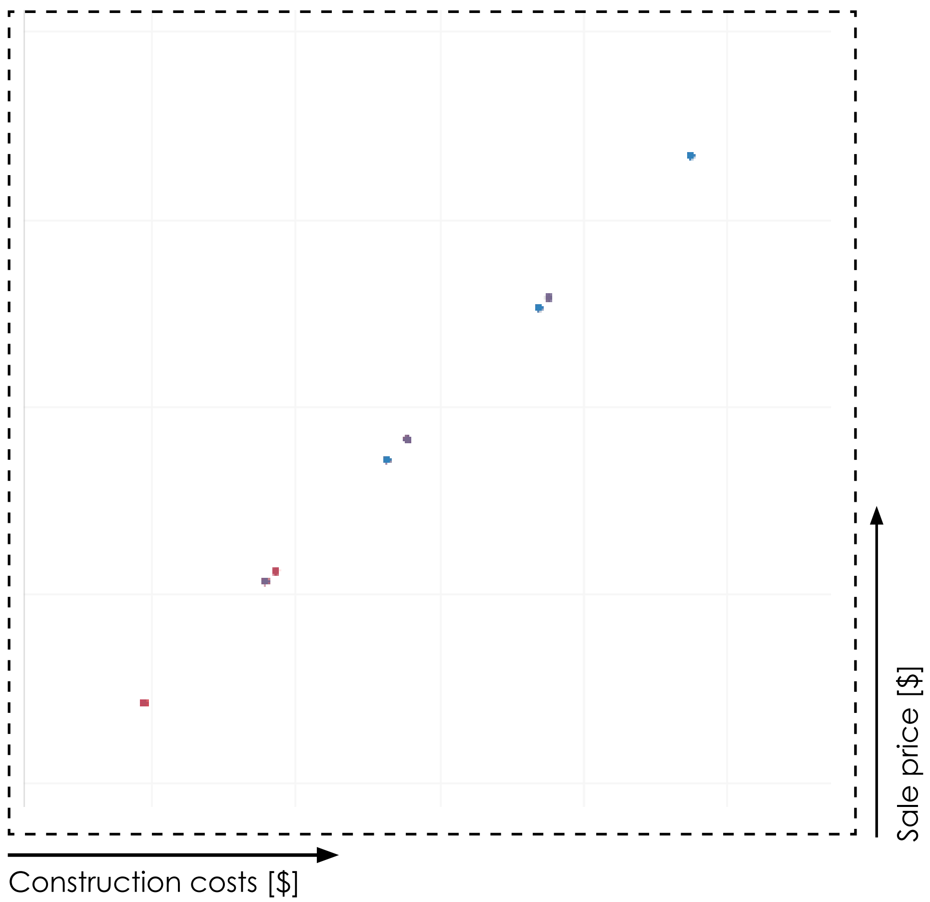


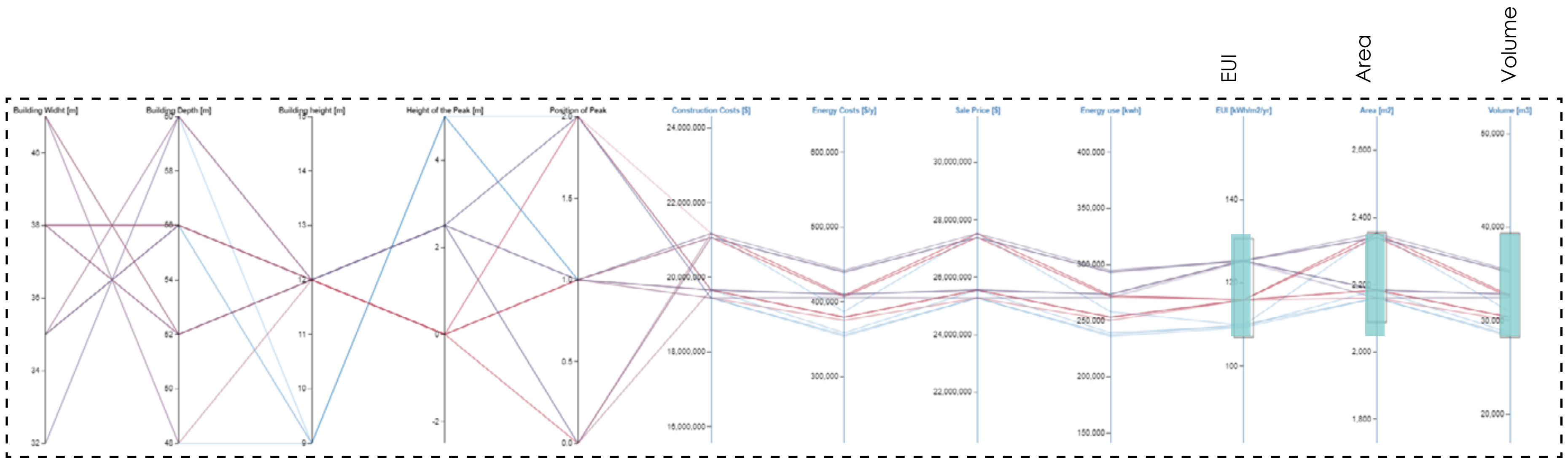
STAGE	NUMBER OF PARAMETERS	NUMBER OF GENERATIONS	DESIGN SPACE	DOMINATED / NON DOMINATED	COMPUTATIONAL TIME
	5 Parameters	6 Generations 100 Population	313-576	115 Non-dominated 73 Dominated	15 Minutes

STAGE 1: MASSING

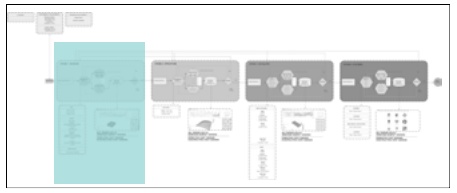


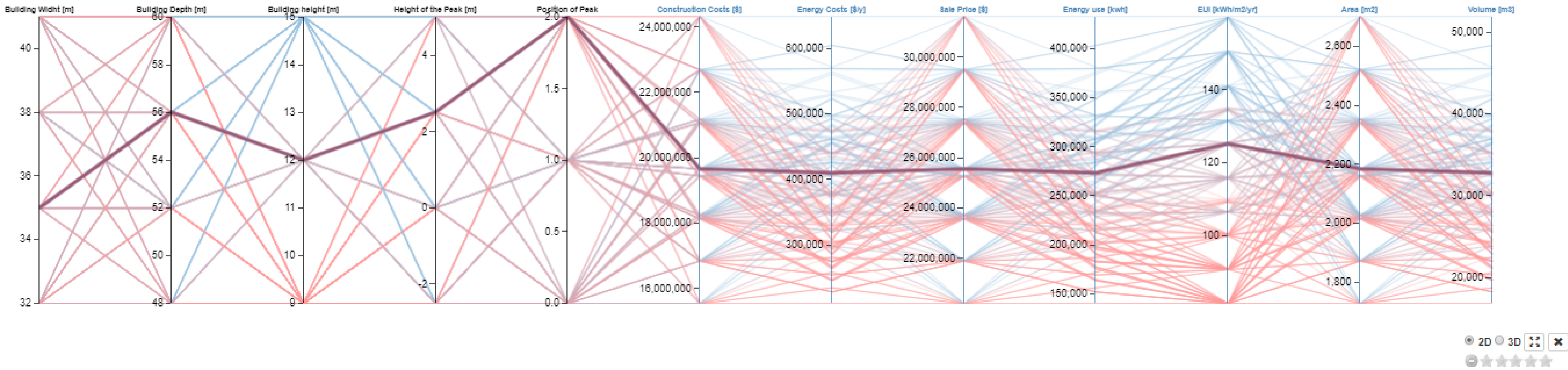


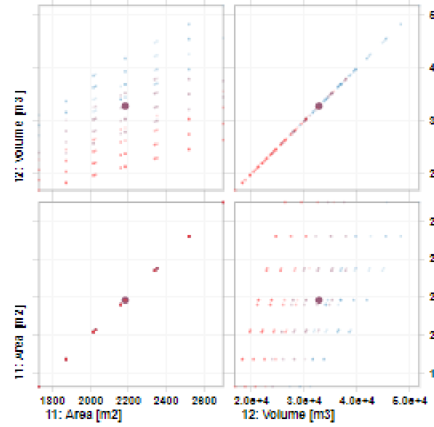


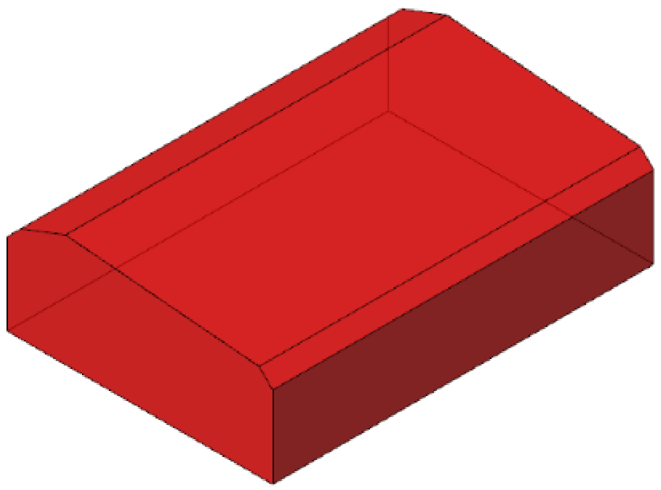


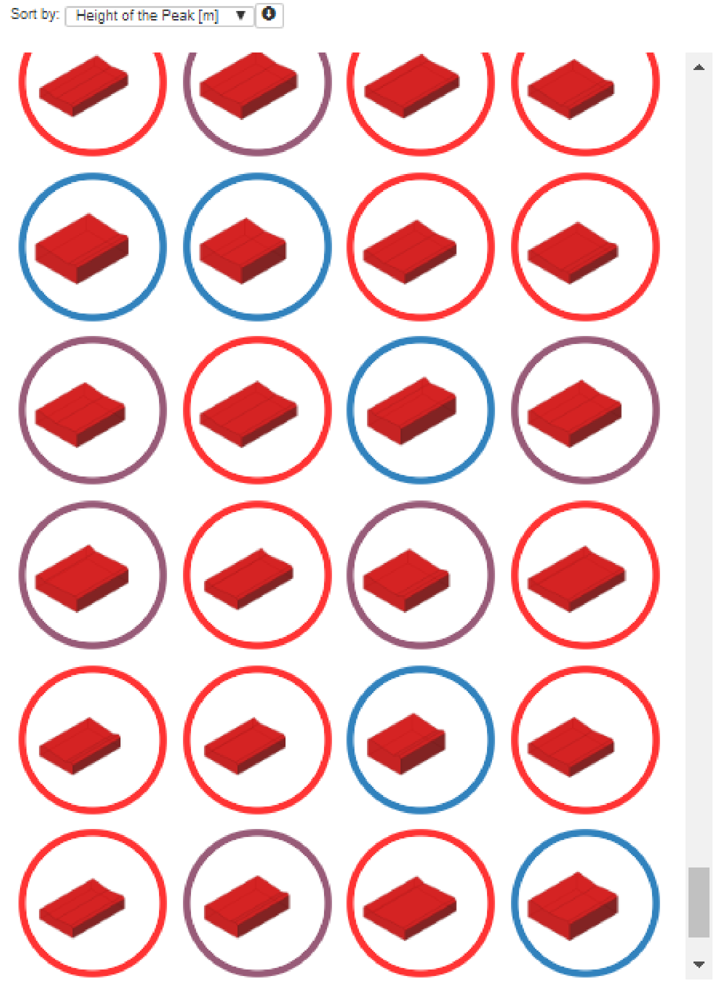
STAGE 1: MASSING







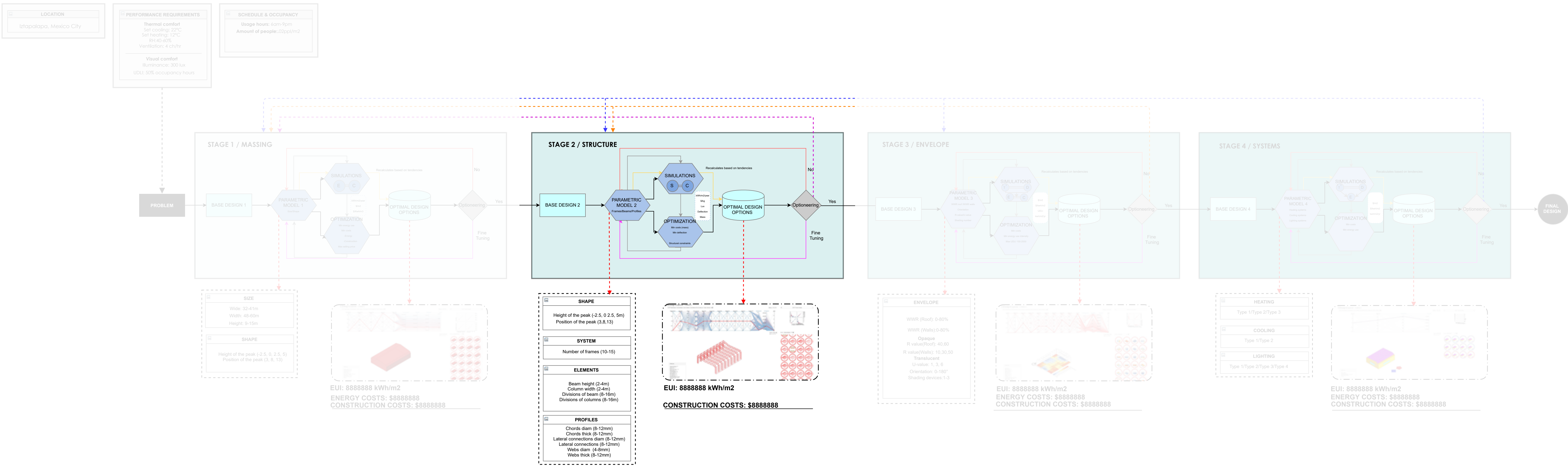




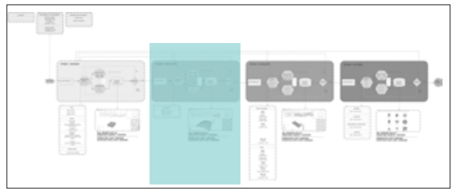
Attributes

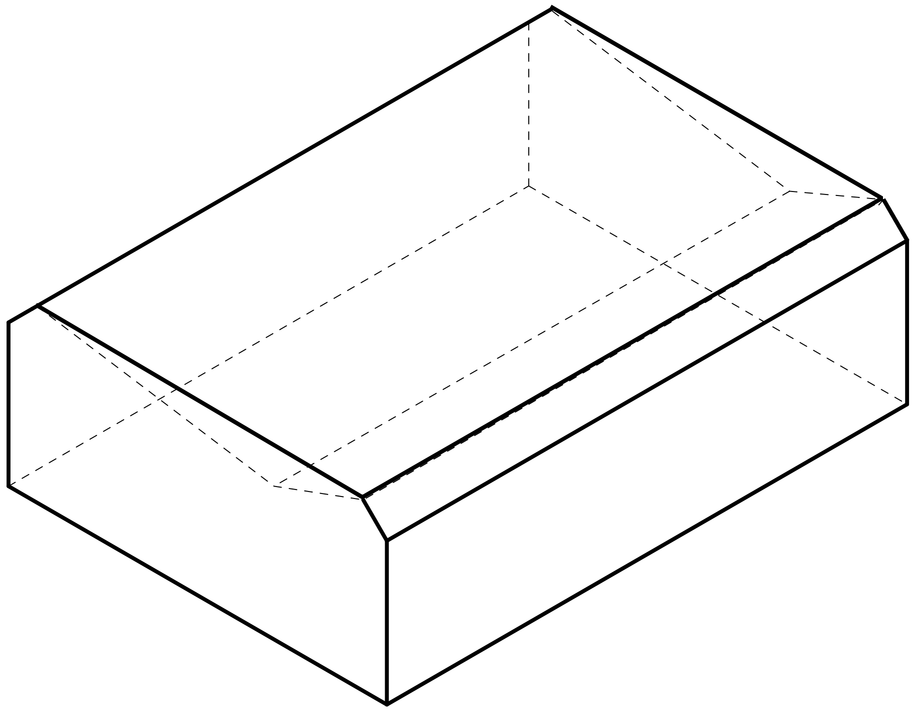
Building Widht [m] : 35.0
Building Depth [m] : 56.0
Building height [m] : 12.0
Height of the Peak [m] : 2.5
Position of Peak : 2.0
Construction Costs [$] : 19656000.0
Energy Costs [$/y] : 410024.983599
Sale Price [$] : 25552800
Energy use [kwh] : 273349.989066
EUI [kWh/m2/yr] : 125.160251
Area [m2] : 2184
Volume [m3] : 32802
Rating : 0

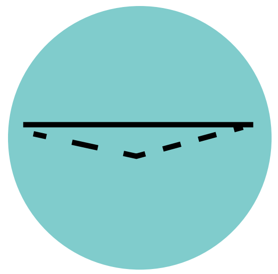
STAGE 2: STRUCTURE



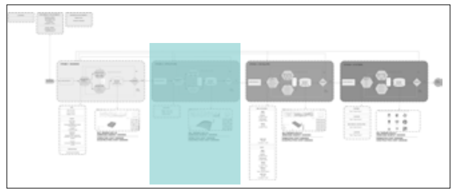
STAGE 2: STRUCTURE

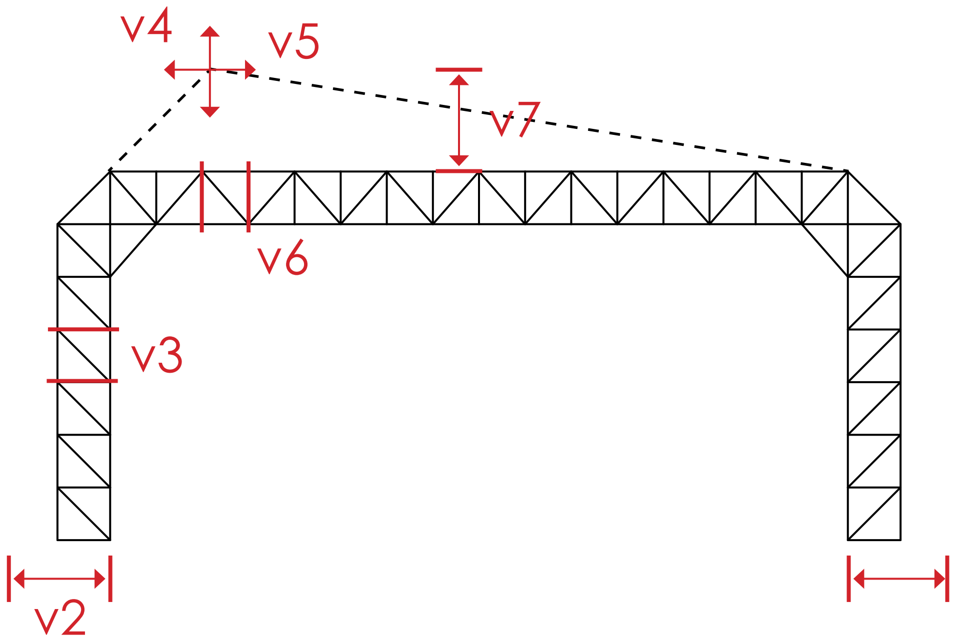


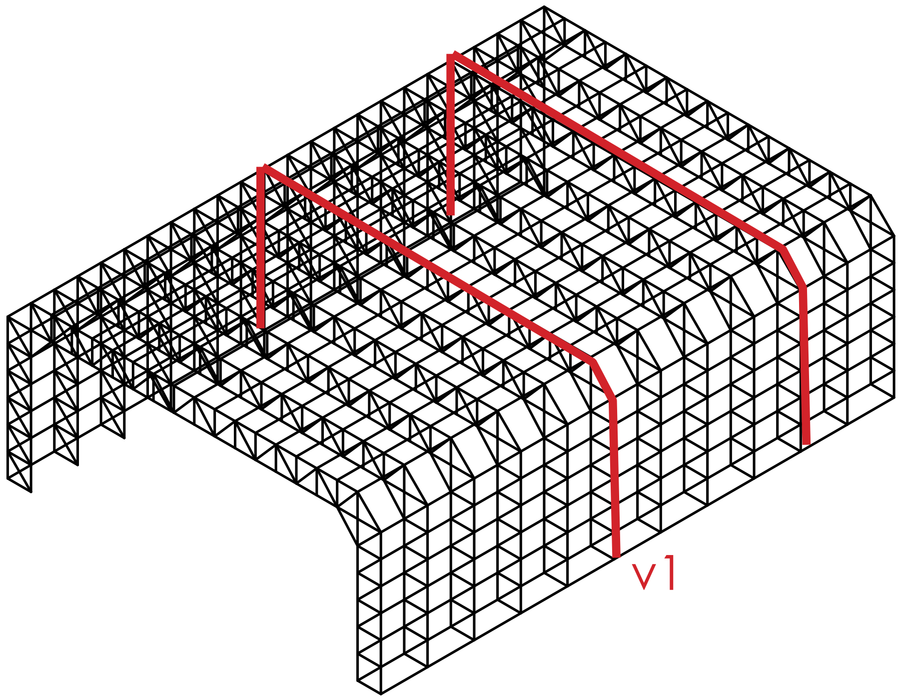


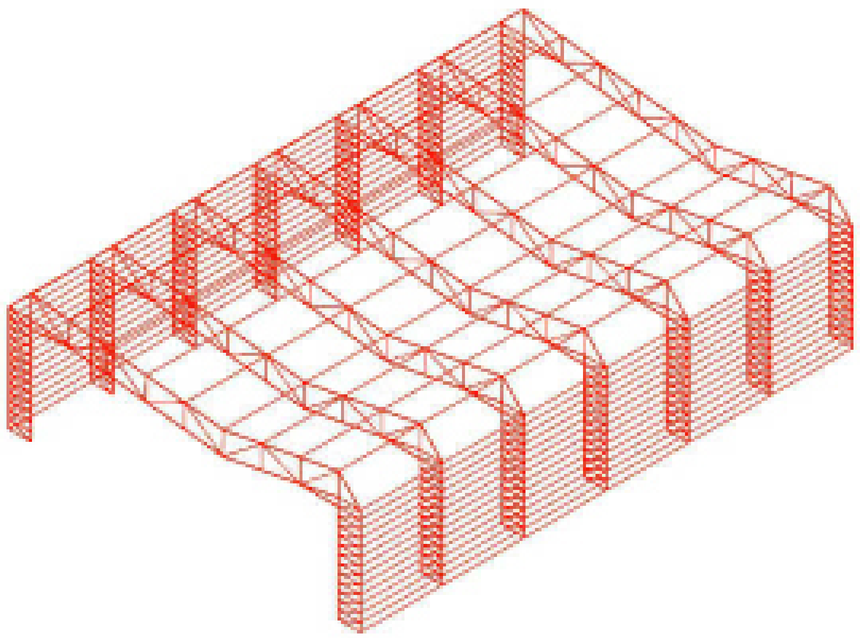


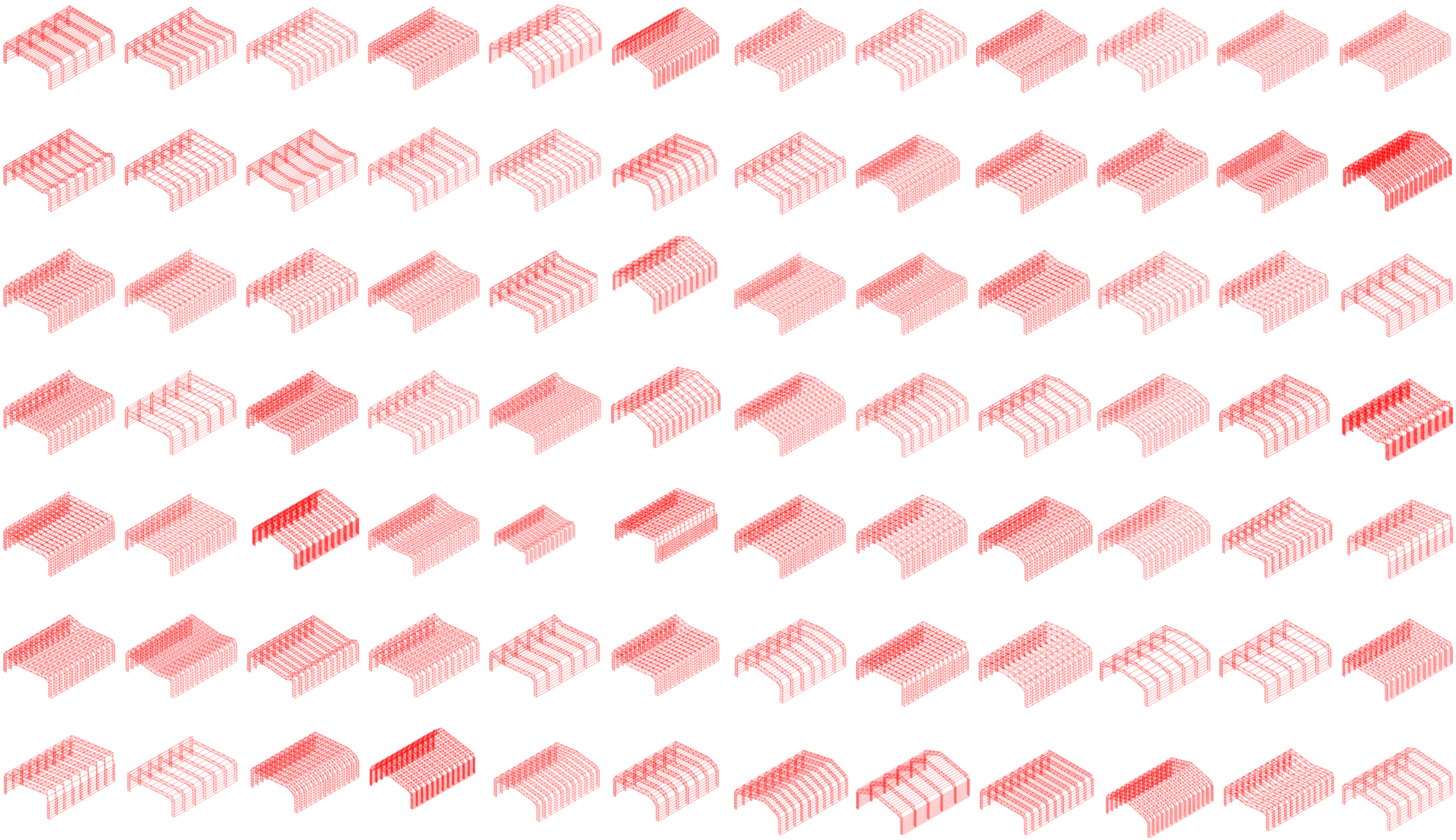
STAGE 2: STRUCTURE



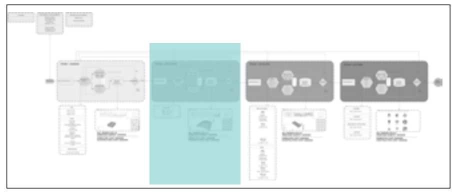


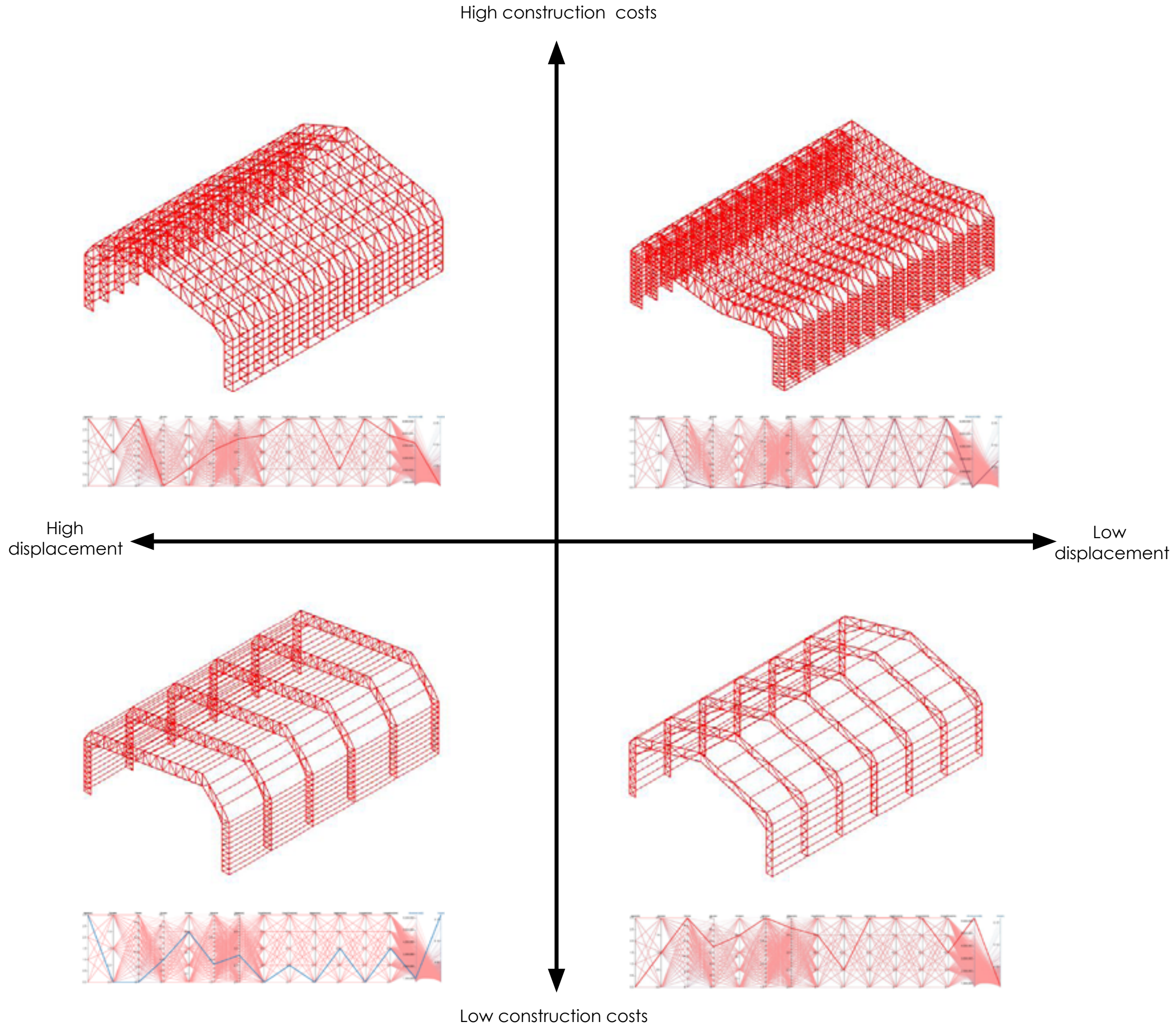


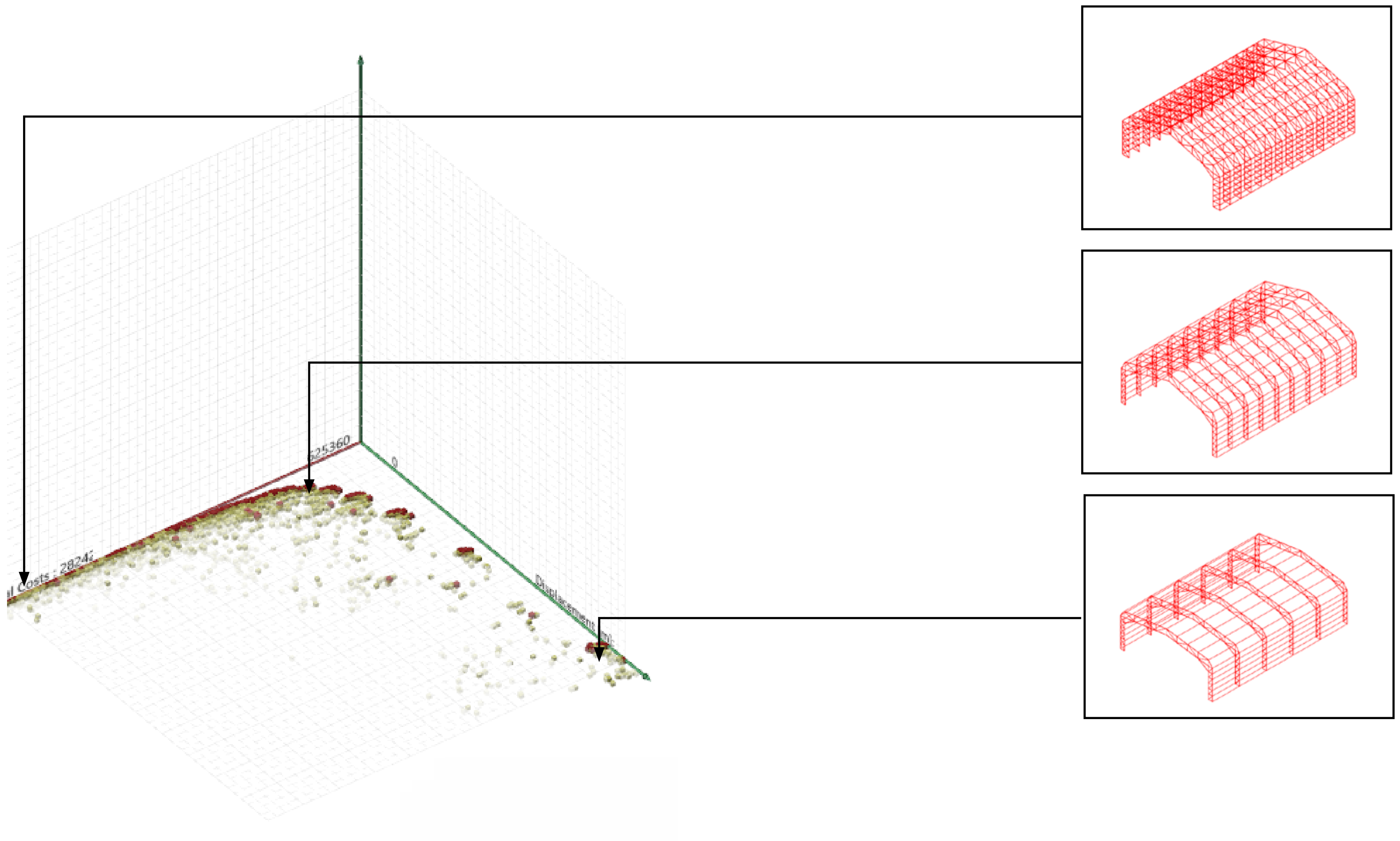


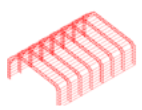


STAGE 2: STRUCTURE

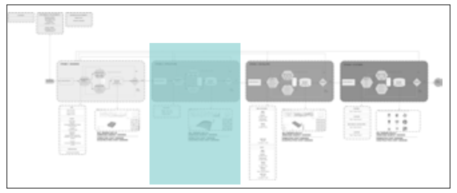


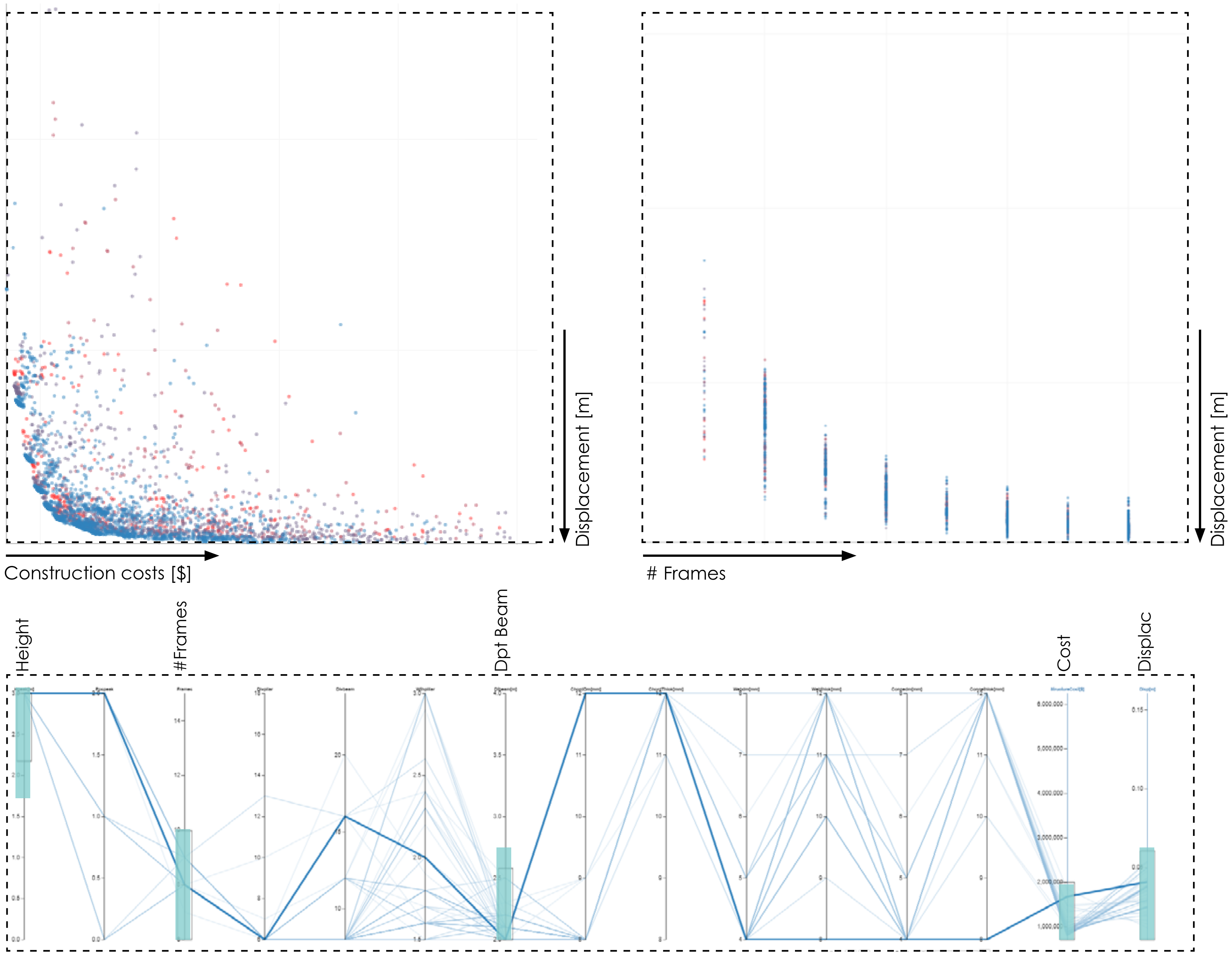




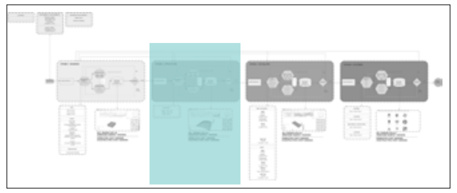
STAGE	NUMBER OF PARAMETERS	NUMBER OF GENERATIONS	DESIGN SPACE	DOMINATED / NON DOMINATED	COMPUTATIONAL TIME
	13 Parameters	50 Generations 100 Population	3200 from 118125000	140 Non-dominated 60 Dominated	2.5 Hours

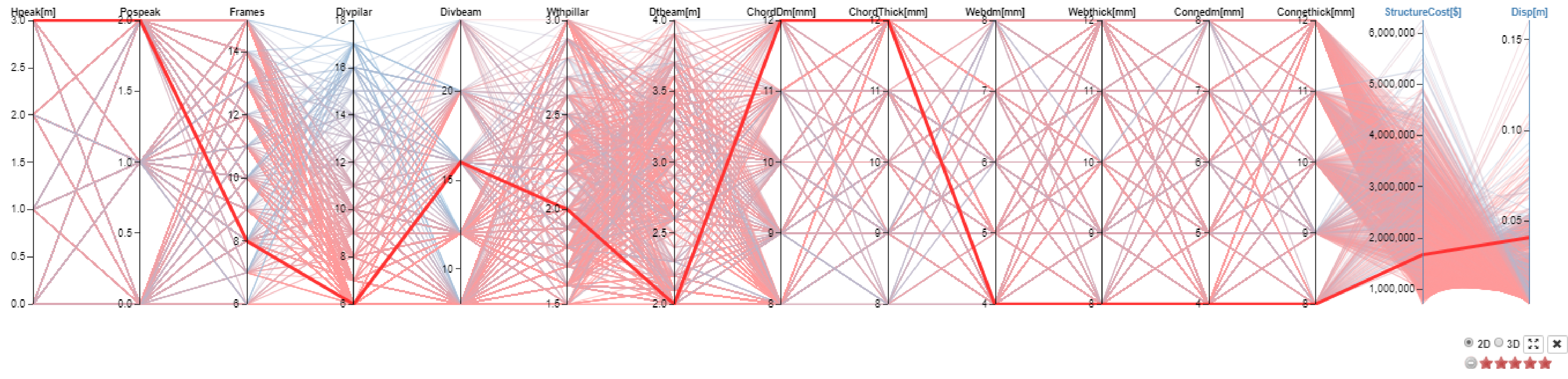
STAGE 2: STRUCTURE

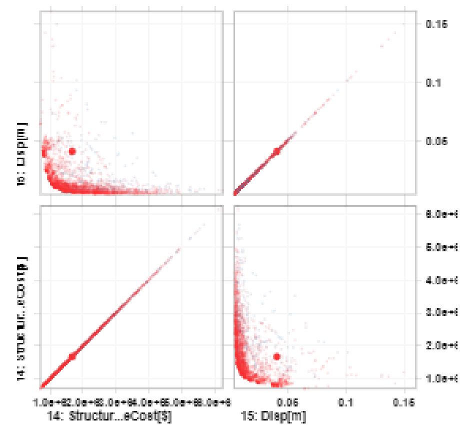


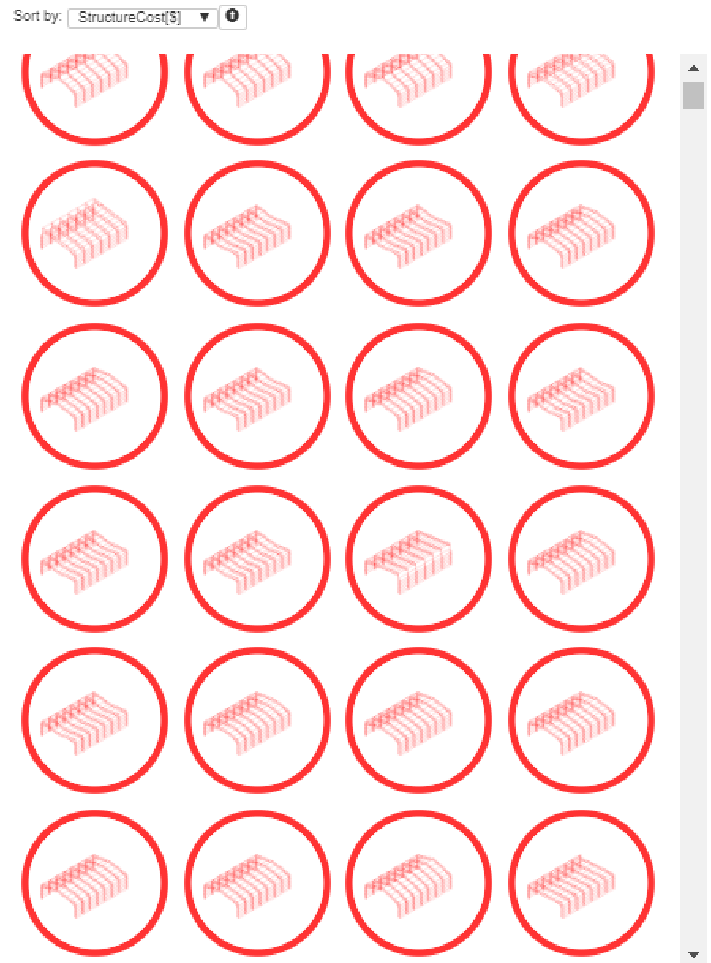


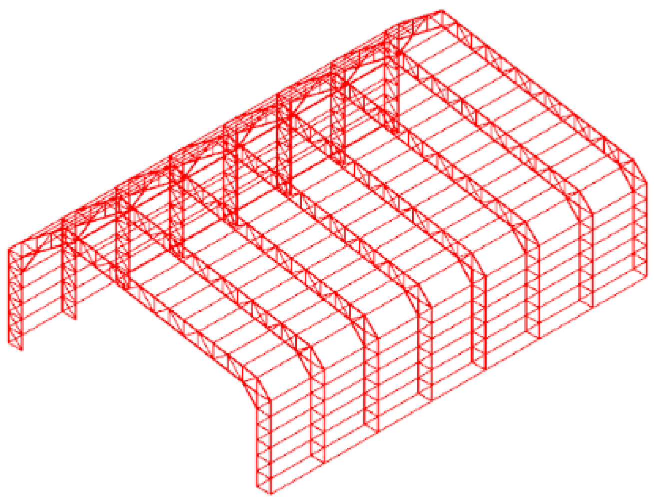
STAGE 2: STRUCTURE







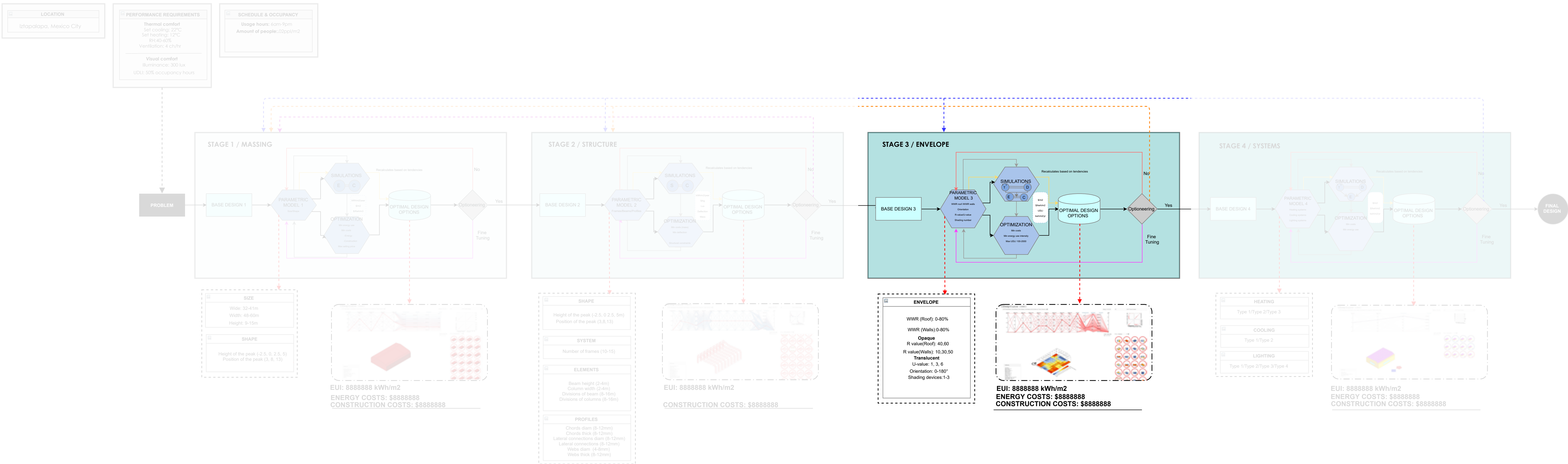




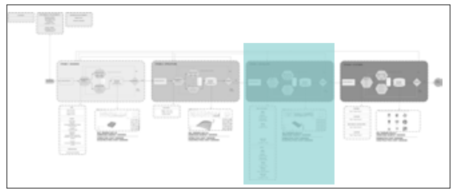
Attributes

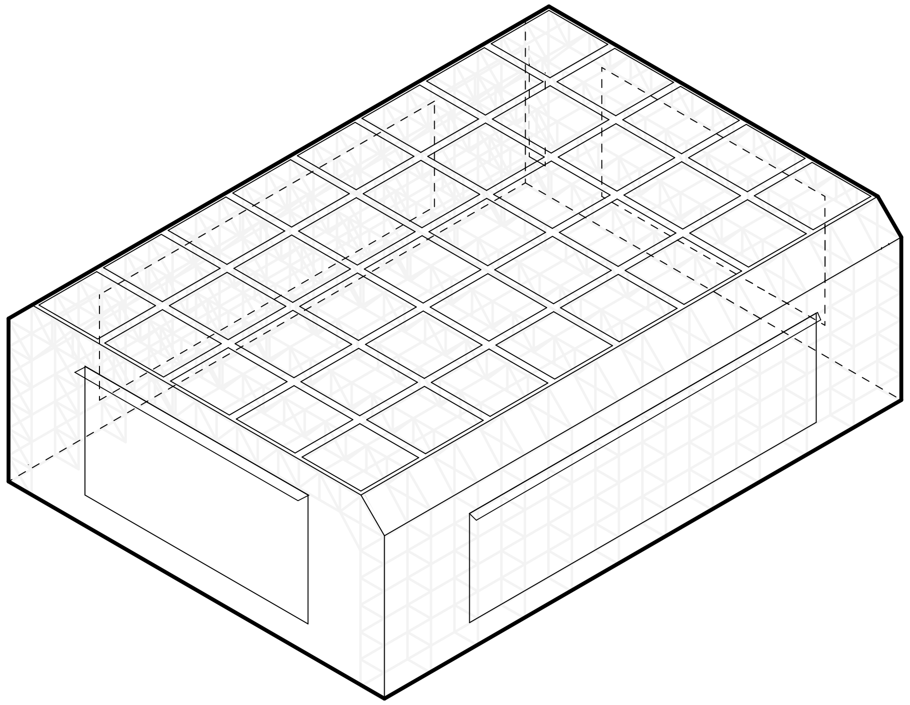
Hpeak[m] : 3.0
Pospeak : 2.0
Frames : 8.0
Divpilar : 6.0
Divbeam : 16.0
Wthpillar : 2.0
Dtbeam[m] : 2.0
ChordDm[mm] : 12.0
ChordThick[mm] : 12.0
Webdm[mm] : 4.0
Webthick[mm] : 8.0
Connedm[mm] : 4.0
Connethick[mm] : 8.0
StructureCost[$] : 1672760
Disp[m] : 0.040746
Rating : 0

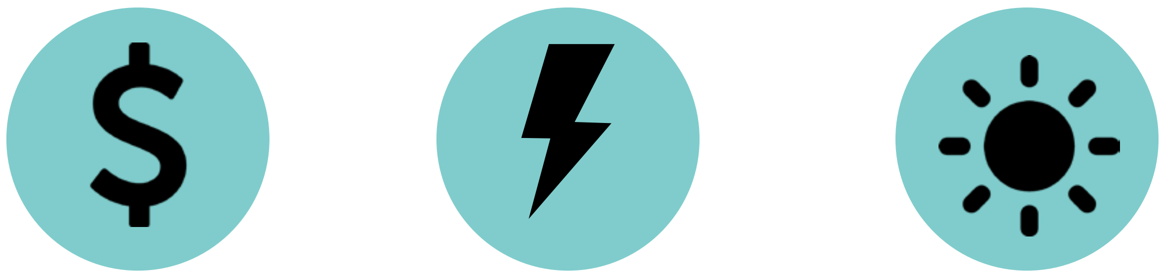
STAGE 3: ENVELOPE



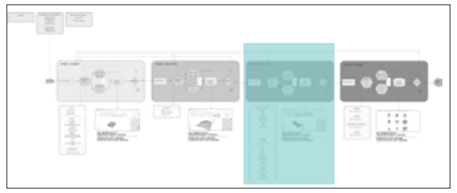
STAGE 3: ENVELOPE

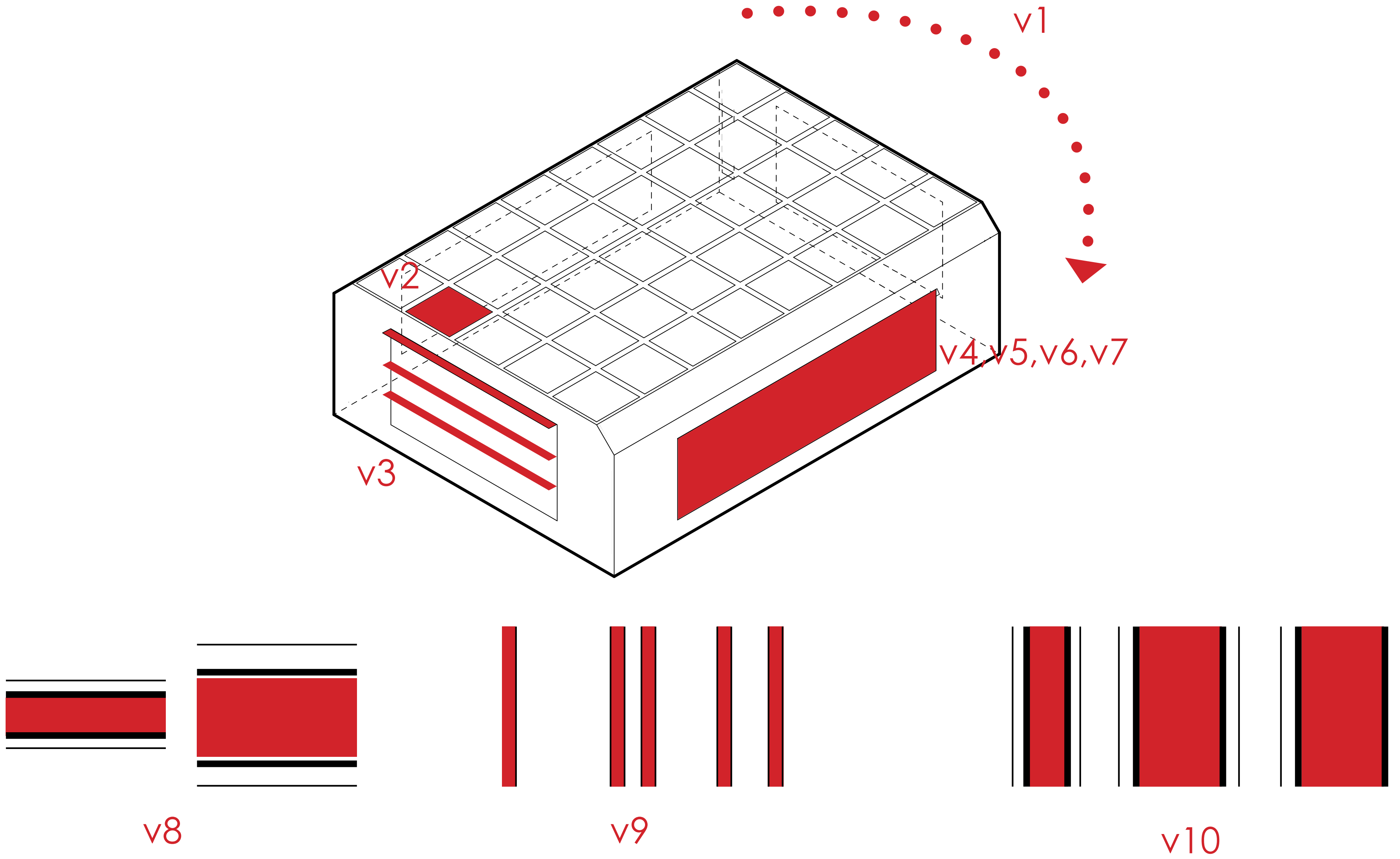


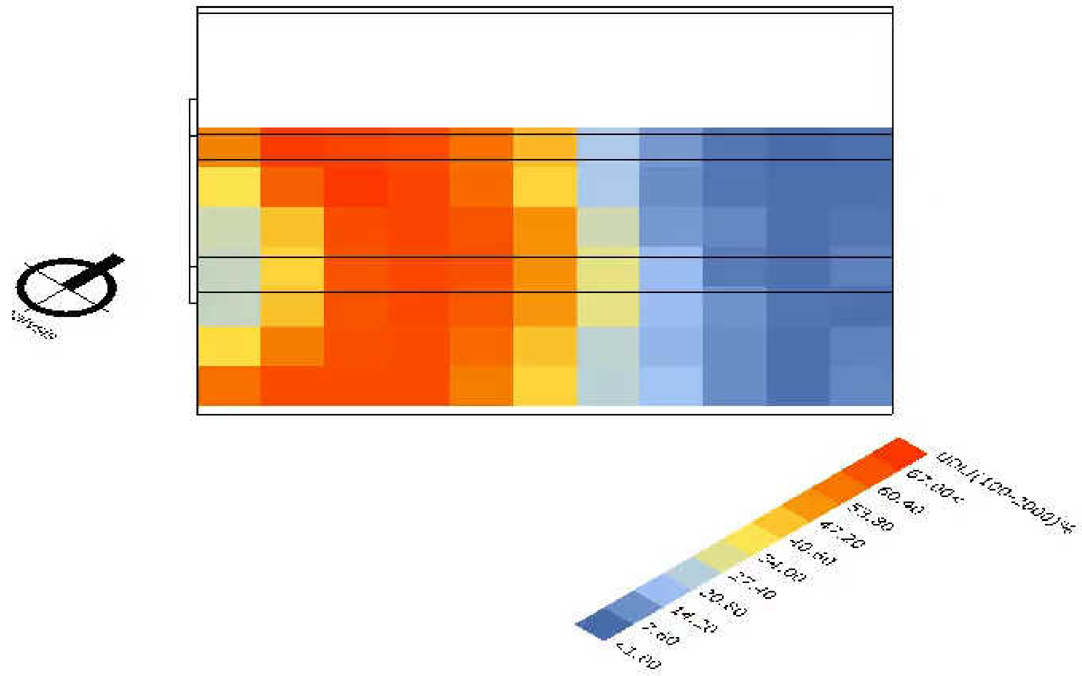




STAGE 3: ENVELOPE



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53.80
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34.00
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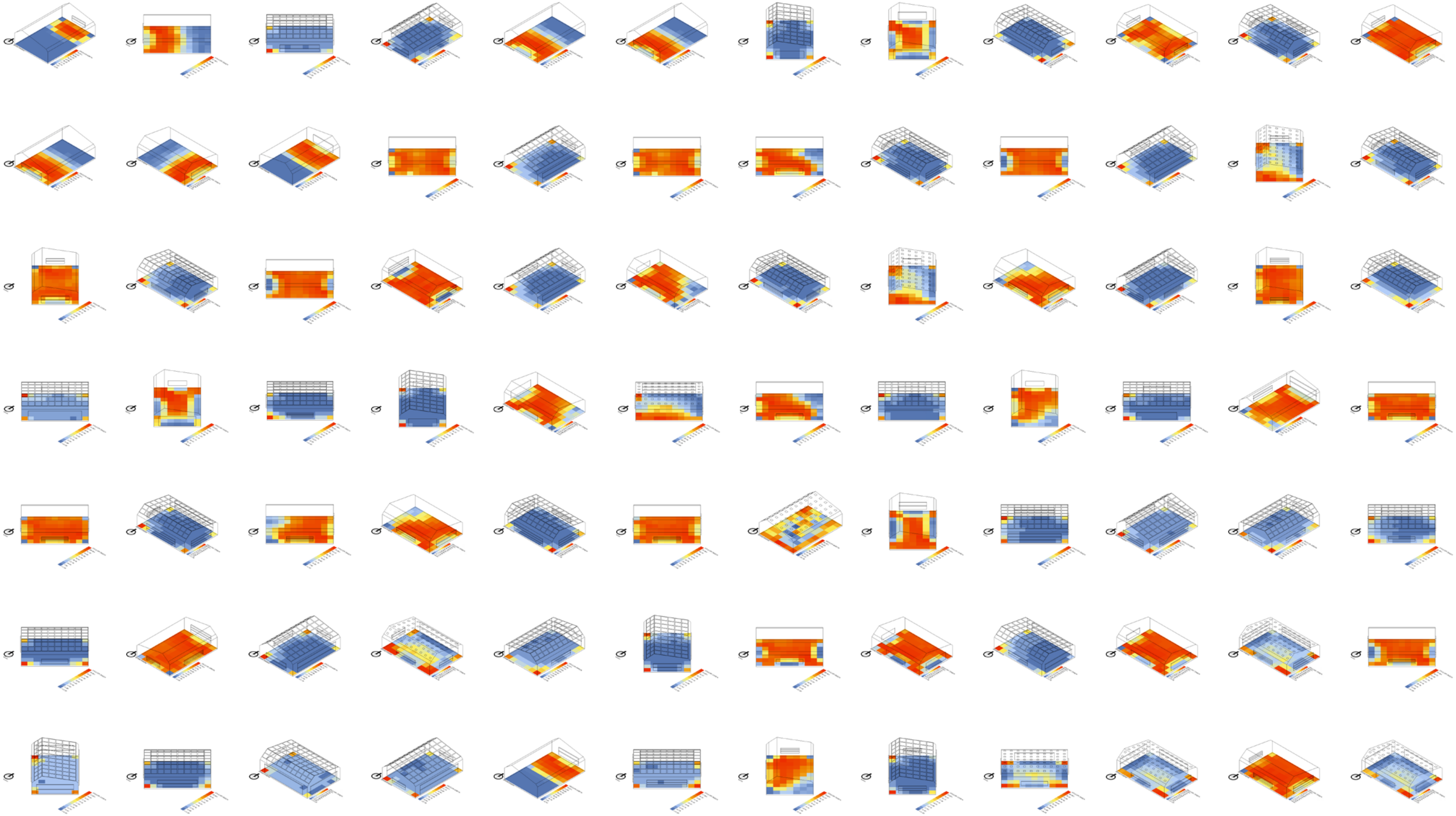
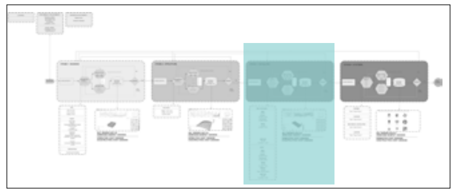
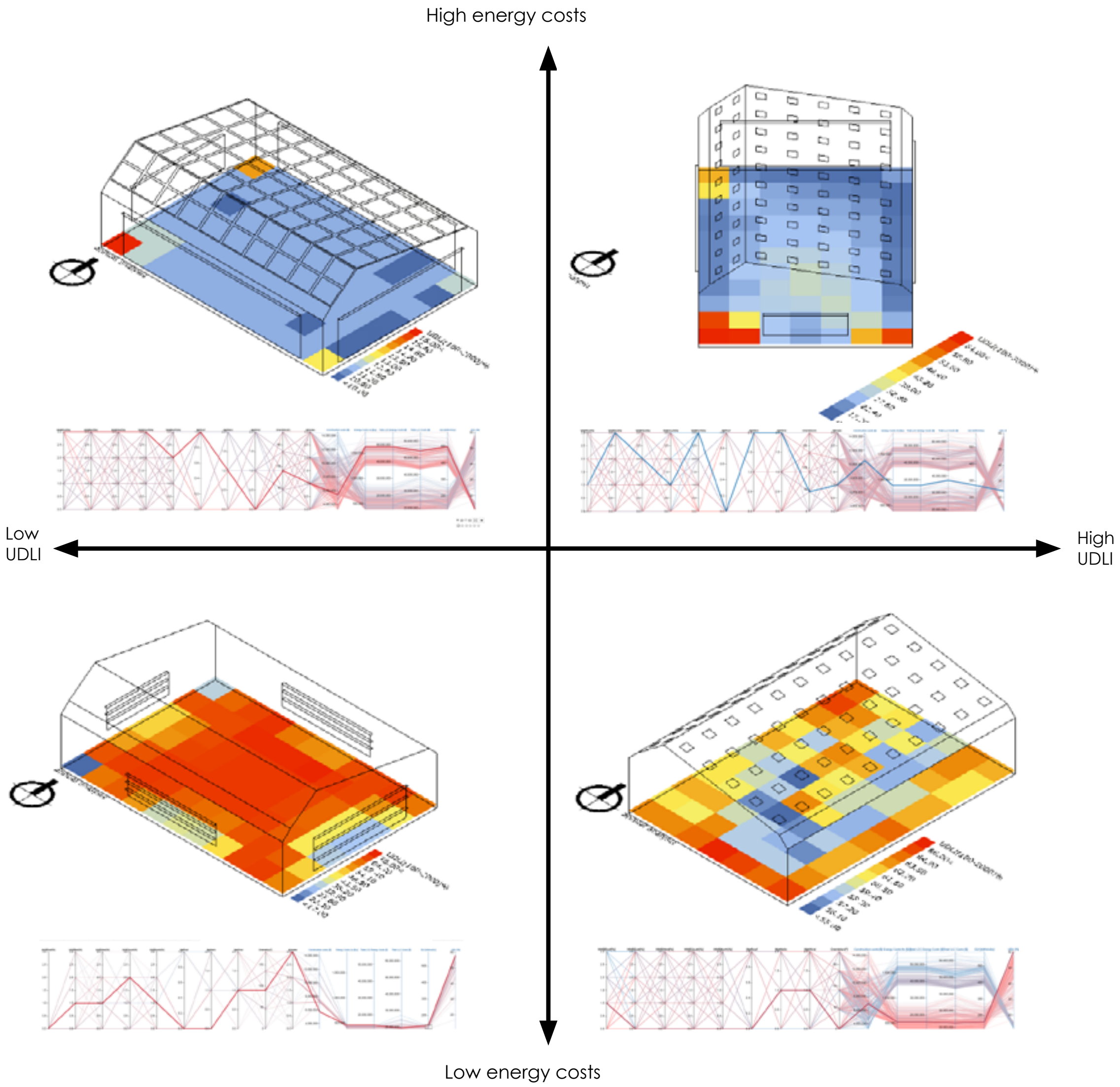
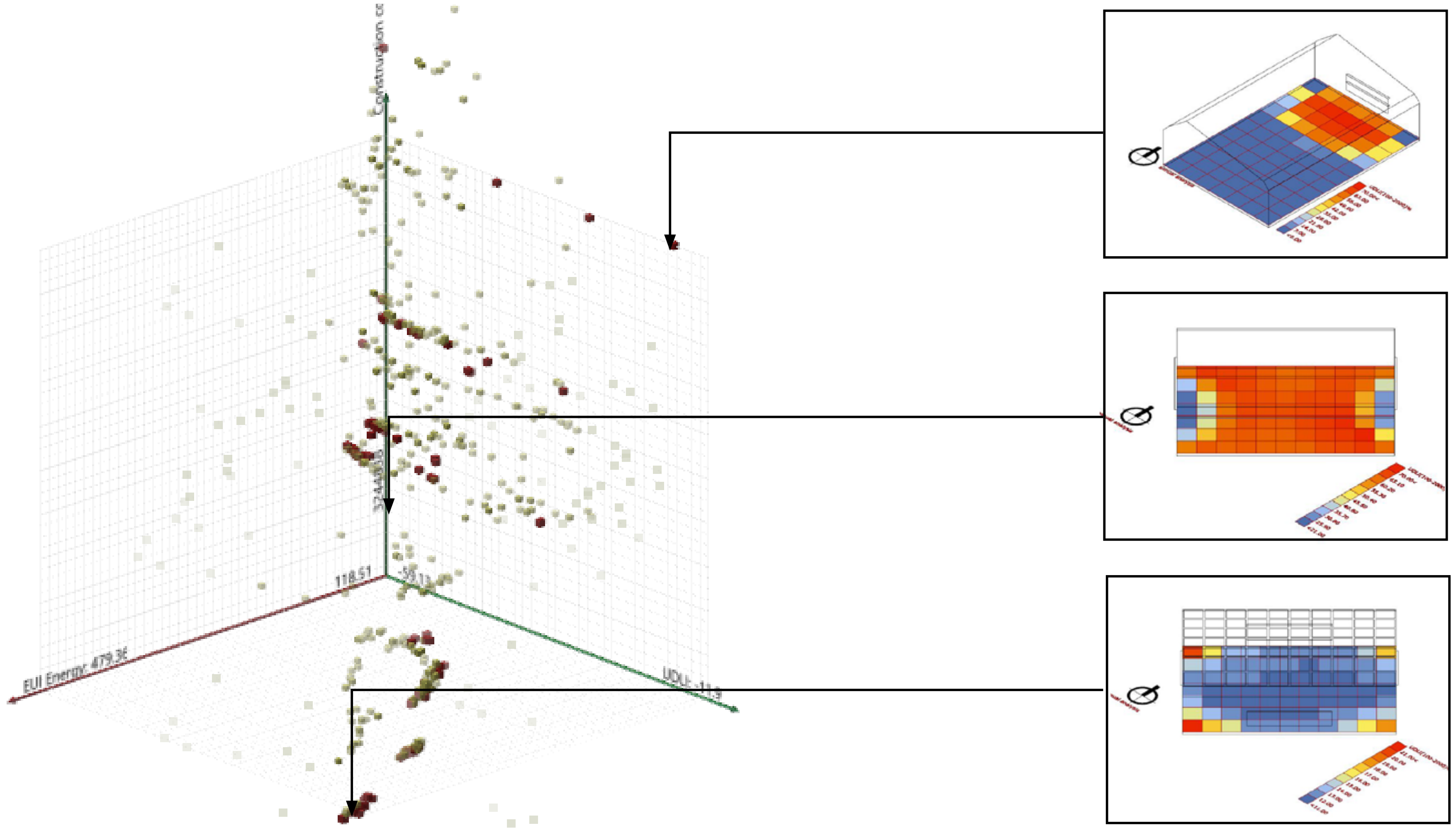
14.20
7.60

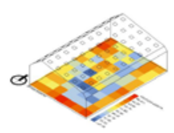


STAGE 3: ENVELOPE

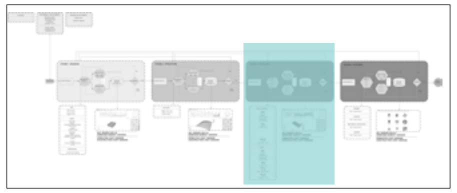


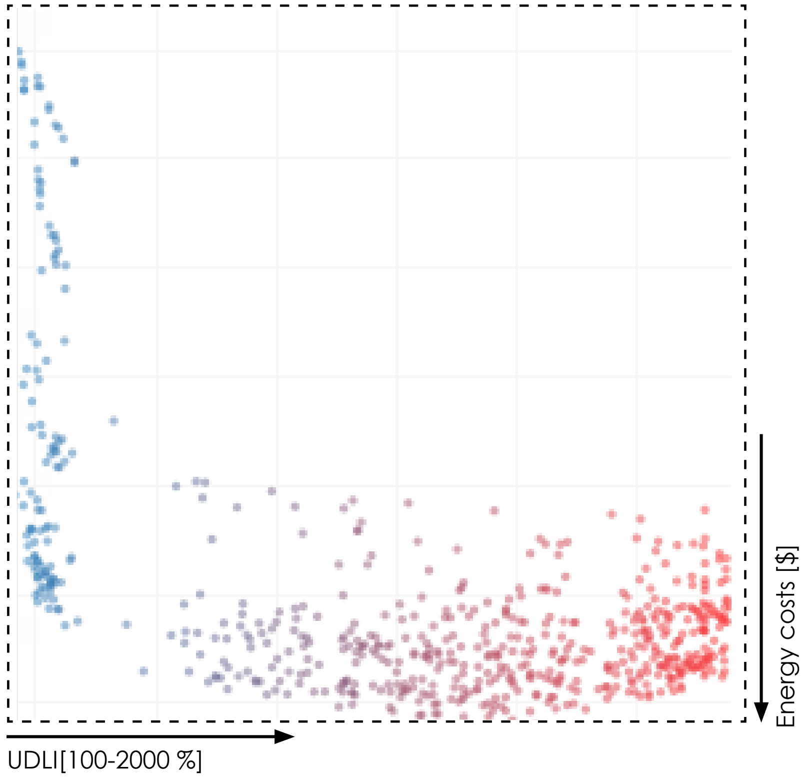


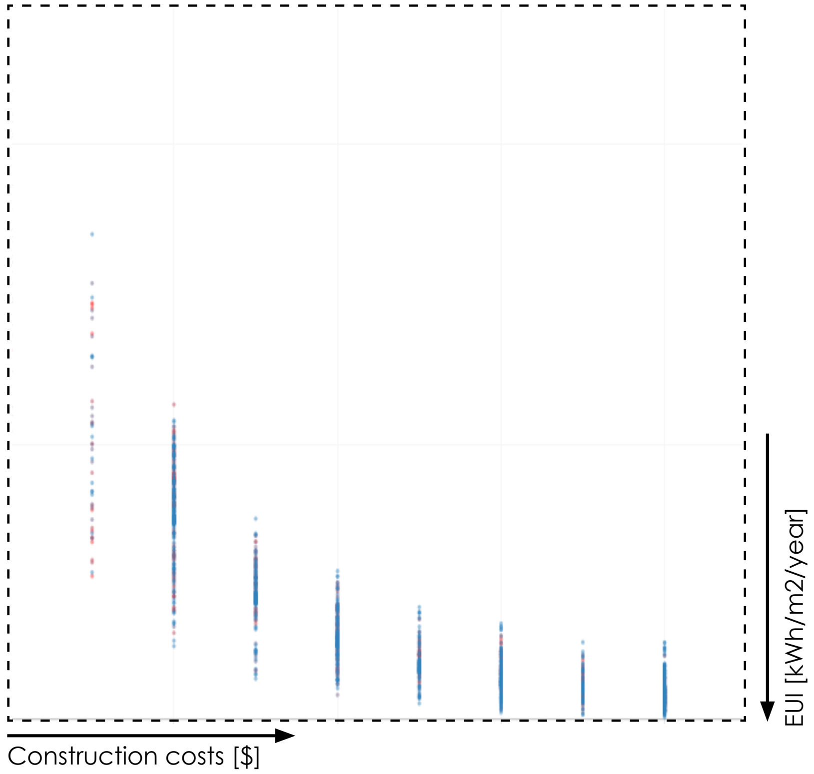


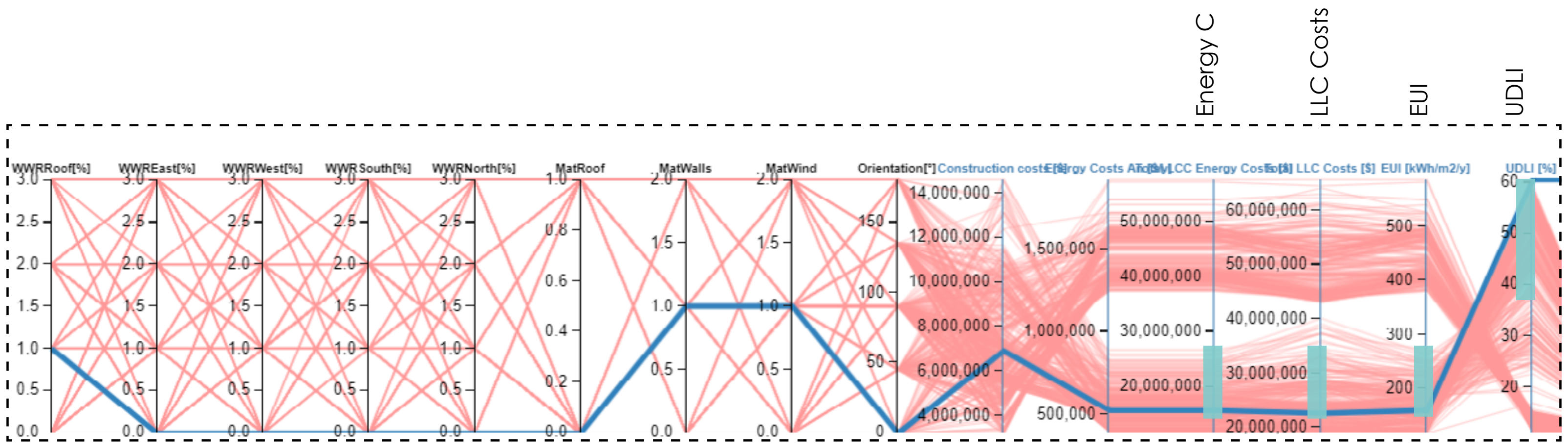
STAGE	NUMBER OF PARAMETERS	NUMBER OF GENERATIONS	DESIGN SPACE	DOMINATED / NON DOMINATED	COMPUTATIONAL TIME
	10 Parameters	7 Generations 100 Population	900 from 2774800	60 Non-dominated 64 Dominated	1.5 Days

STAGE 3: ENVELOPE

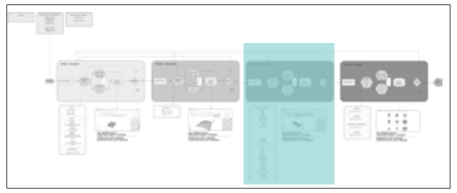


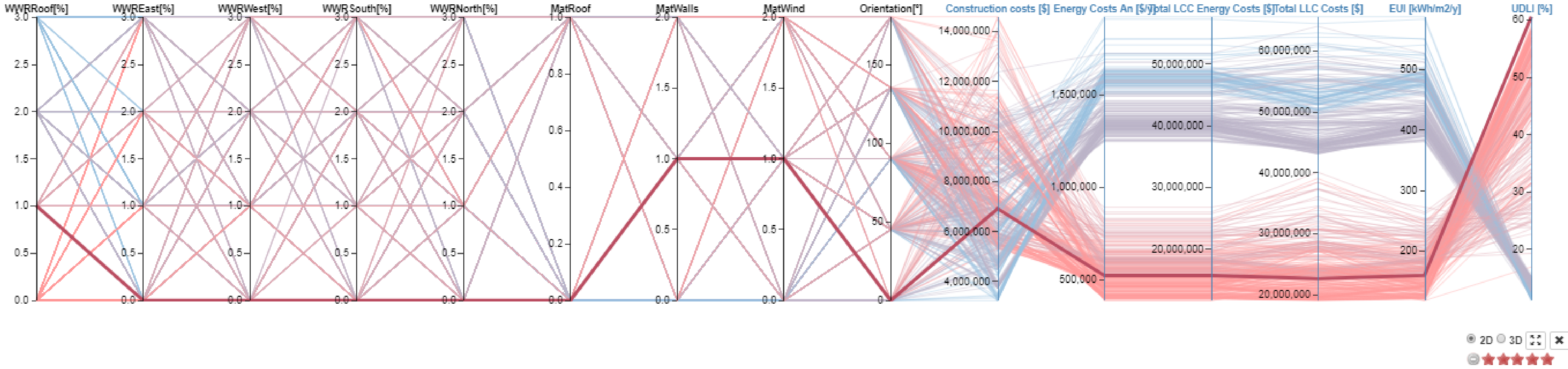


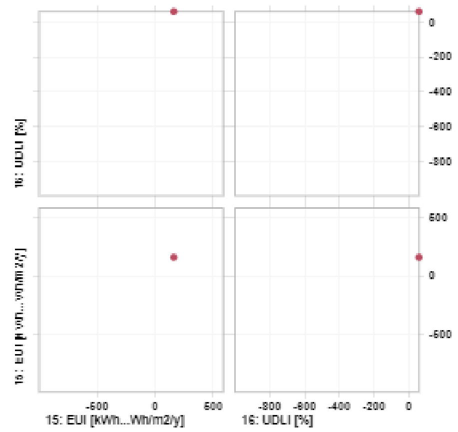


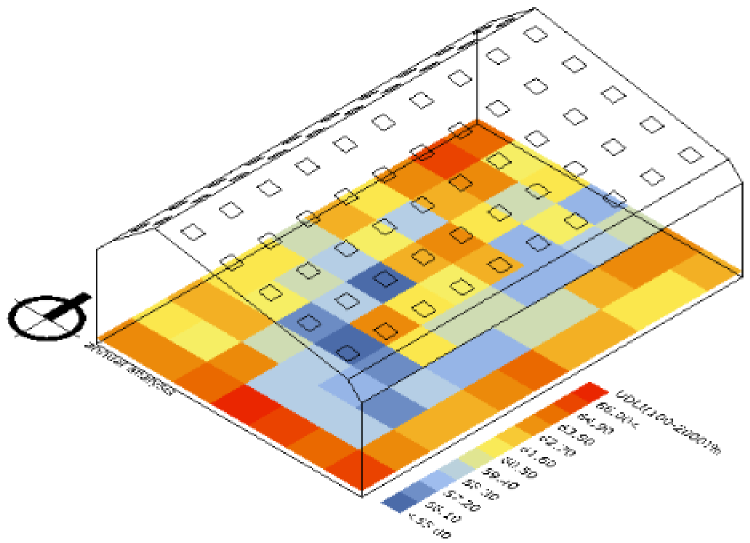


STAGE 3: ENVELOPE









Attributes

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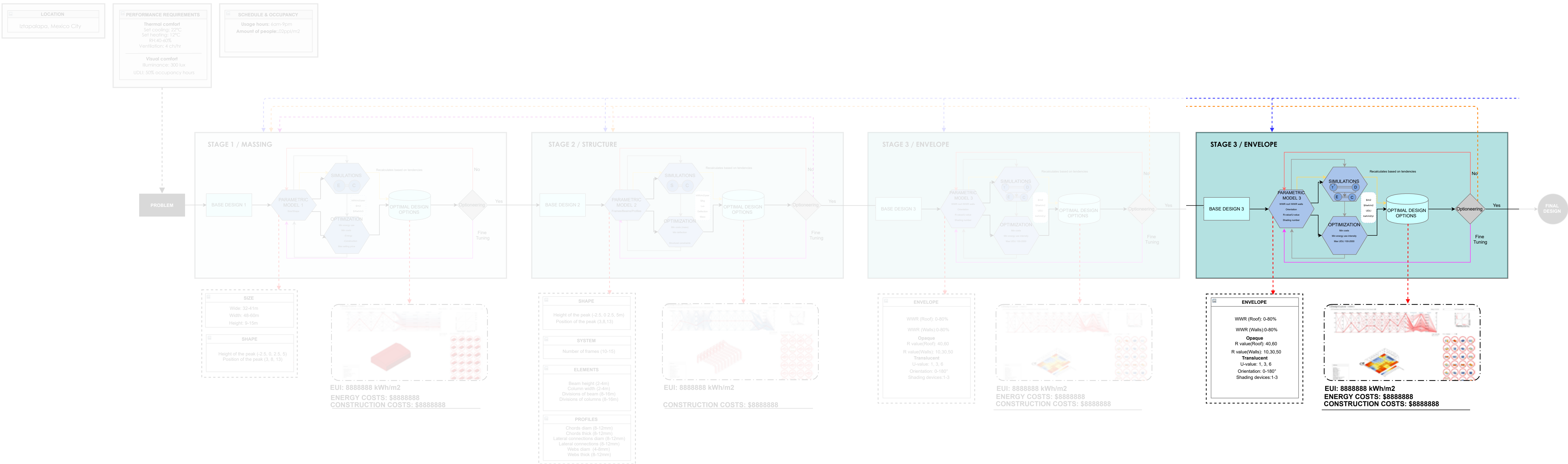
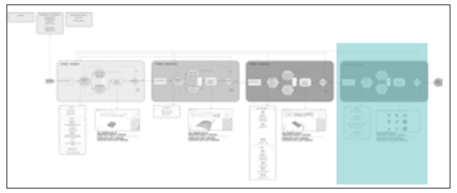
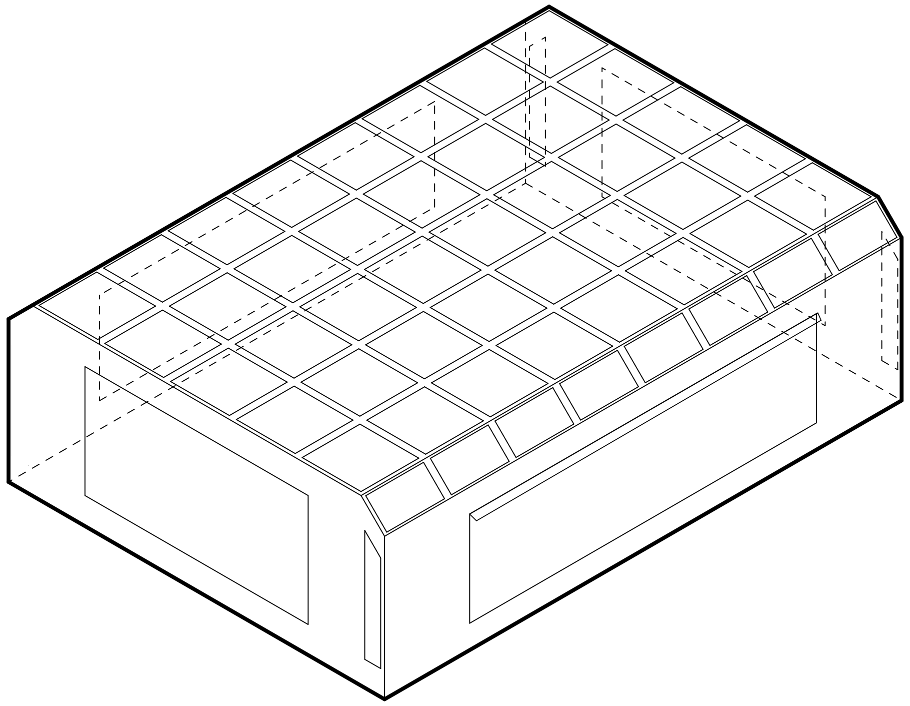
WWREast[%] : 0.0
WWRWest[%] : 0.0
WWRSouth[%] : 0.0
WWRNorth[%] : 0.0
MatRoof : 0.0
MatWalls : 1.0
MatWind : 1.0
Orientation[°] : 0.0
#Shades : 2.0
Construction costs [$] : 6911351.0
Energy Costs An [$/y] : 524470.0
Total LCC Energy Costs [$] : 15734100.0
Total LLC Costs [$] : 22645451.0
EUI [kWh/m2/y] : 160.130474
UDLI [%] : 60.441558
Rating : 5

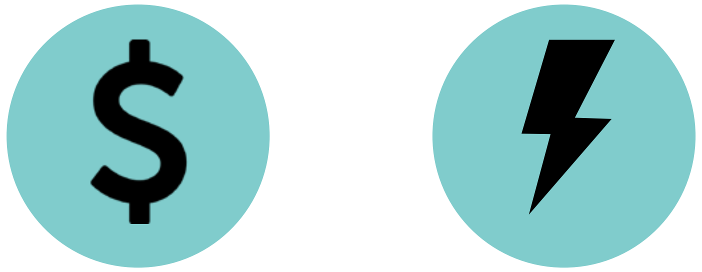
STAGE 4: SYSTEMS



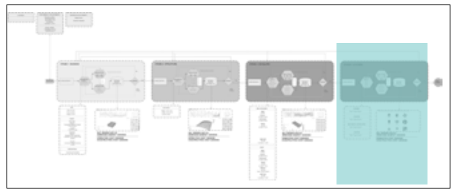
STAGE 4: SYSTEMS

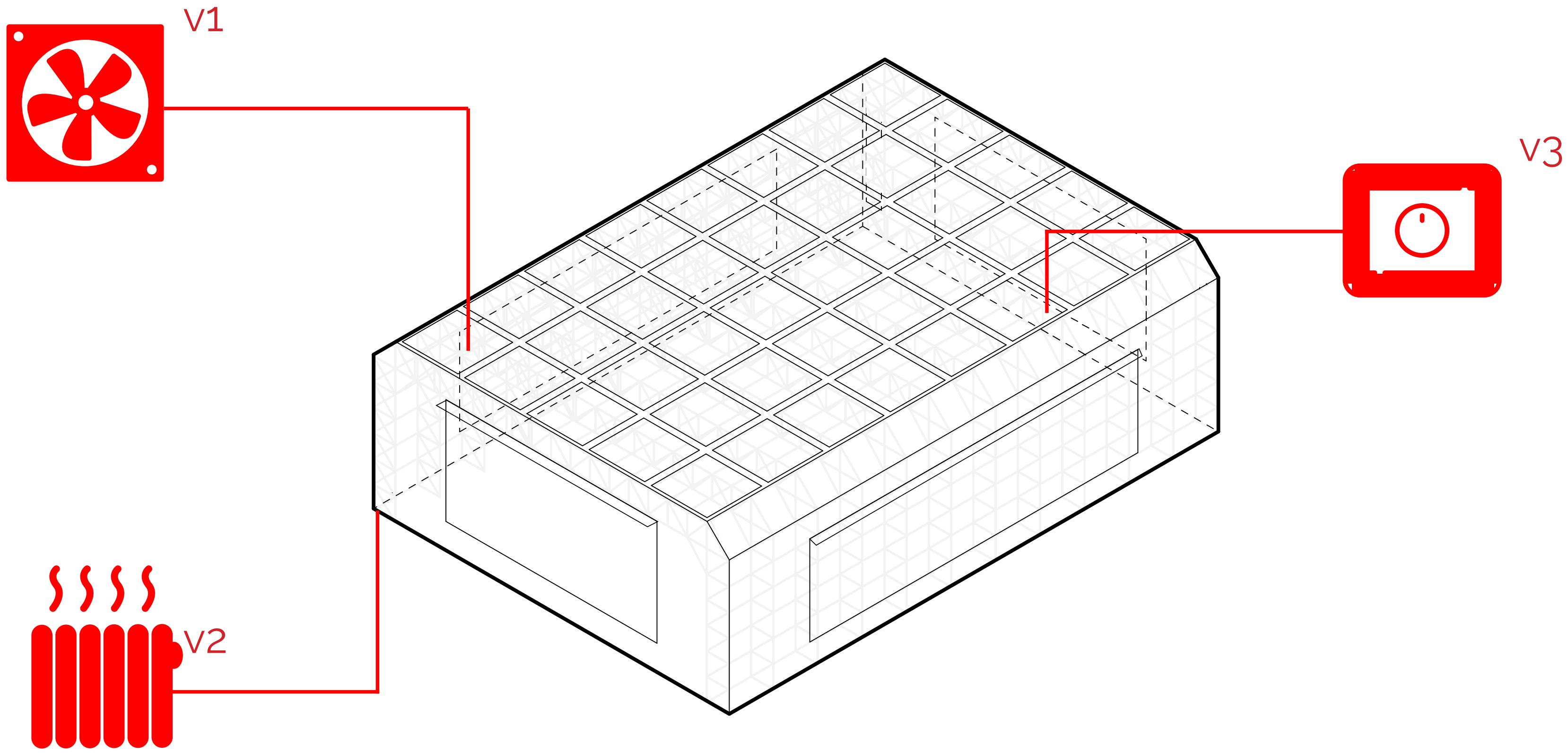


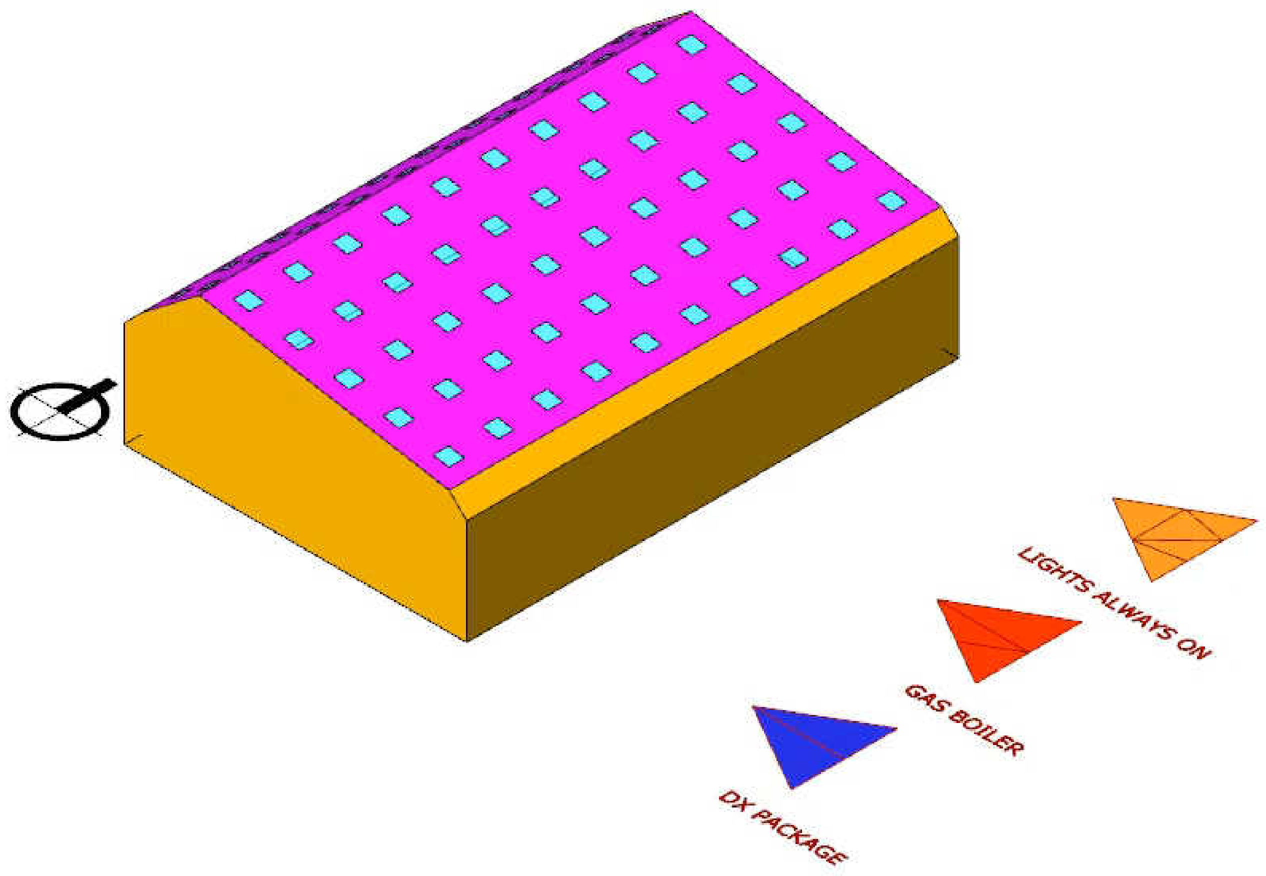


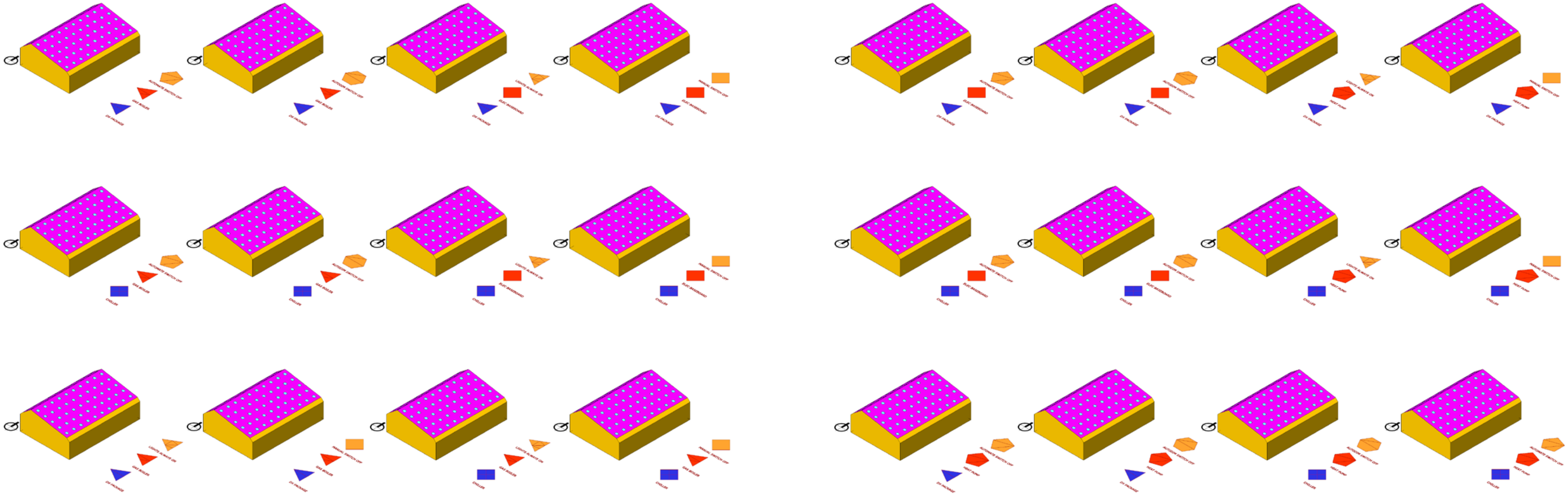


STAGE 4: SYSTEMS

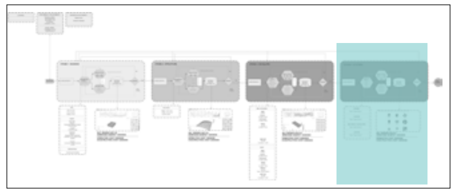


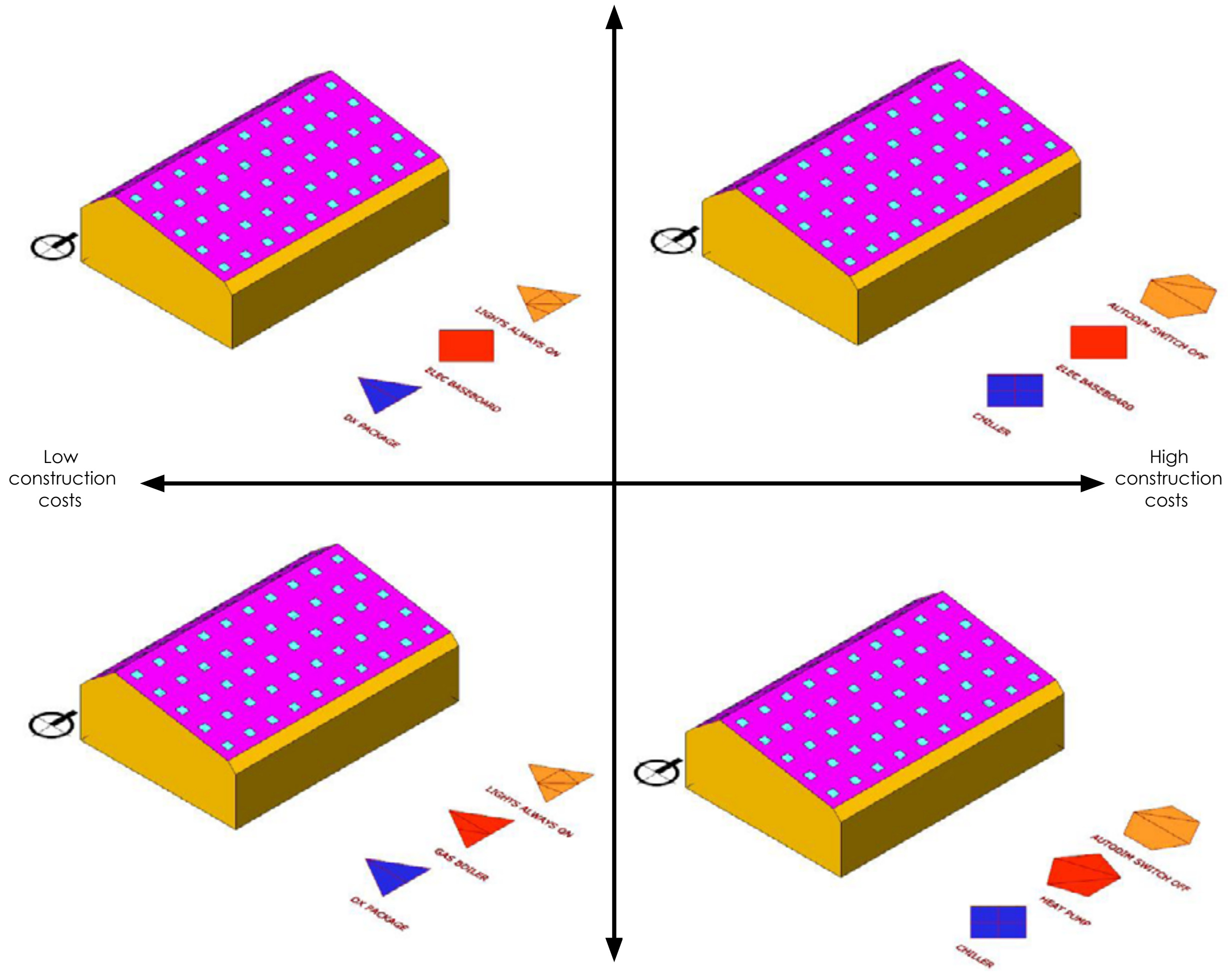


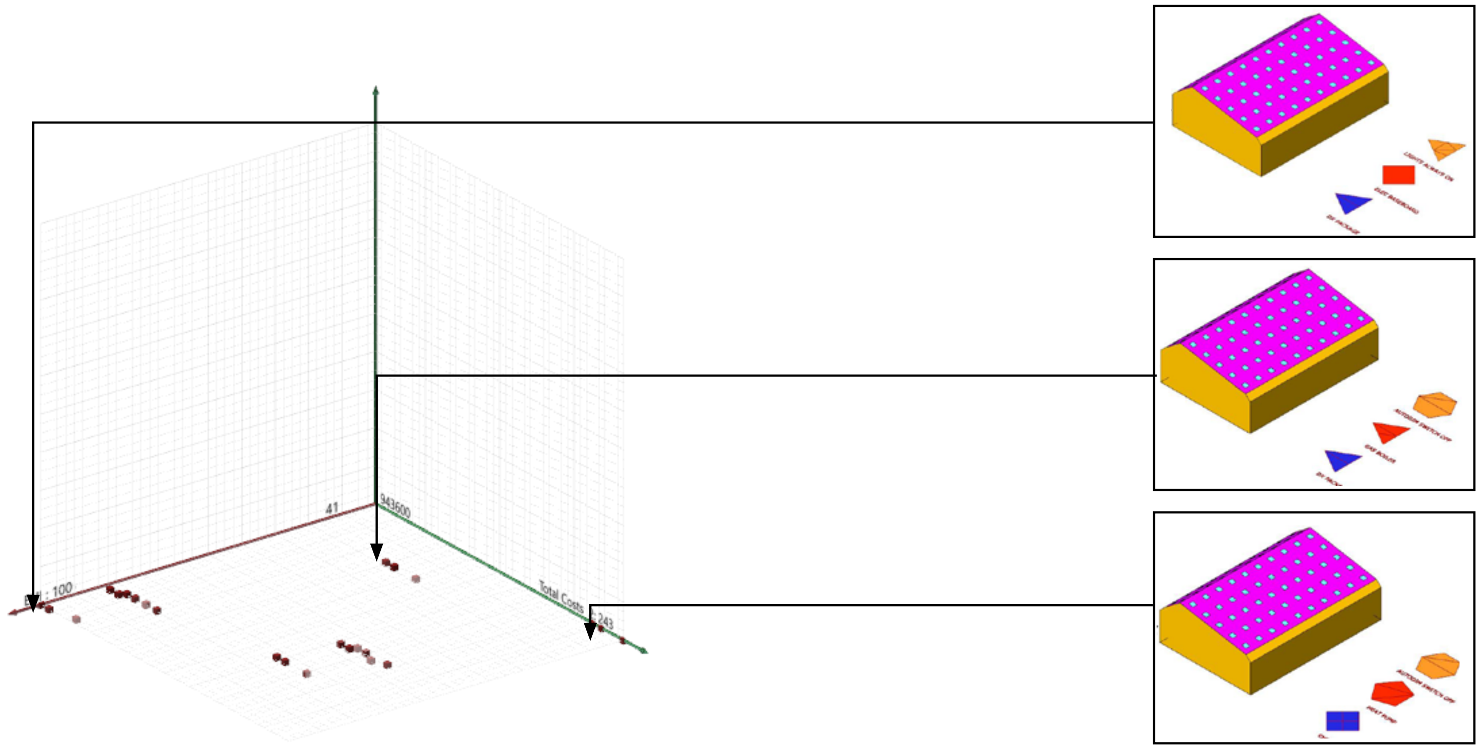

LIGHTS ALWAYS ON
GAS BOILER
DX PACKAGE

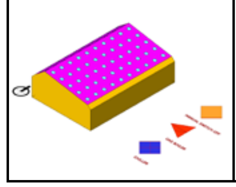


STAGE 4: SYSTEMS

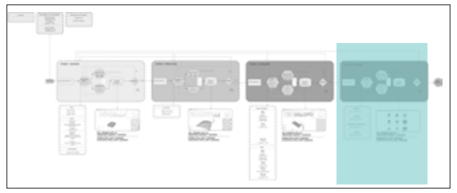


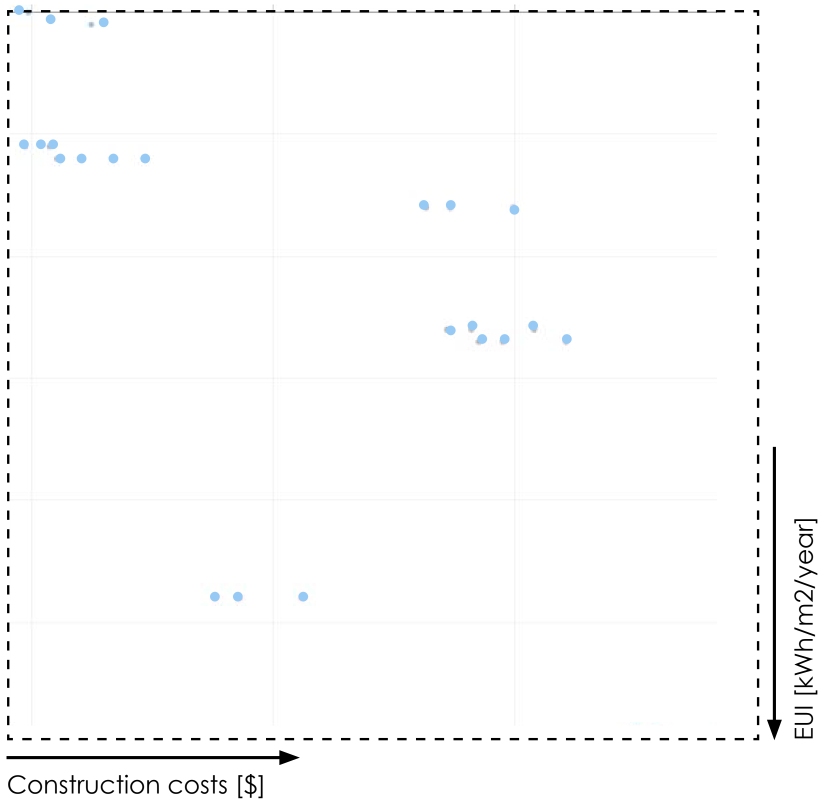


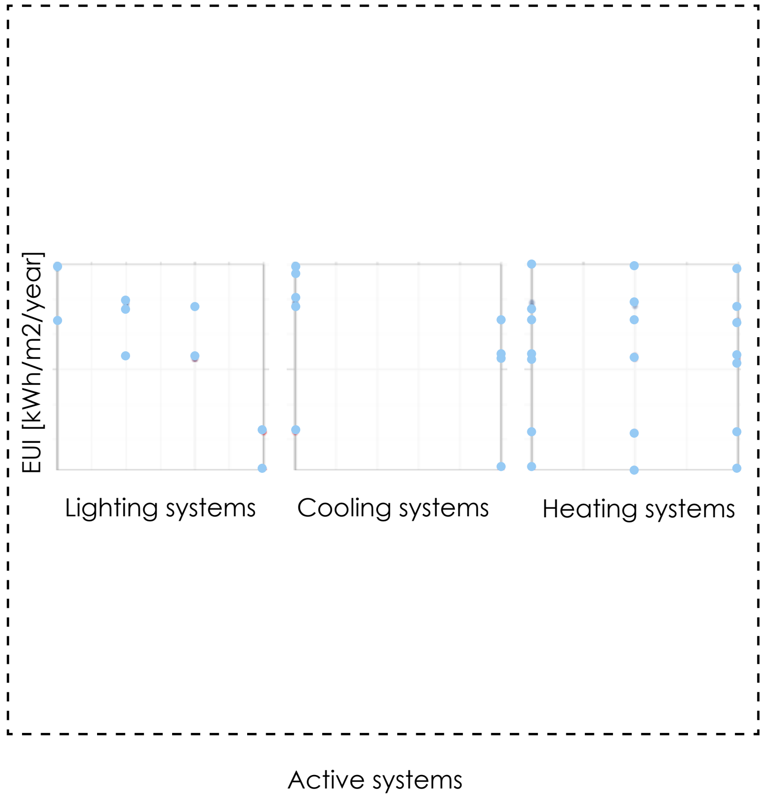


STAGE	NUMBER OF PARAMETERS	NUMBER OF GENERATIONS	REDUCTION	DOMINATED / NON DOMINATED	COMPUTATIONAL TIME
	3 Parameters	1 Generations 100 Population	24-24	23 Non-dominated 106 Dominated	5 Hours

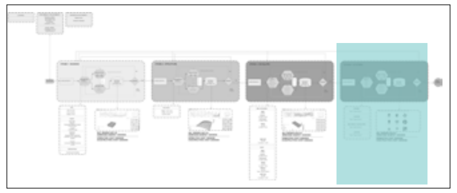
STAGE 4: SYSTEMS

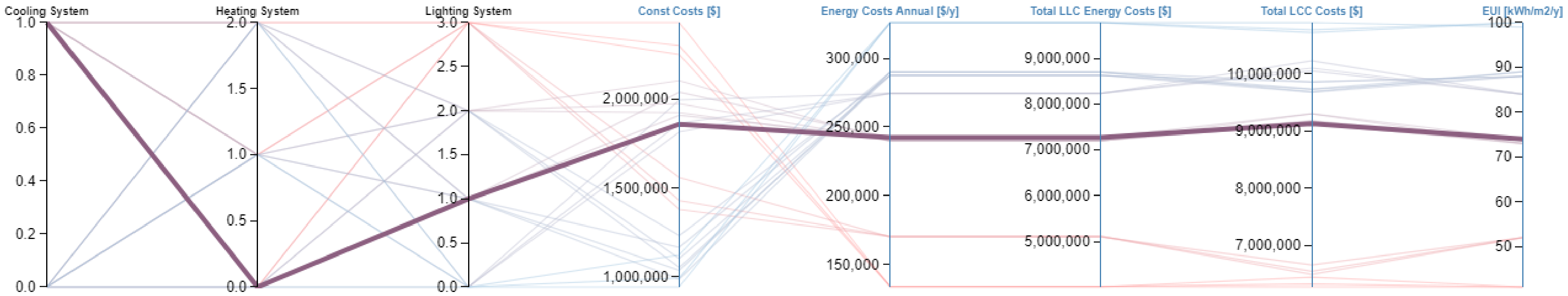


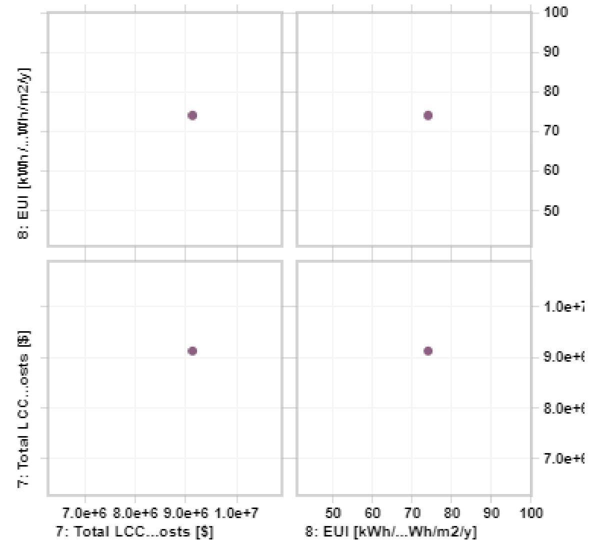


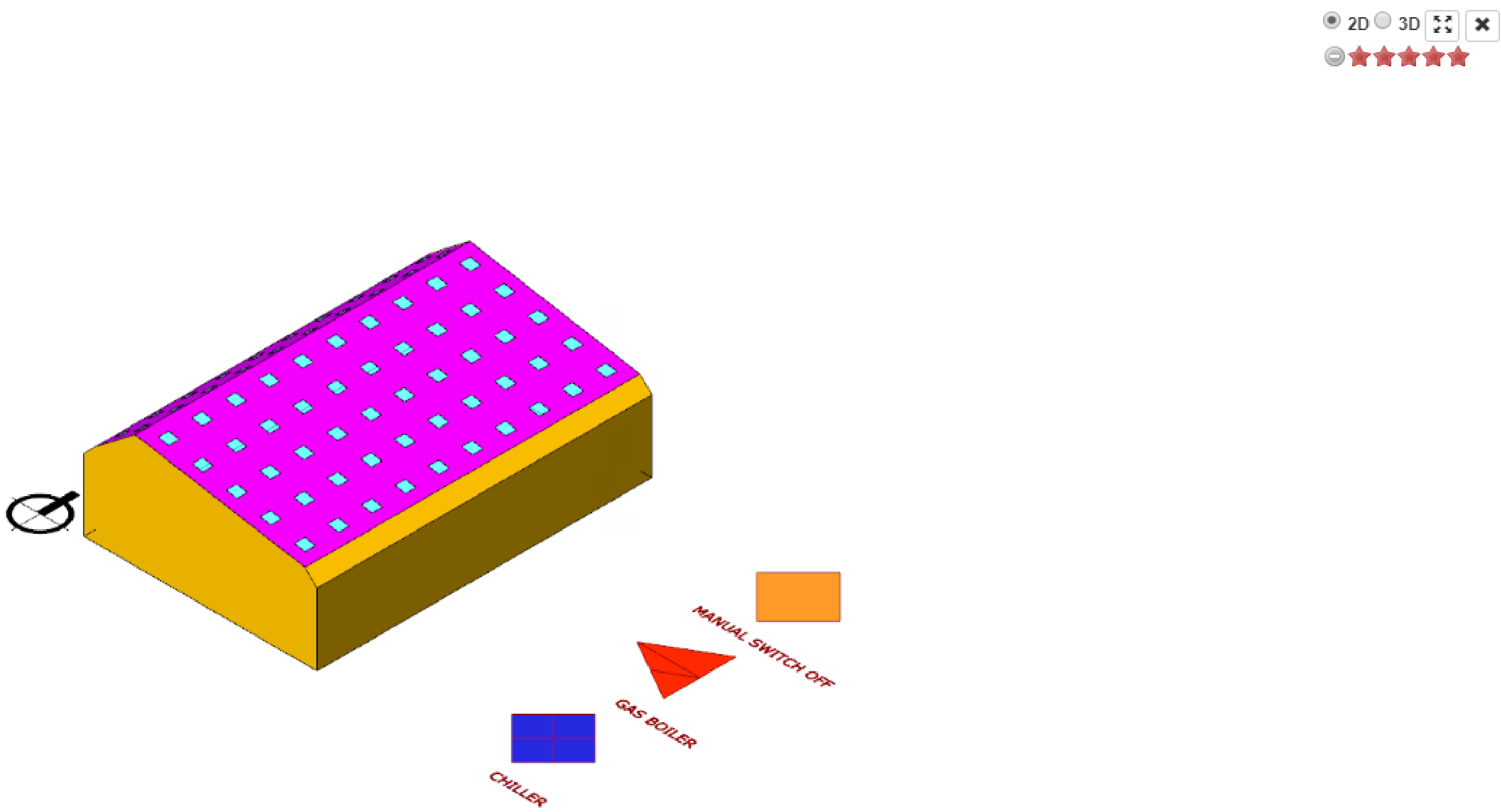


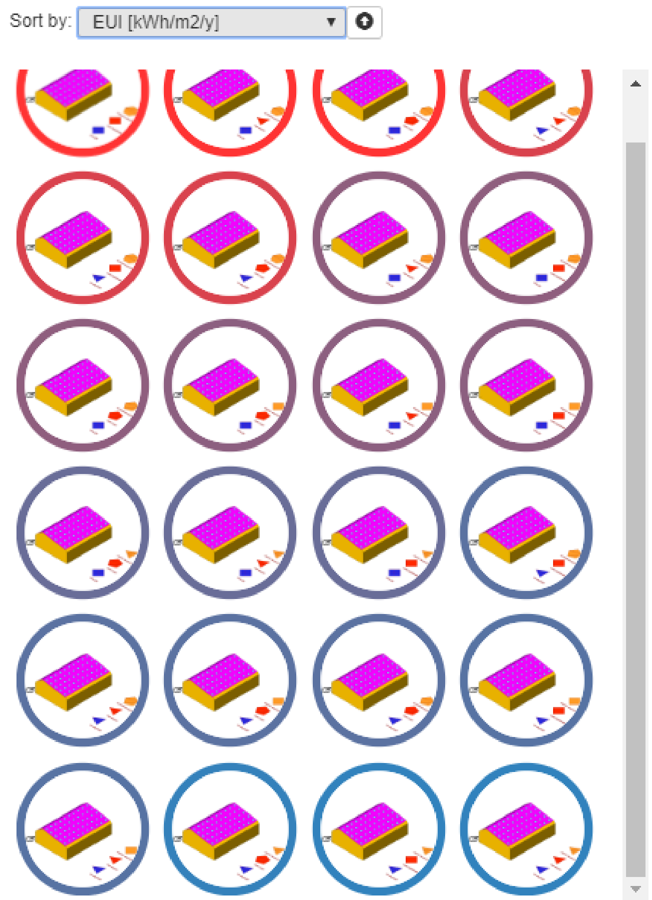
STAGE 4: SYSTEMS







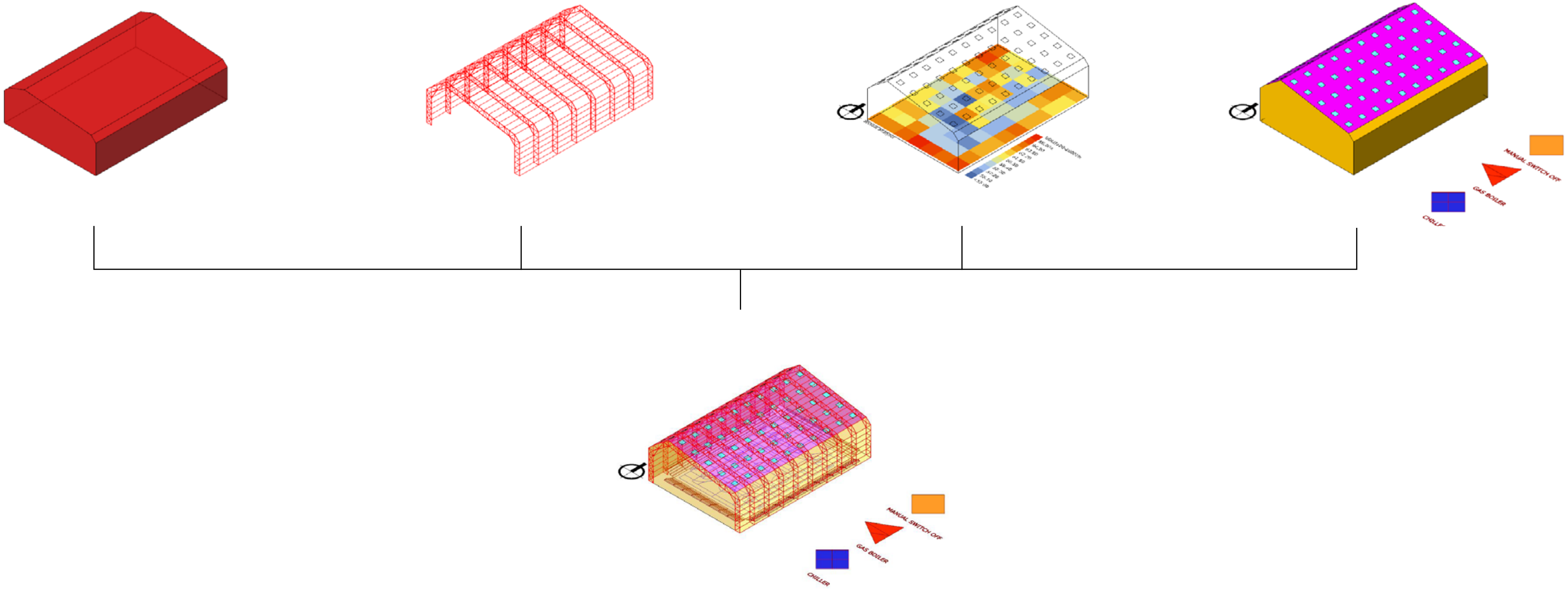




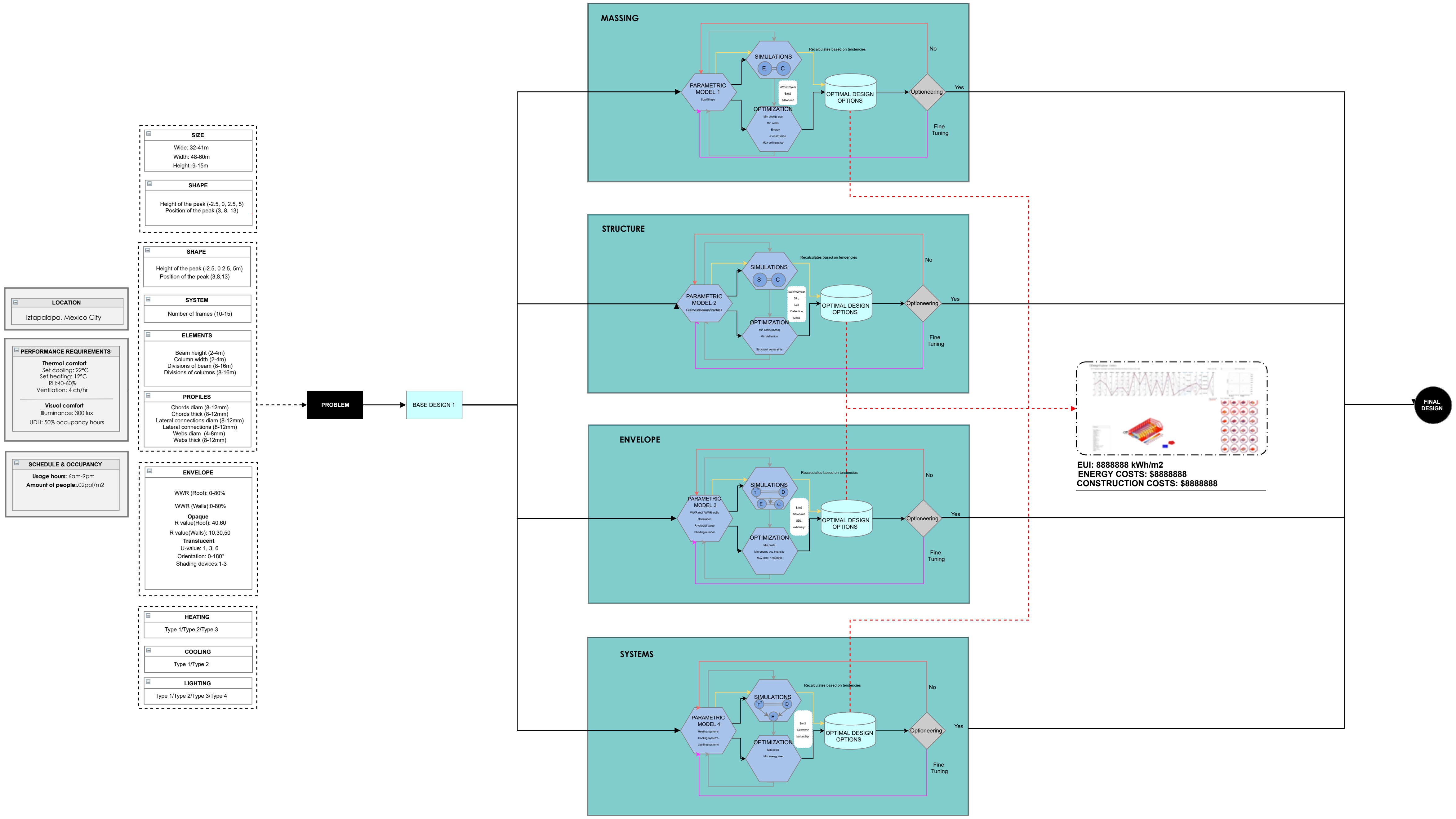
Attributes

Cooling System : 1.0
Heating System : 0.0
Lighting System : 1.0
Const Costs [$] : 1860880.0
Energy Costs Annual [$/y] : 242316.0
Total LLC Energy Costs [$] : 7269480.0
Total LCC Costs [$] : 9130360
EUI [kWh/m2/y] : 74
Rating : 5

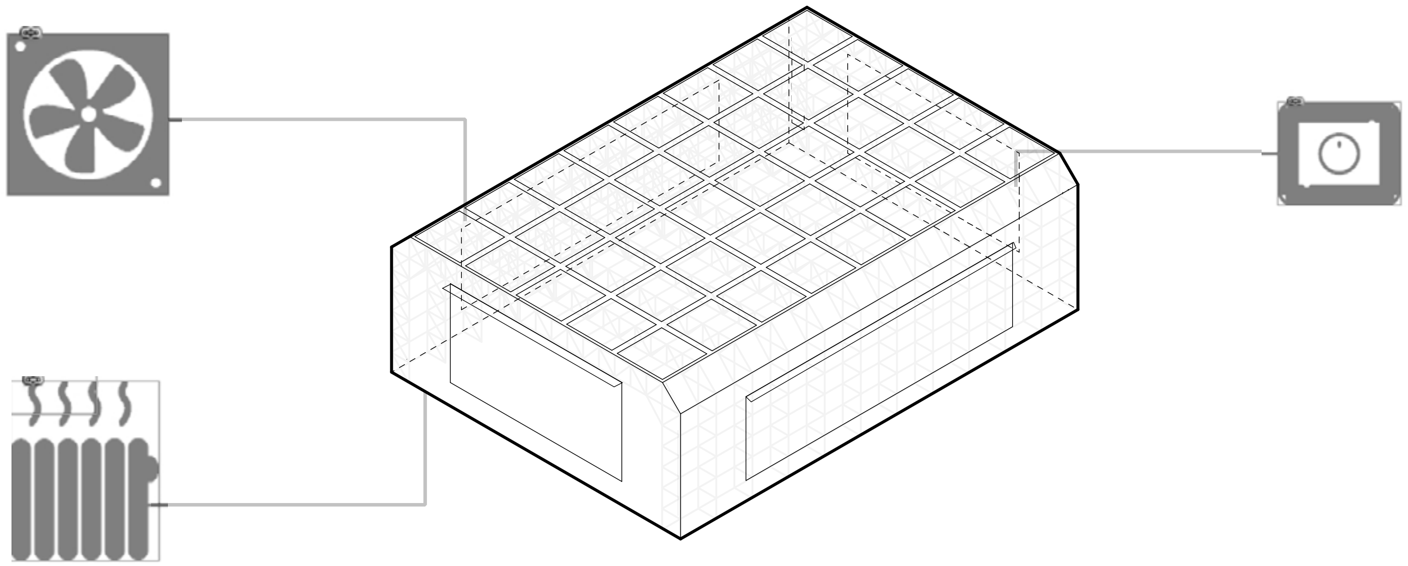
FINAL DESIGN

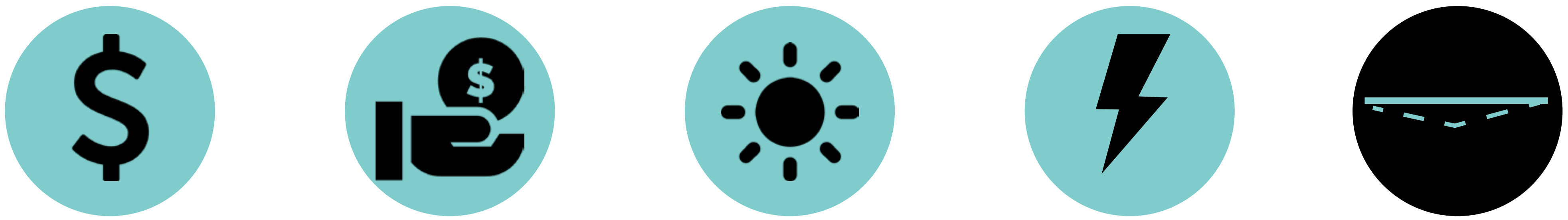


INTEGRATED STRATEGY

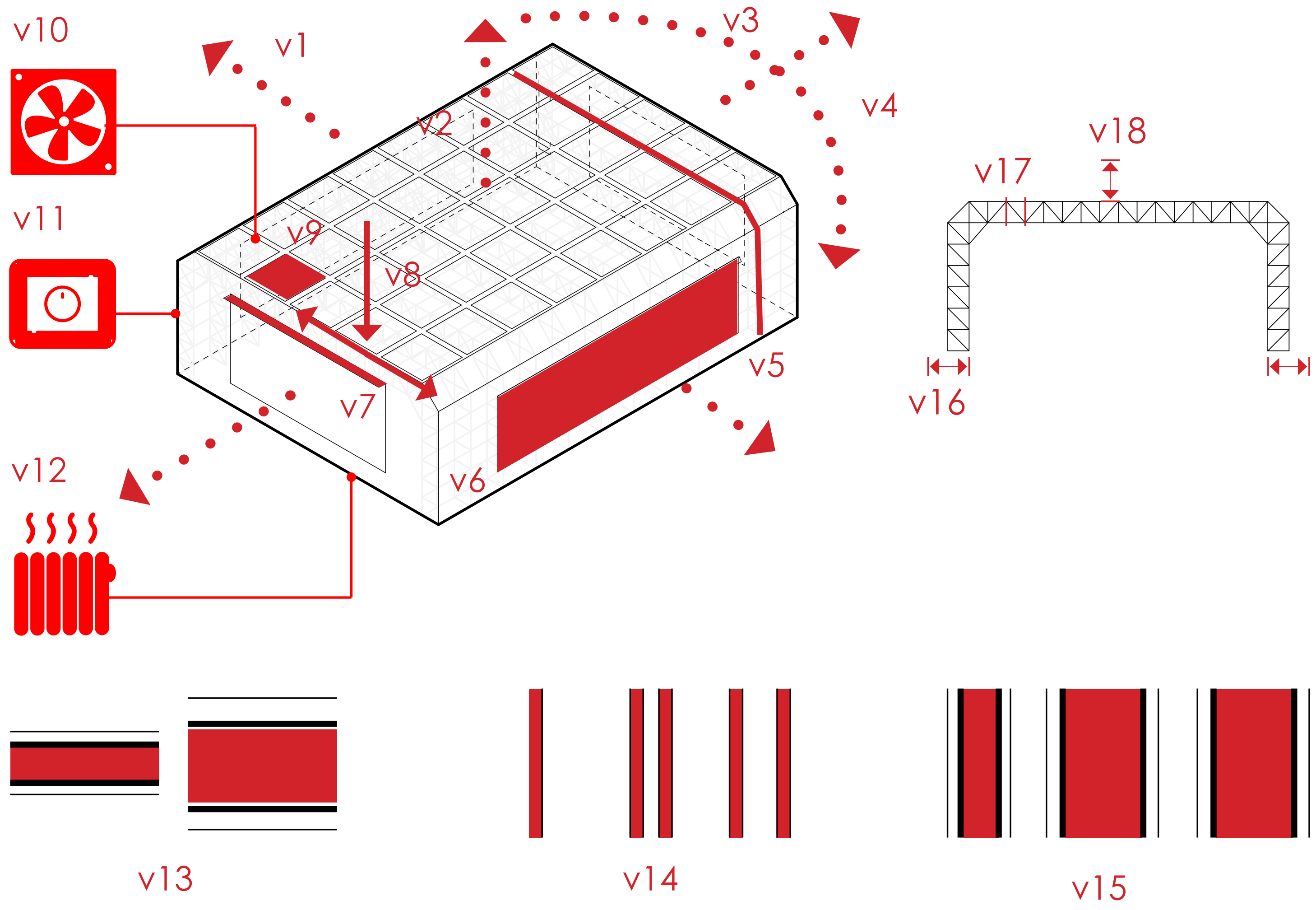


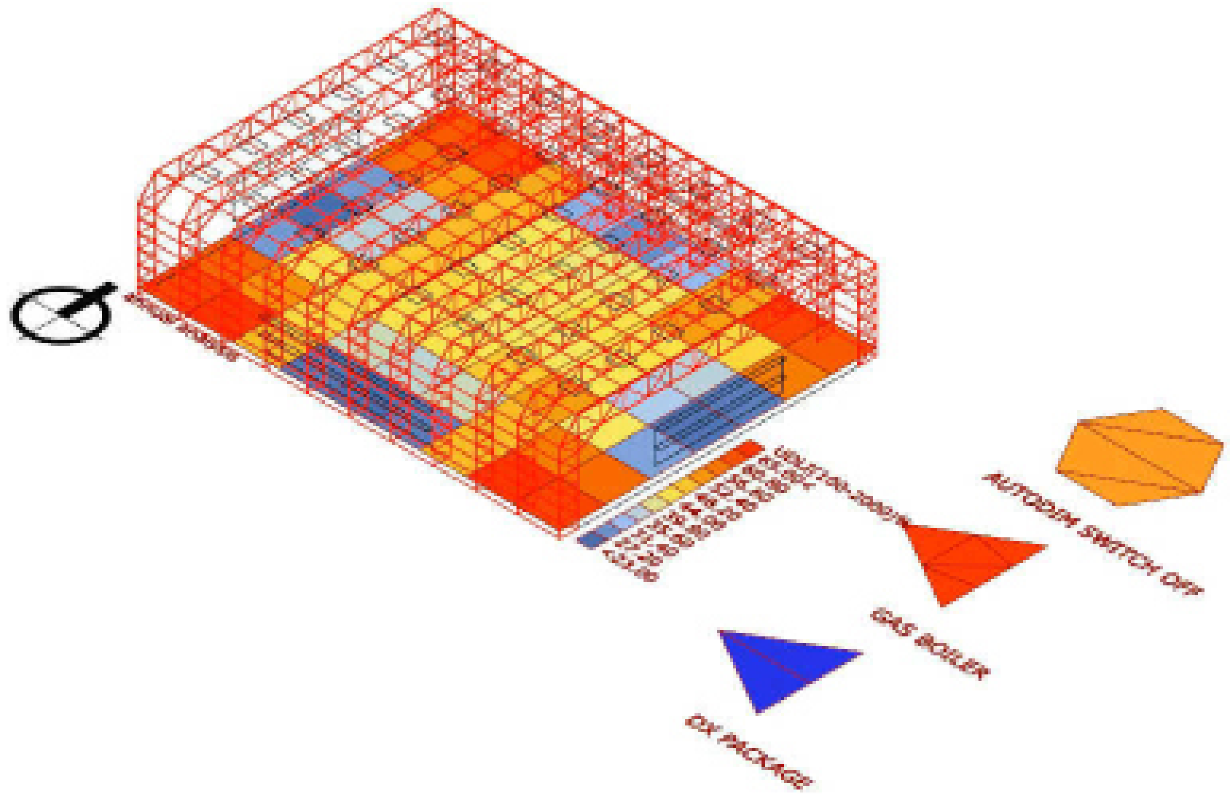
INTEGRATED STRATEGY

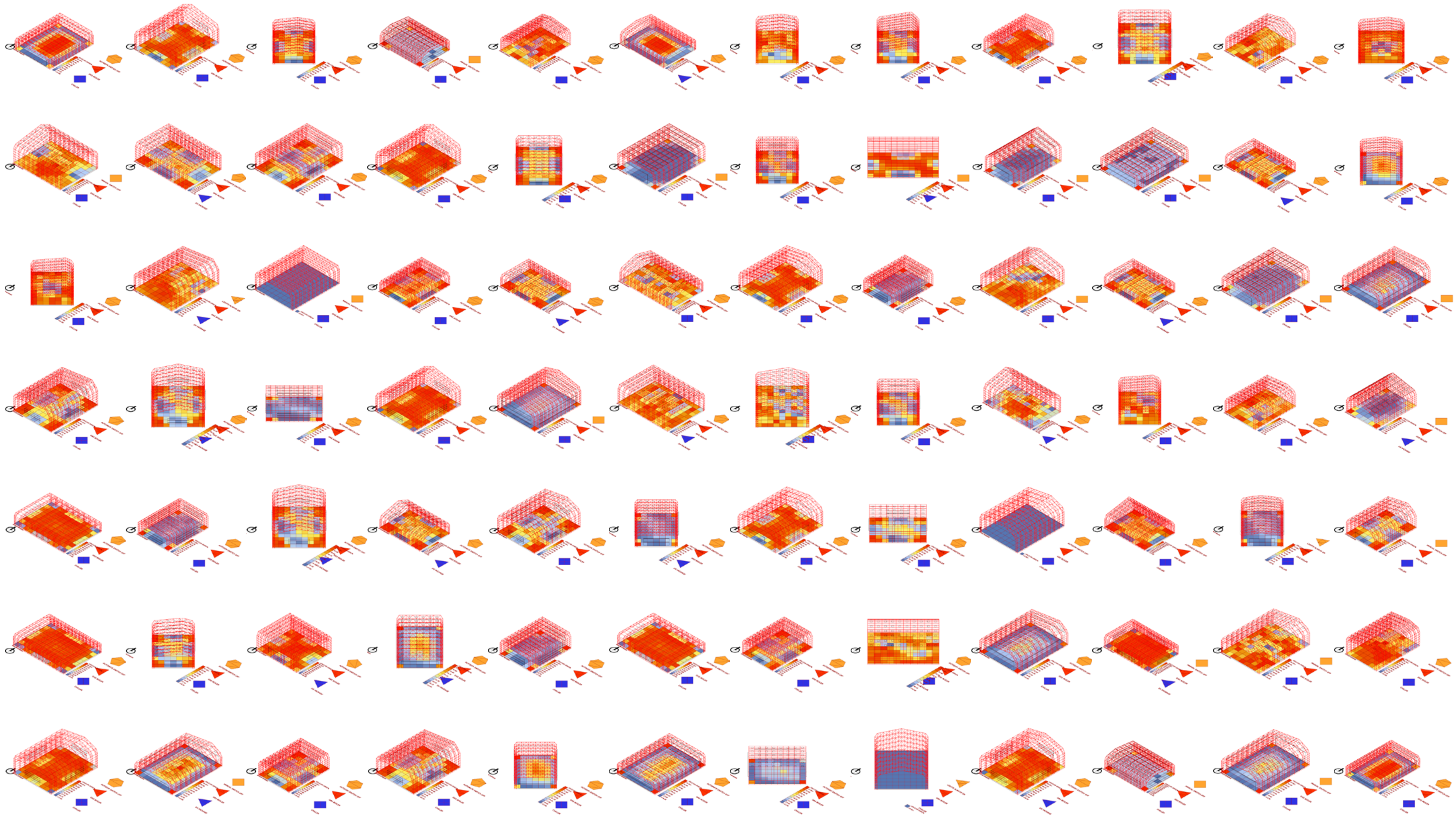




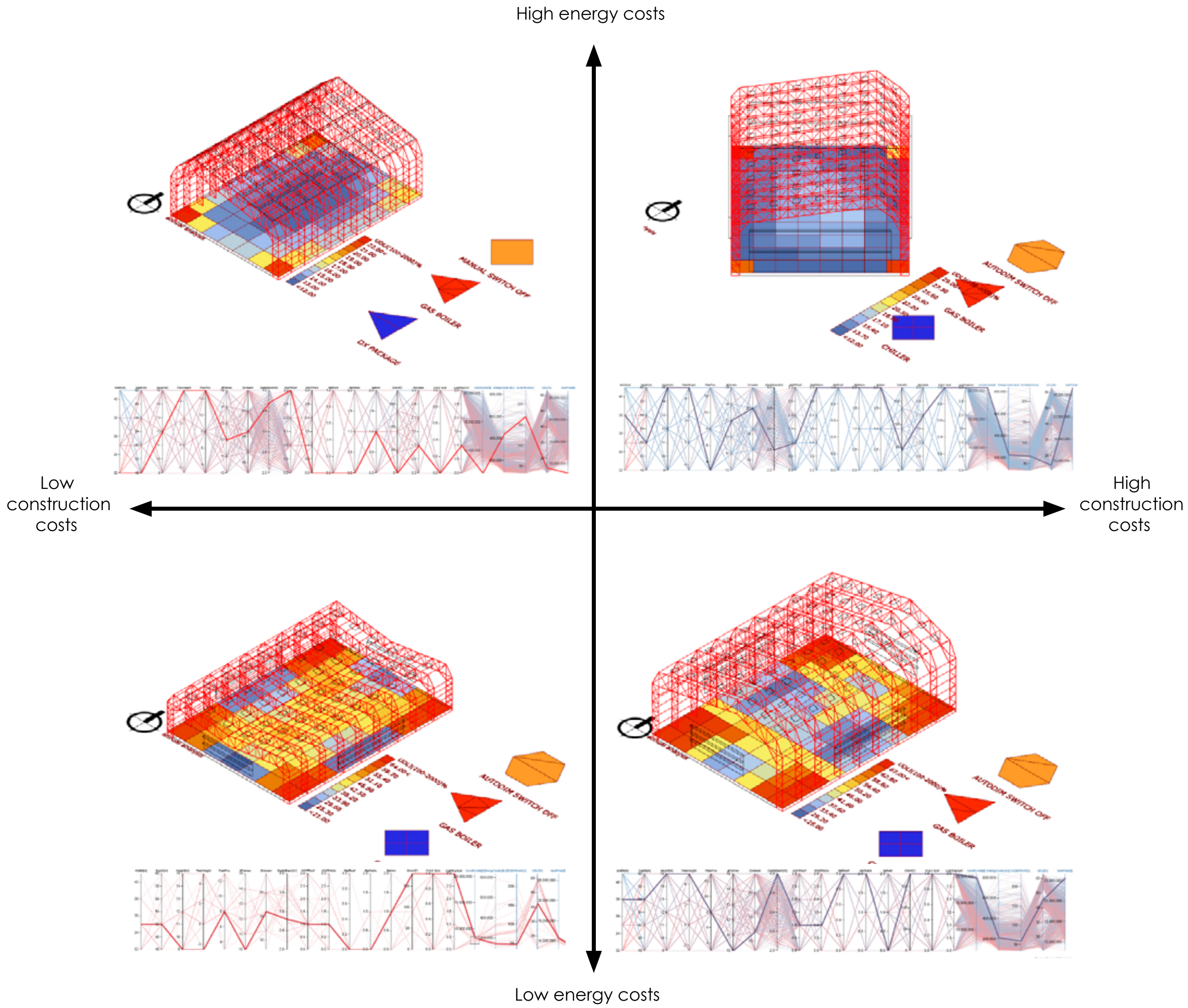
INTEGRATED STRATEGY

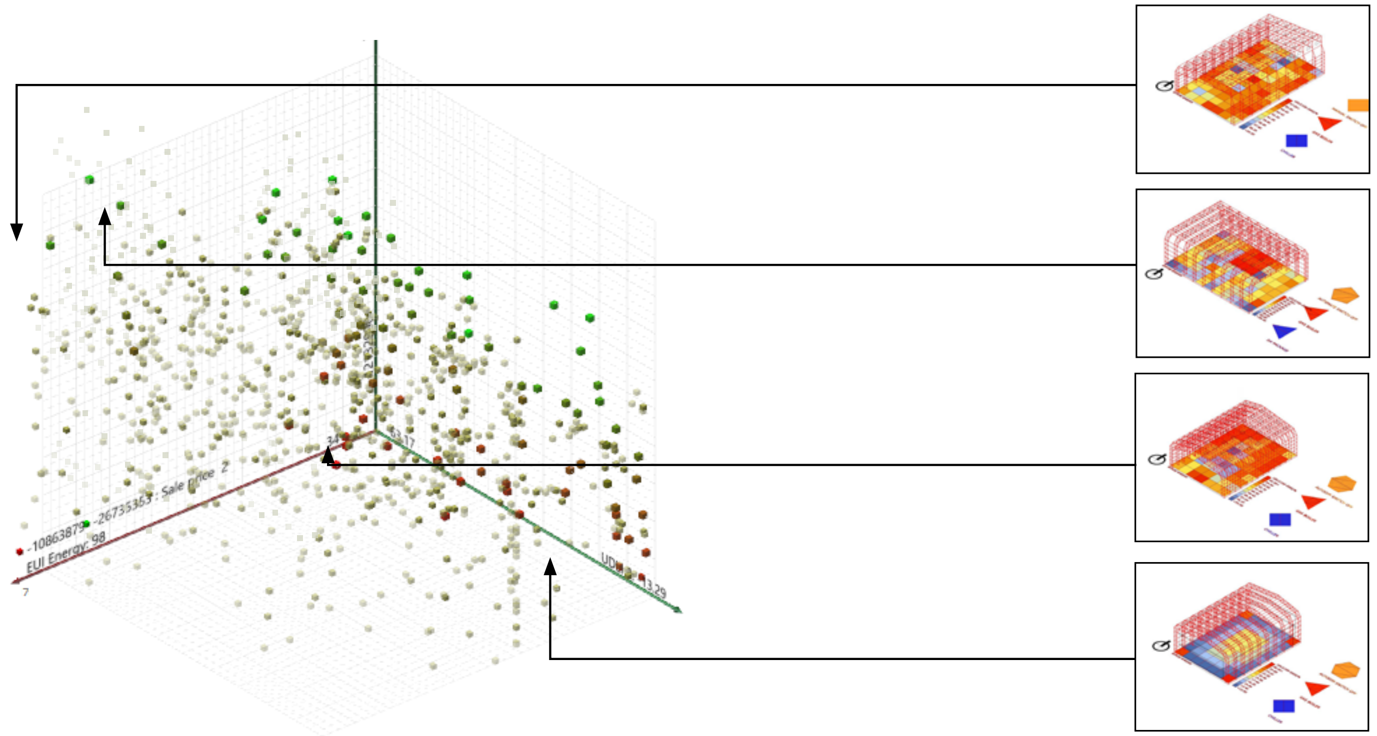


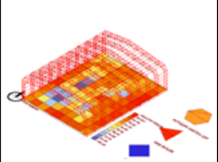

AUTODSM SWITCH OFF
GAS BOILER
DX PACKAGE



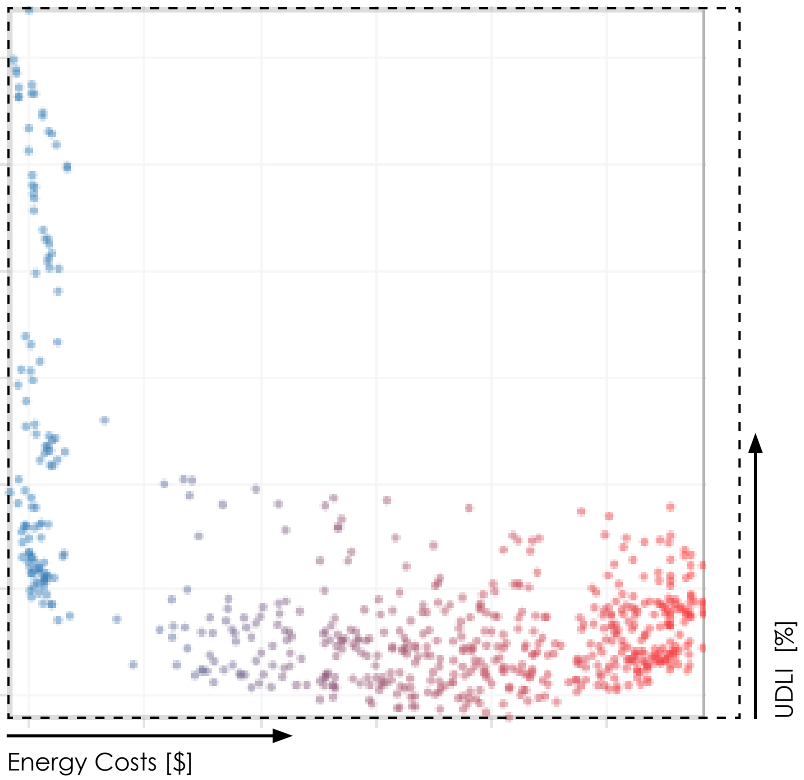
INTEGRATED STRATEGY

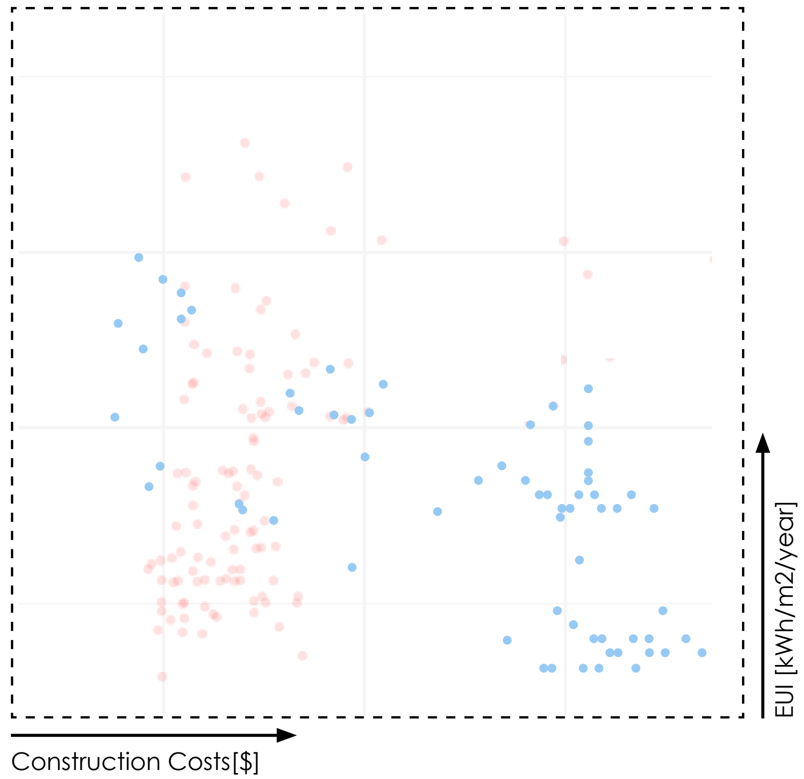


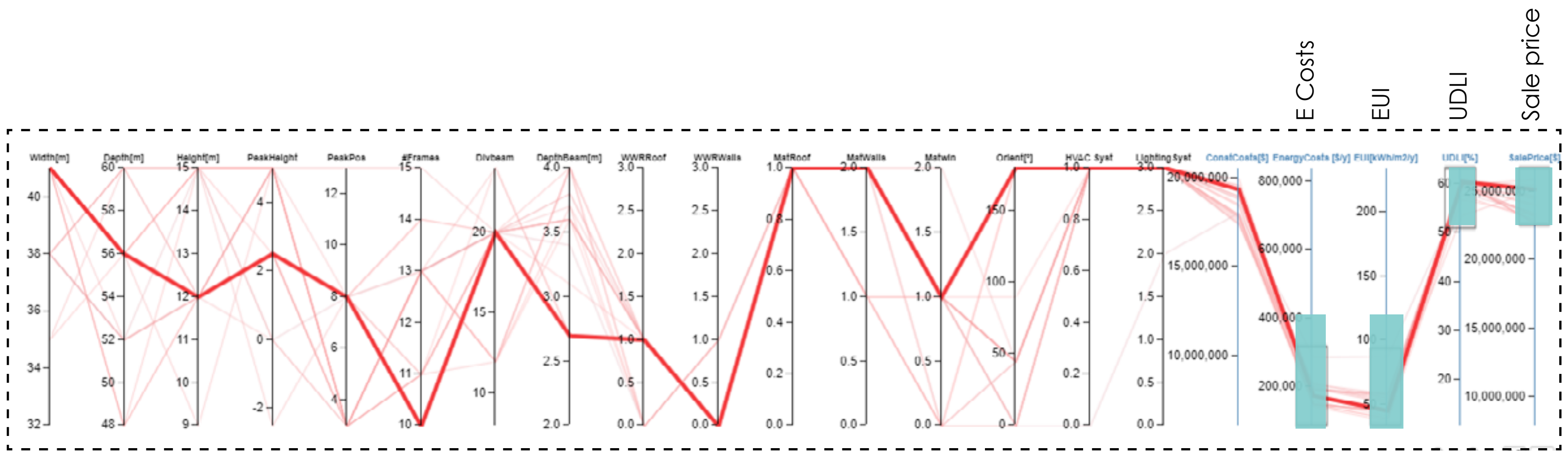


STAGE	NUMBER OF PARAMETERS	NUMBER OF GENERATIONS	DESIGN SPACE	DOMINATED / NON DOMINATED	COMPUTATIONAL TIME
	18 Parameters	10 Generations 100 Population	1200 from 97820835840000	88 Non-dominated 1 Dominated	2.5 Days

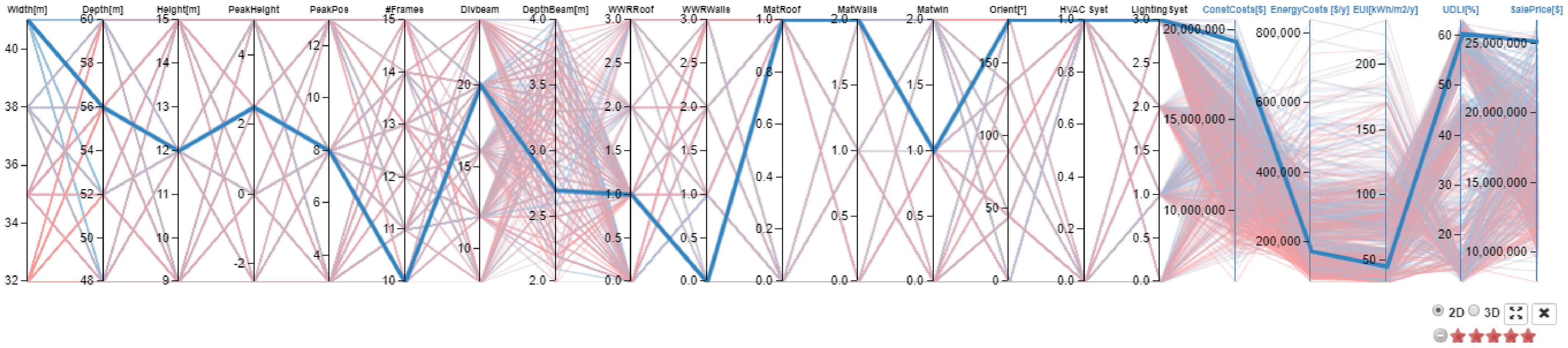
INTEGRATED STRATEGY

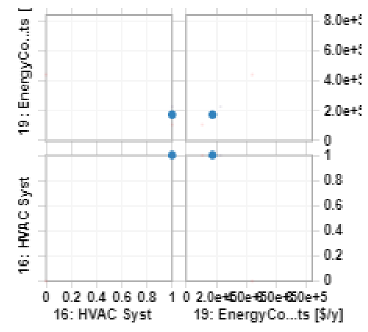






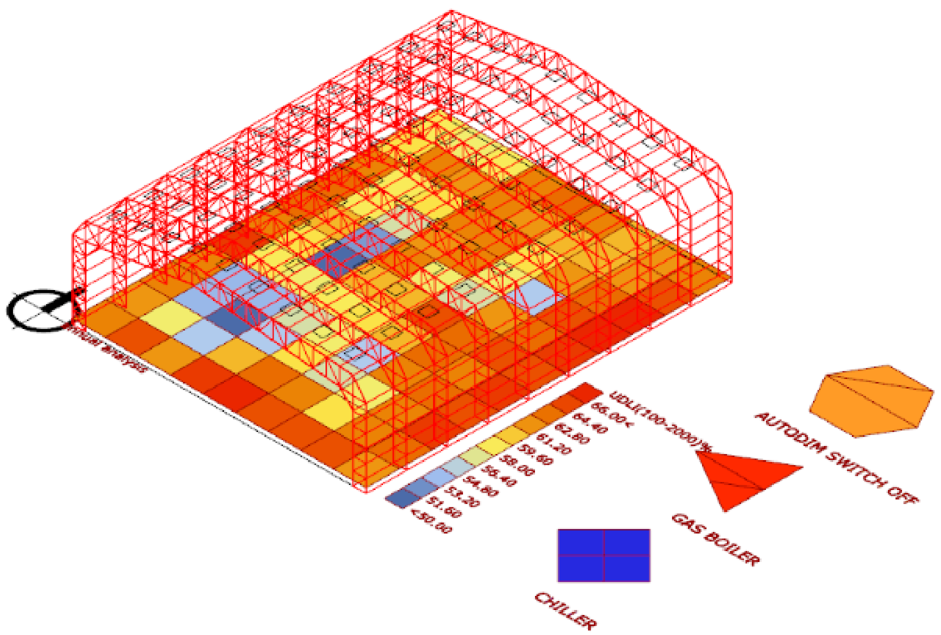
INTEGRATED STRATEGY



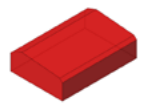
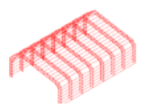
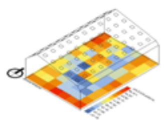
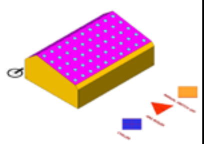


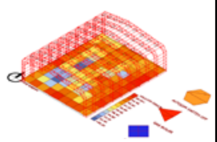
Attributes

Width[m] : 41
Depth[m] : 56
Height[m] : 12.0
PeakHeight : 2.5
PeakPos : 8
#Frames : 10.0
Divbeam : 20.0
DepthBeam[m] : 2.7
WWRRoof : 1.0
WWRWalls : 0
MatRoof : 1
MatWalls : 2.0
Matwin : 1.0
Orient[°] : 180.0
#Shades : 1
HVAC Syst : 1
LightingSyst : 3.0
ConstCosts[$] : 19348645
EnergyCosts [$/y] : 174902
EUI[kWh/m2/y] : 46
UDLI[%] : 60.323232
SalePrice[$] : 25153238
Rating : 5

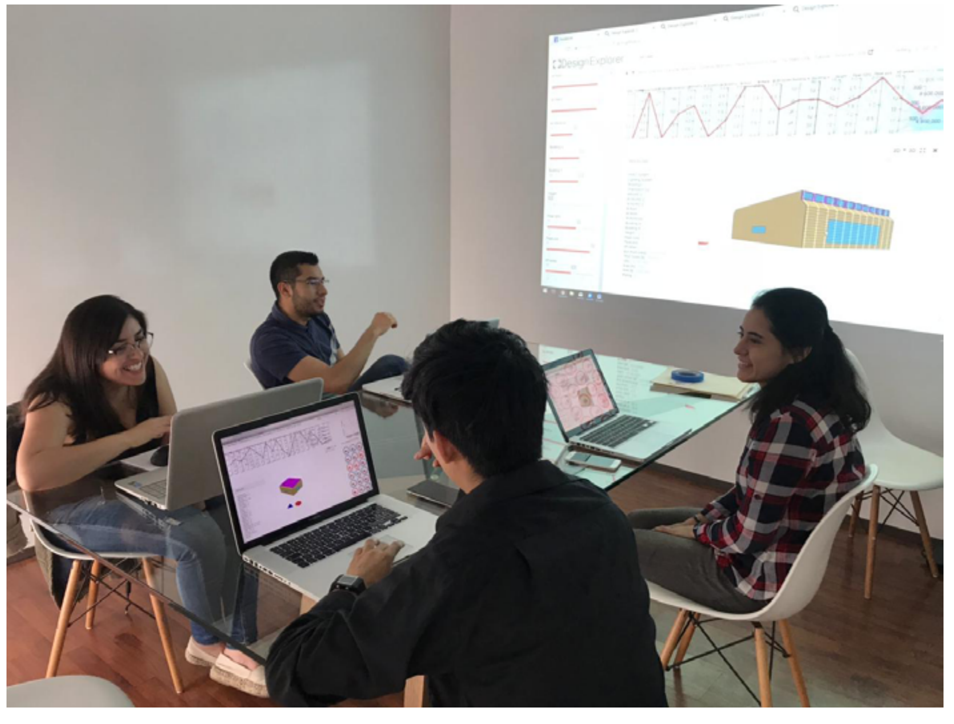


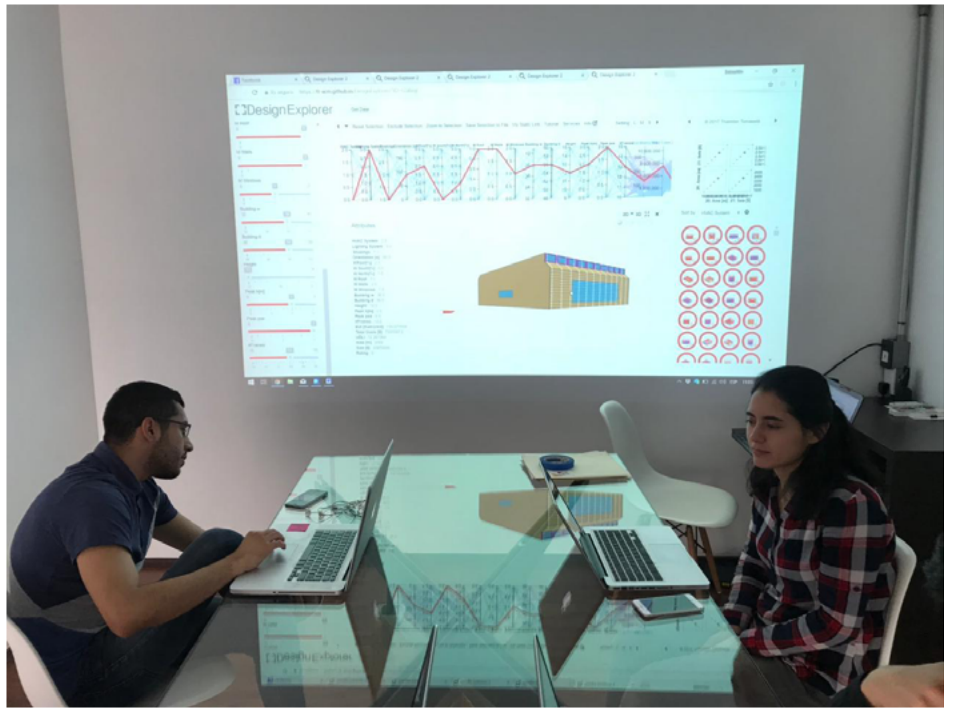
STRATEGIES COMPARISON

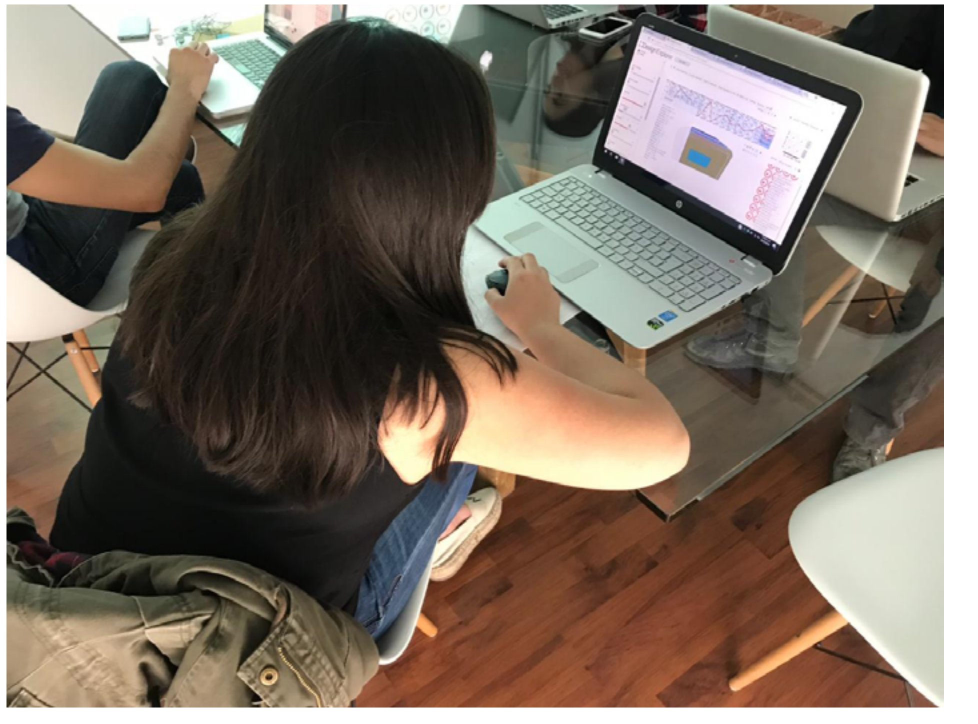
STAGE	NUMBER OF PARAMETERS	NUMBER OF GENERATIONS	DESIGN SPACE	DOMINATED / NON DOMINATED	COMPUTATIONAL TIME
	10 Parameters	7 Generations 100 Population	313-576	72 Non-dominated 245 Dominated	1.5 Hours
	13 Parameters	50 Generations 100 Population	3200 from 118125000	140 Non-dominated 60 Dominated	2.5 Hours
	10 Parameters	7 Generations 100 Population	900 from 277544800	60 Non-dominated 64 Dominated	1.5 Days
	3 Parameters	1 Generations 100 Population	24-24	23 Non-dominated 106 Dominated	5 Hours

STAGE	NUMBER OF PARAMETERS	NUMBER OF GENERATIONS	DESIGN SPACE	DOMINATED / NON DOMINATED	COMPUTATIONAL TIME
	18 Parameters	10 Generations 100 Population	1200 from 97820835840000	88 Non-dominated 1 Dominated	2.5 Days

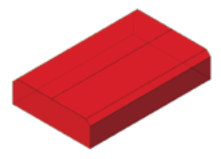
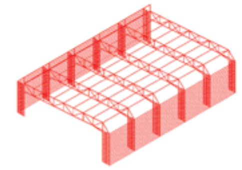
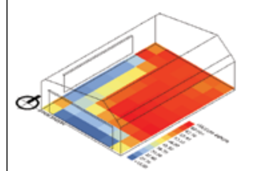
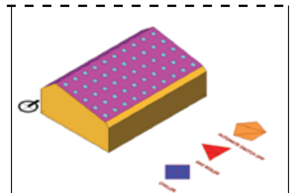
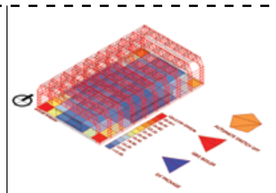
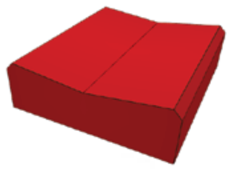
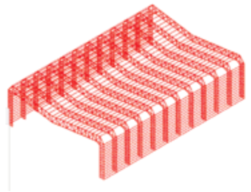
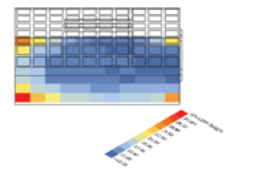
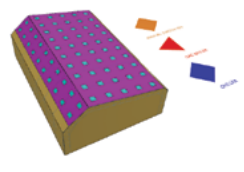
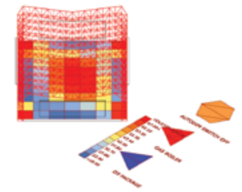
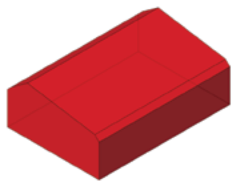
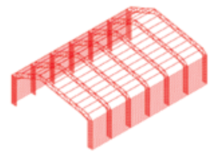
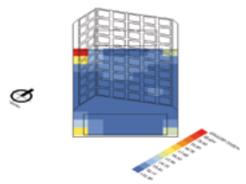
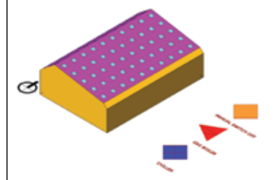
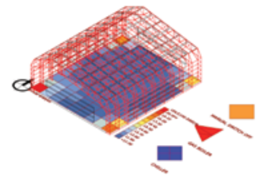
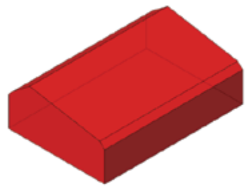
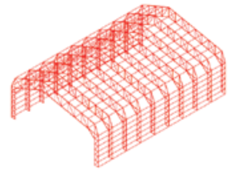
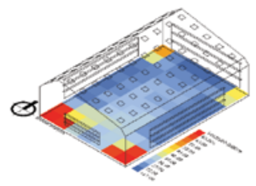
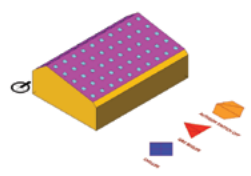
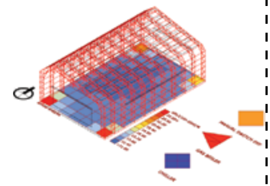
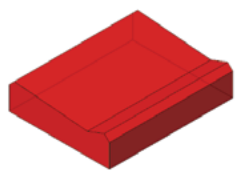
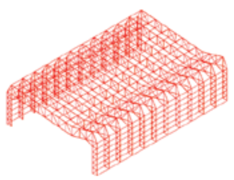
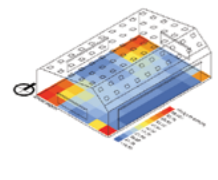
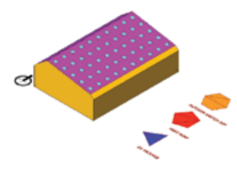
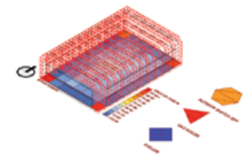
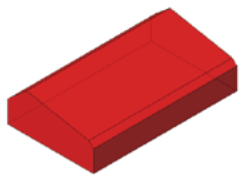
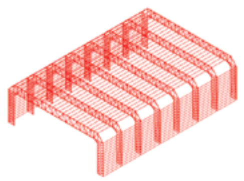
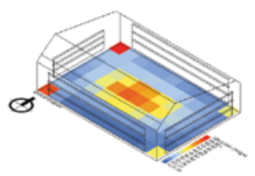
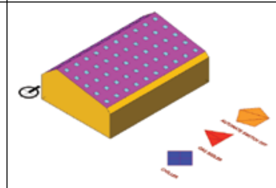
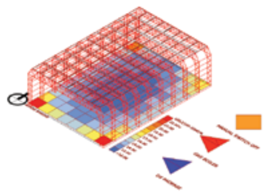
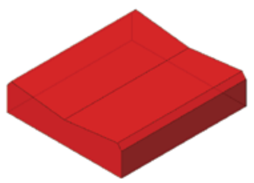
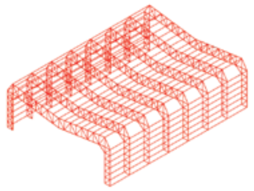
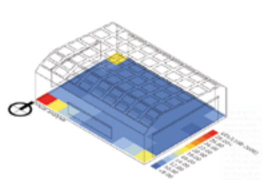
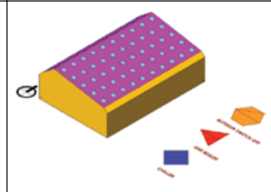
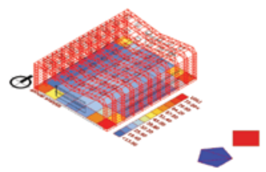
USERS VALIDATION







USERS VALIDATION

DANIEL LAREDO ARCHITECT	 THIS SHAPE FITS THE STRUCTURE I CHOSE.	 I WAS LOOKING FOR A STRUCTURE WITH THE LOWEST AMOUNT POSSIBLE OF SUPPORTS.	 THE BUILDING WILL BE MOSTLY USED ON DAY TIME, SO IT TAKE ADVANTAGE OF SOLAR ENERGY AND SUN LIGHT.	 LOW COST .	 THIS SYSTEM COMBINES FUNCTION, ENERGY EFFICIENCY AND THE LOCATION OF THE BUILDING.
ISRAEL HERNÁNDEZ ARCHITECT	 SHAPE WITH AVERAGE VOLUME	 AVERAGE COST OF STRUCTURE WITH THE FIRST SHAPE.	 LOWER COST OF ENERGY FOR ORIENTATION	 ONLY NEED LIGHTING SYSTEM, AND COOLLING SYSTEM.	 THE MOST SIMILAR BETWEEN SHAPE AND STRUCTURE WITH A AVERAGE ENERGY COST.
JAYANTI JUÁREZ ARCHITECT	 I WAS LOOKING A TALL PEAK	 I WAS LOOKING FOR FEW FRAMES AND DIVISION OF THE BEAMS	 I PREFER AN OPTION WITH LITTLE USE OF ENERGY	 I DON´T UNDERSTAND IF THE SYSTEMS ARE NATURAL, IF THEY´RE NOT I PREFER USE COOLING SYSTEM THAN HEATING AND LIGHTING SYSTEM	 I TRIED TO COMBINE ALL THE ASPECTS BEFORE WRITTEN
MONSERRAT MARTÍNEZ ARCHITECT	 BY FORM H	 EIGHT AND NUMBER OF FRAMES	 ORIENTATION AND LOWER USE OF ENERGY	 LOW USE OF COOLING AND LIGHTING	 COMBINES ALL THE ASPECTS
SELENE GUERRA ARCHITECTURE STUDENT	 IRREGULAR FORM	 LOW COST	 LOW ENERGY CONSUMPTION	 LOW ENERGY COST	 LOW ENERGY CONSUMPTION
SEBASTIÁN NAVARRO ARCHITECT	 BY FORM	 LOW COST	 ORIENTATION AND LOW COST	 ONLY USE OF COOLING AND LIGHTING	 I CHOSE FOR THE LIGHTING, STRUCTURE, SHAPE AND HEIGHT.
HÉCTOR FUENTES ARCHITECT	 BY FORM	 STRUCTURE ACCORDING TO FORM	 LOWER ENERGY USE	 LOW COST	 LOW COST

USERS VALIDATION

USERS QUESTIONNAIRE

Name: Israel Hernández Pérez
Background: Architect

1. **How complex do you consider the interface?**

☐Easy ☒Medium ☐High

2. **Which stage was more helpful when talking about decision support?**

☐Stage 1_Massing
☒Stage 2_Structure
☐Stage 3_Envelope
☐Stage 4_Systems

3. **Which stage was more complicated to understand or to deal with it?**

☐Stage 1_Massing
☐Stage 2_Structure
☒Stage 3_Envelope
☐Stage 4_Systems

4. **In a scale of 1 to 5 how did each section helped you to take a design decision?**

Stage 1_Massing: ☐ ☐ ☐ ☒ ☐
Stage 2_Structure: ☐ ☐ ☐ ☐ ☒
Stage 3_Envelope: ☐ ☐ ☐ ☒ ☐
Stage 4_Systems: ☐ ☐ ☐ ☒ ☐

5. **When comparing the two different approaches (Stages / Complete) which one do you prefer?**

   Stage division ☐
   Complete ☒

6. **For which phase of the project would you think this strategy would be more helpful**

☒Conceptual ☐Development ☐Documentation

7. **What else would you also include inside the interface?**
   -It would be nice to have the possibility to see the volume (m3)

USERS QUESTIONNAIRE

Name: Jayanti Juárez Barragán
Background: Architect

1. **How complex do you consider the interface?**

☐Easy ☒Medium ☐High

2. **Which stage was more helpful when talking about decision support?**

☐Stage 1_Massing
☒Stage 2_Structure
☐Stage 3_Envelope
☐Stage 4_Systems

3. **Which stage was more complicated to understand or to deal with it?**

☐Stage 1_Massing
☐Stage 2_Structure
☒Stage 3_Envelope
☐Stage 4_Systems

4. **In a scale of 1 to 5 how did each section helped you to take a design decision?**

Stage 1_Massing: ☐ ☐ ☐ ☒ ☐
Stage 2_Structure: ☐ ☐ ☐ ☐ ☒
Stage 3_Envelope: ☐ ☐ ☐ ☒ ☐
Stage 4_Systems: ☐ ☐ ☒ ☐ ☐

5. **When comparing the two different approaches (Stages / Complete) which one do you prefer?**

   Stage division ☐
   Complete ☒

6. **For which phase of the project would you think this strategy would be more helpful**

☐Conceptual ☒Development ☐Documentation

7. **What else would you also include inside the interface?** More specifications in the parameters table

USERS QUESTIONNAIRE

Name: Sebastian Navarro Mora
Background: Architect

1. **How complex do you consider the interface?**

☐Easy ☒Medium ☐High

2. **Which stage was more helpful when talking about decision support?**

☐Stage 1_Massing
☒Stage 2_Structure
☒Stage 3_Envelope
☐Stage 4_Systems

3. **Which stage was more complicated to understand or to deal with it?**

☐Stage 1_Massing
☐Stage 2_Structure
☐Stage 3_Envelope
☒Stage 4_Systems

4. **In a scale of 1 to 5 how did each section helped you to take a design decision?**

Stage 1_Massing: ☐ ☐ ☐ ☒ ☐
Stage 2_Structure: ☐ ☐ ☐ ☐ ☒
Stage 3_Envelope: ☐ ☐ ☐ ☐ ☒
Stage 4_Systems: ☐ ☐ ☒ ☐ ☐

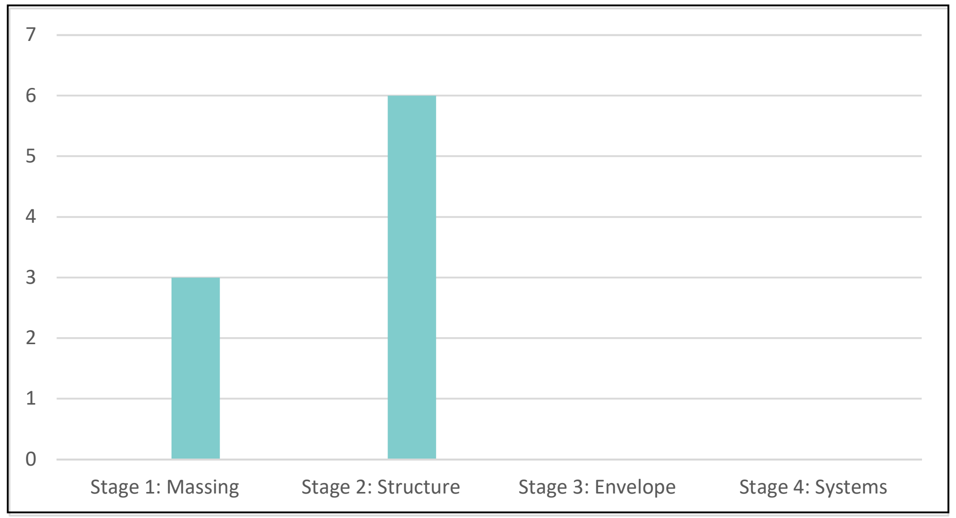
5. **When comparing the two different approaches (Stages / Complete) which one do you prefer?**

   Stage division ☒Complete ☐

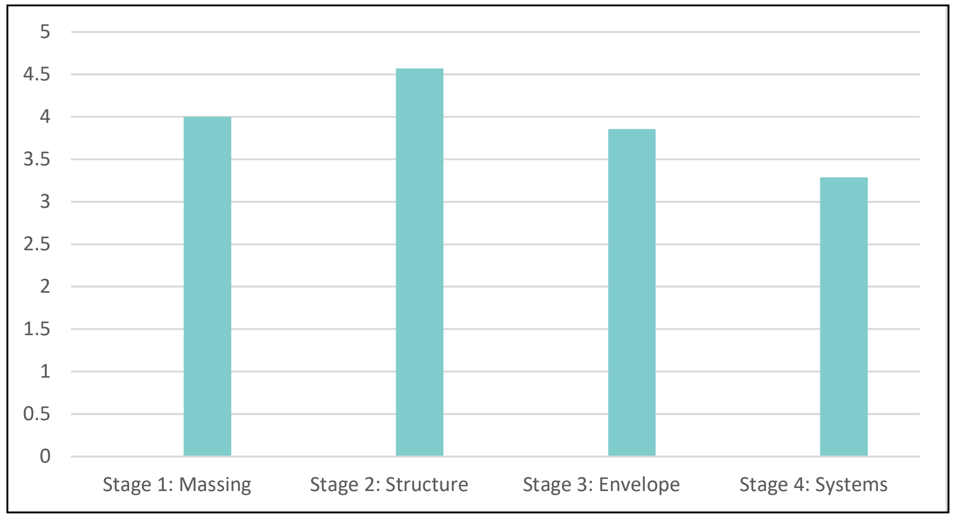
6. **For which phase of the project would you think this strategy would be more helpful**

USERS VALIDATION

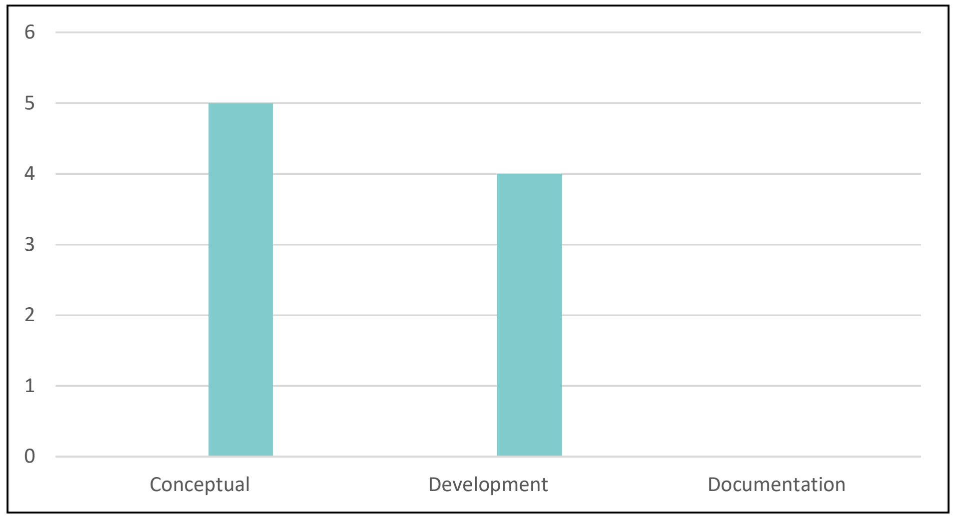
WHICH ONE WAS MORE HELPFUL



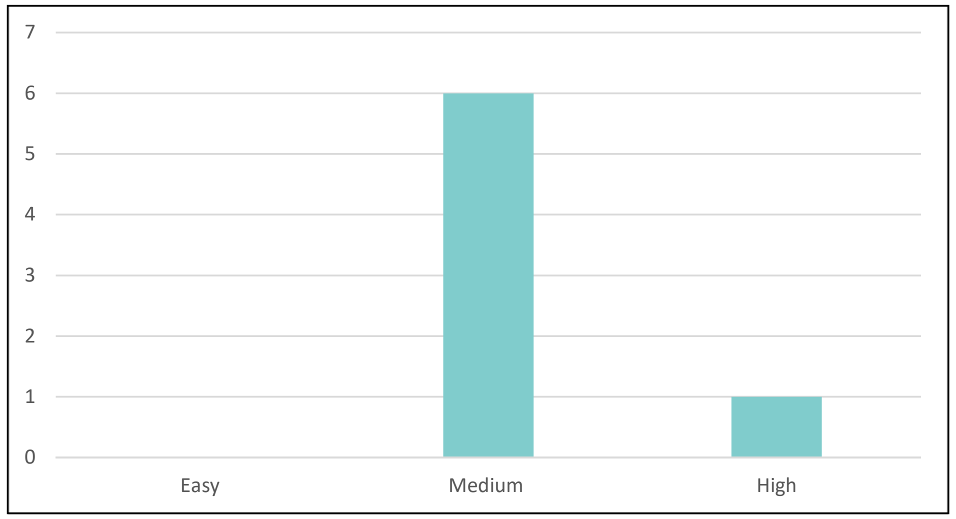
USEFULNESS SCALE



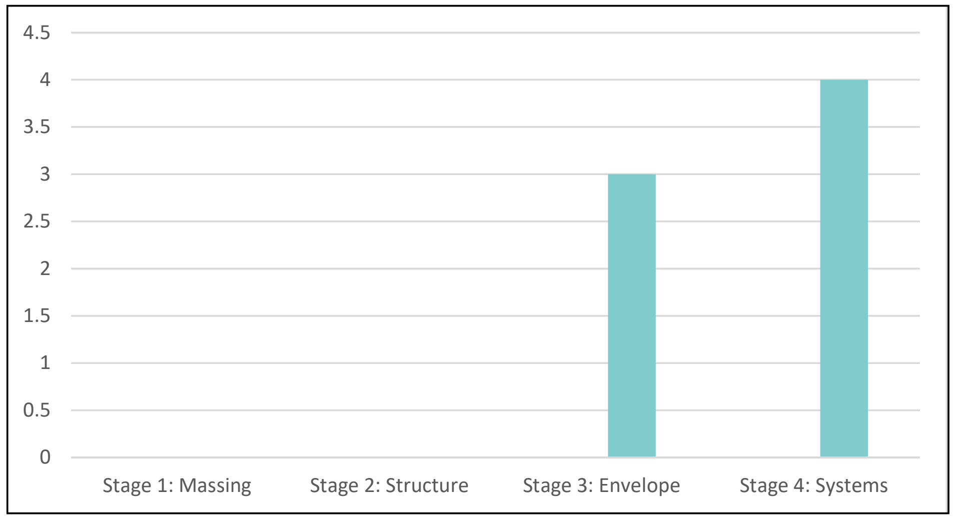
PROJECT PHASE APPLICATION



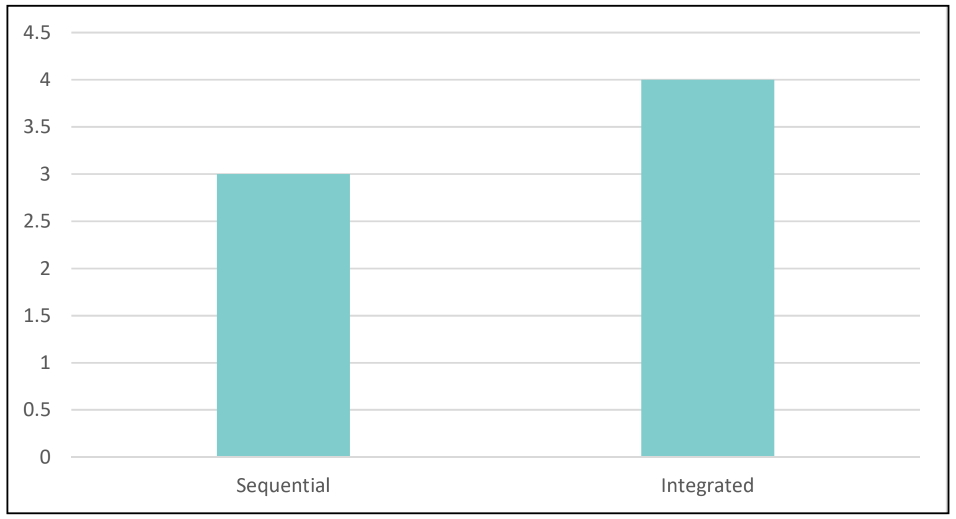
WORKFLOW COMPLEXITY



STAGE DIFFICULTY



SEQUENTIAL VS INTEGRATED



DISCUSSION & CONCLUSIONS

CONCLUSIONS

1. There is no one **ideal optimization** workflow (flexibility , available data & company)

2. The most critical part of the entire process is the beginning, **designing the problem** defining what will change or not, besides clarifying the specific needs and having the right **information** at the right **time** is a fundamental consideration.

3. It is necessary to work **together** with the **specialists** of the diverse fields to define the different parametric models and set up the **performance** simulations.

4. Computers can effectively work as **design decision supporters** and as **educational tools** for architects and designers. Specifically when talking about cost and energy, it can help in finding good **balanced solutions** based on **performance** analysis in combination with **aesthetic** aspects. In this process, it is crucial also to involve the designers **intuition** and **expertise.**

5. Technology is already there we just only need to **change** and **improve** the way we use it and apply it.

THANK YOU