María[A]
Puerto Rico

Chris [SE]
Stanford

Wenhao [SE]
Stanford

Rob [MEP]
Stanford

Gustav [CM]
Sweden

Sabrina[LCFM]
Germany

ISLAND TEAM

"No man is an island, entire of itself;
every man is a…part of the main…"
-John Donne

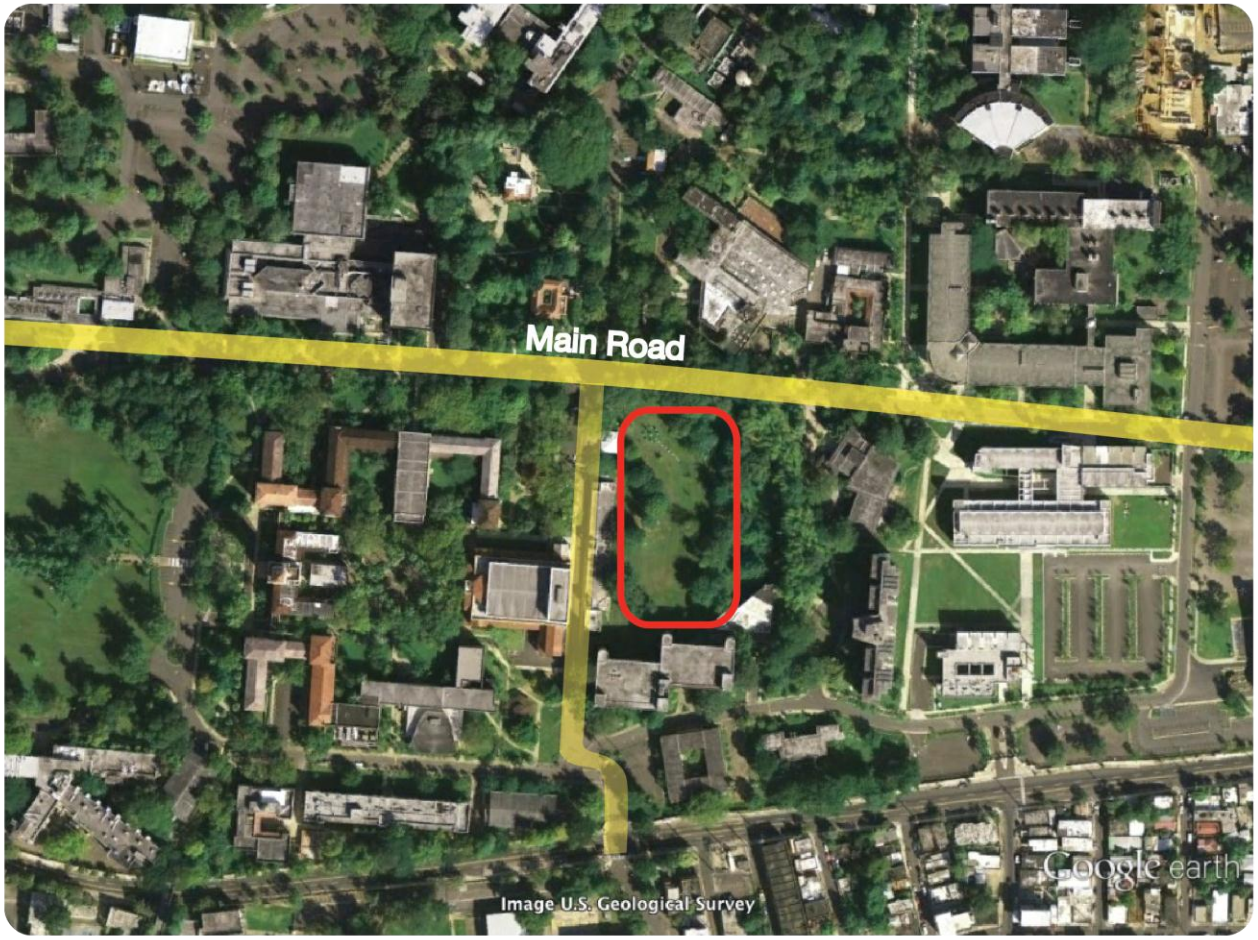
Final Presentation

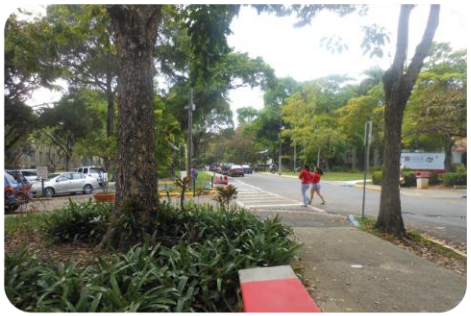
Rob Best, Maria Carrion, Wenhao Chen, Chris Lee, Sabrina Lingemann, Gustav Westphal

Puerto Rico


Kansas
Wichita
Missouri
Louisville
Virginia
Kentucky
Virginia
Connecticut
New Jersey
Tulsa
Albuquerque
Oklahoma
Arkansas
Tennessee
North Carolina
Delaware
Maryland
North Atlantic Ocean
New Mexico
Lubbock
Dallas
Memphis
Mississippi
Atlanta
South Carolina
District of Columbia
Alabama
Juárez
Texas
Mobile
Georgia
Austin
Louisiana
Jacksonville
Houston
Orlando
Chihuahua
San Antonio
Corpus Christi
Florida
Ciudad Obregón
Monclova
Matamoros
Miami
Torreón
Gulf of Mexico
Saltillo
Monterrey
Durango
México
Ciudad Victoria
León de los Aldama
San Luis Potosí
Poza Rica
Mérida
Cancún
Cuba
Guadalajara
Morelia
Veracruz
Campeche
Dominican Republic
Puerto Rico
San Juan
Ciudad de México
Coatzacoalcos
Villahermosa
Puerto Cortés
Acapulco
Tuxtla Gutiérrez
Guatemala
Honduras
Caribbean Sea
Tapachula
Nicaragua
Costa Rica
Panamá
Medellín
Cúcuta
Venezuela
Garagoa
Guyane (French Guiana)
Bogotá
Guyana
Cali
Colombia
Suriname
Roraima
Amapá
Ecuador
Belém
São Luís
Rio Grande
Arecibo
San Juan
Aguada
Carolina
Puerto Rico
Mayagüez
Caguas
Cayey
Guánica

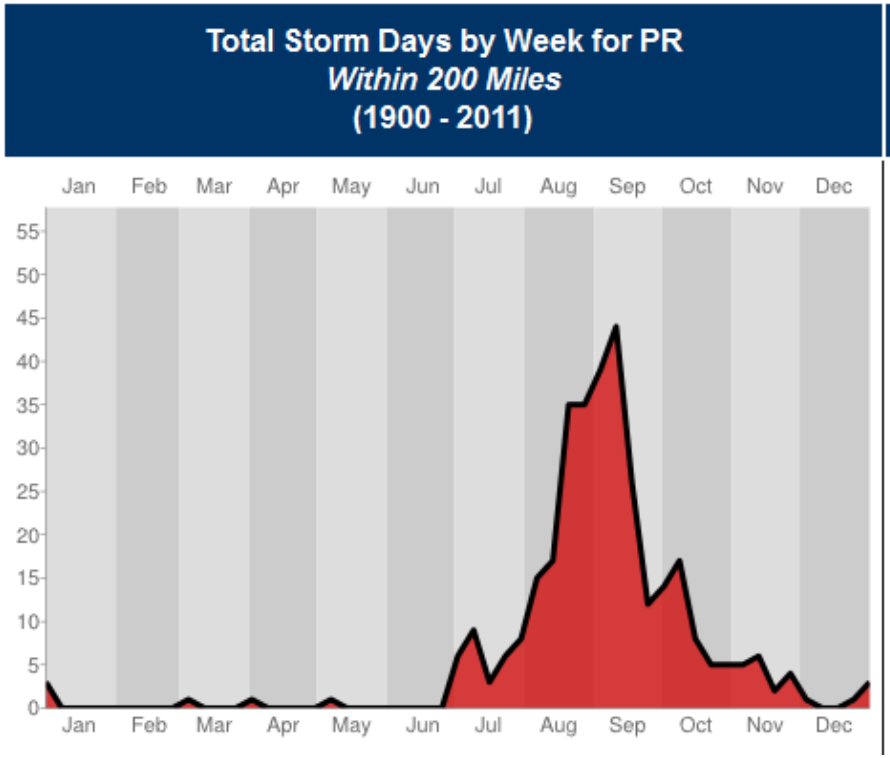
University of Puerto Rico

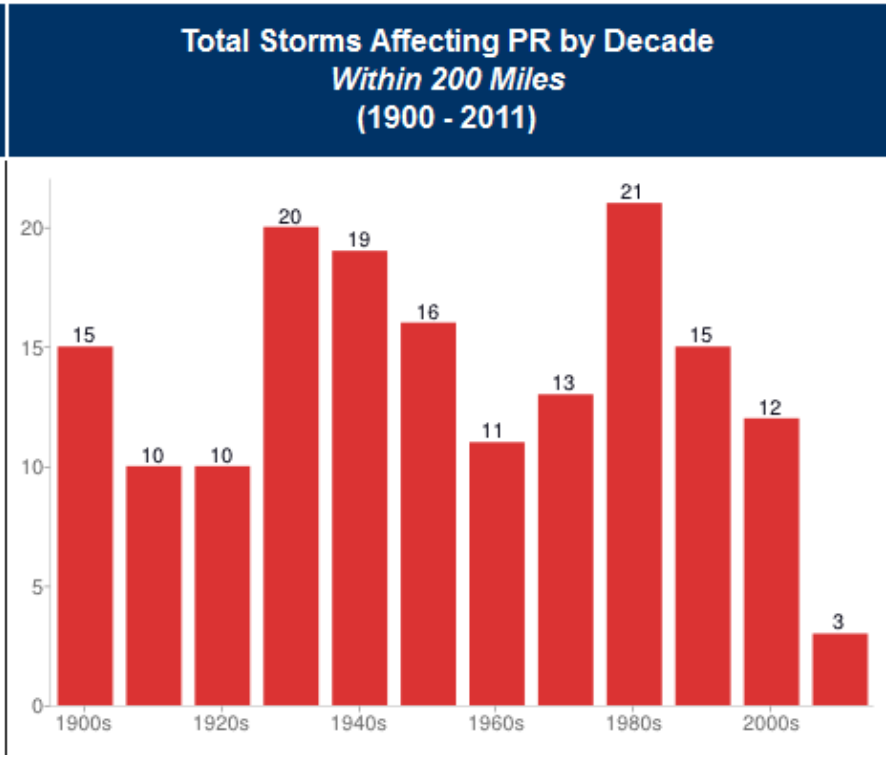




Site constraints

- Earthquakes: seismically active area due to close fault
- Hurricanes: frequent storms during summer and fall





Source: http://www.nc-climate.ncsu.edu/climate/hurricanes/statistics

Climate conditions

- Climatic Design Conditions
  - 2% Cooling Design Temperature: 89.2 F
  - 99% Heating Design Temperature: 70.8 F
    - No Heating Required
- Average Relative Humidity: 76.5%
- Yearly Rainfall: 56.43 inches
  - Monthly Range: 1.95 inches to 6.35 inches

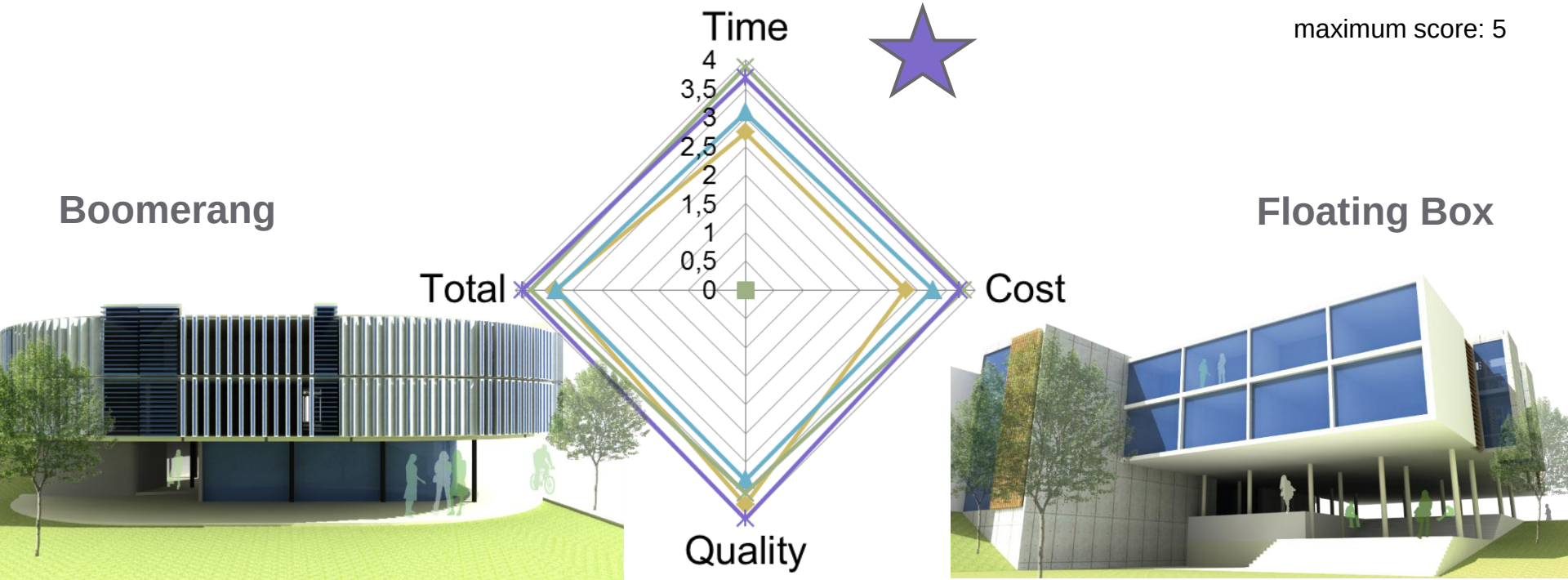
Perception of Climate

The Boomerang

Concept Decision

	Average Weighting	Boomerang Steel	Boomerang Concrete	Floating Box Steel	Floating Box Concrete
Time targets	15,10 %	2,746	3,691	3,091	3,880
Cost targets	27,45 %	2,794	3,732	3,267	3,804
Quality targets	57,45 %	3,742	3,986	3,313	3,535
Total	100 %	3,307	3,879	3,288	3,732

maximum score: 5

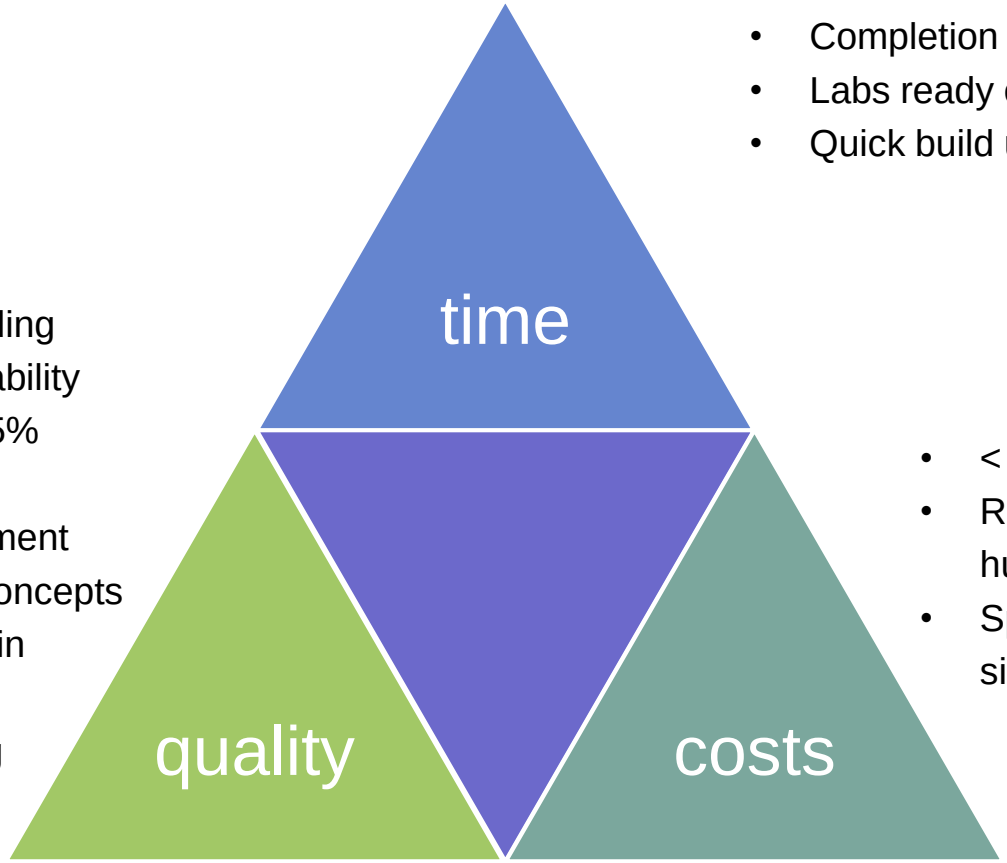


Target Value Design

Targets developed with our owners:

- Completion earlier
- Labs ready earlier
- Quick build up after hurricane

- Spatial requirements
- Social & educating building
- LEED + DGNB sustainability
- Energy perfomance >25% below baseline
- Integration into environment
- Integrated biomimicry concepts
- Structural performance in hurricanes
- Flexibility of the building



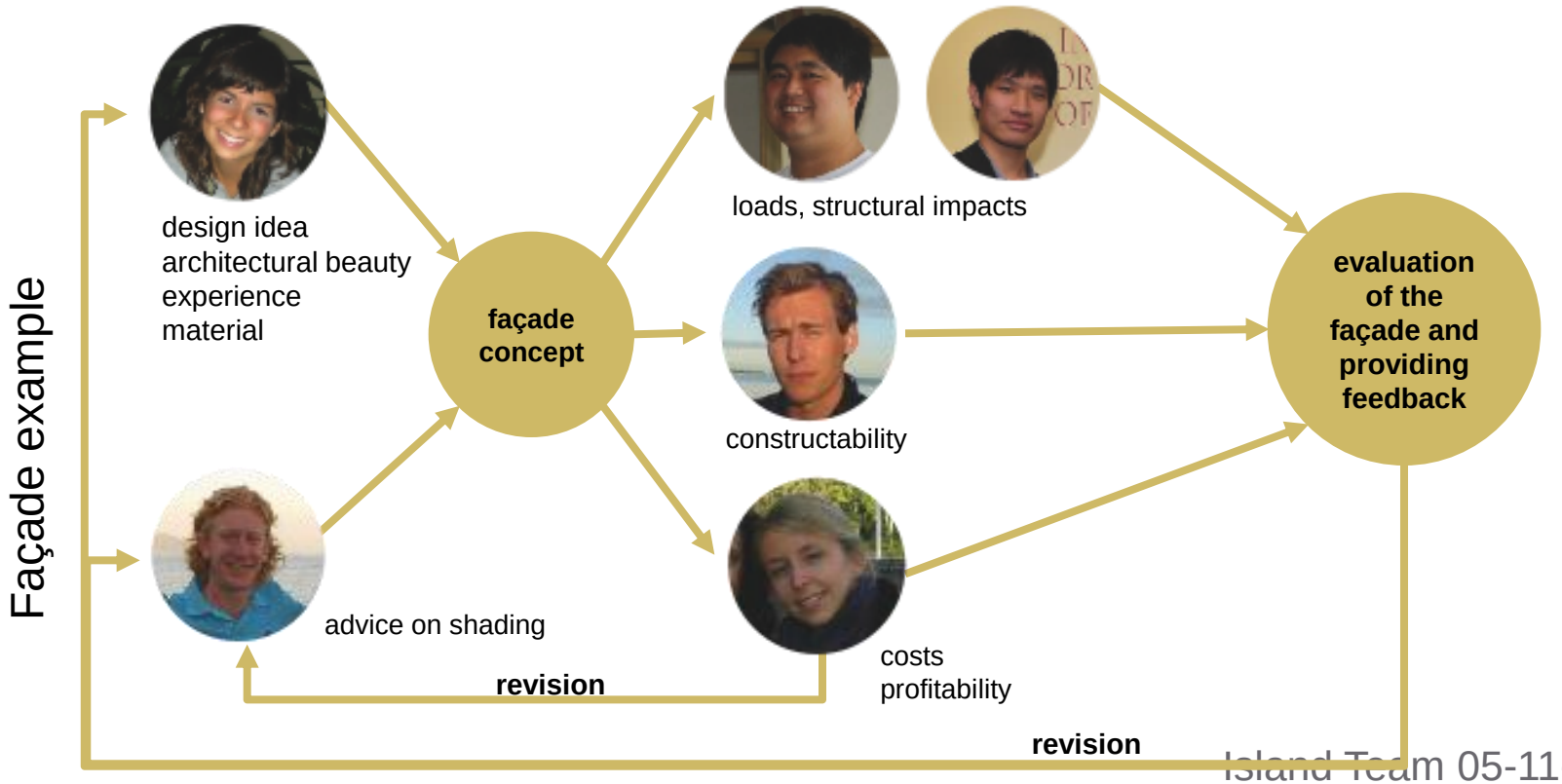
- < 880,000 $ annual rent
- Risk surcharge for hurricanes included
- Space efficiency and simplicity for o+m

SWOT of Boomerang Concrete

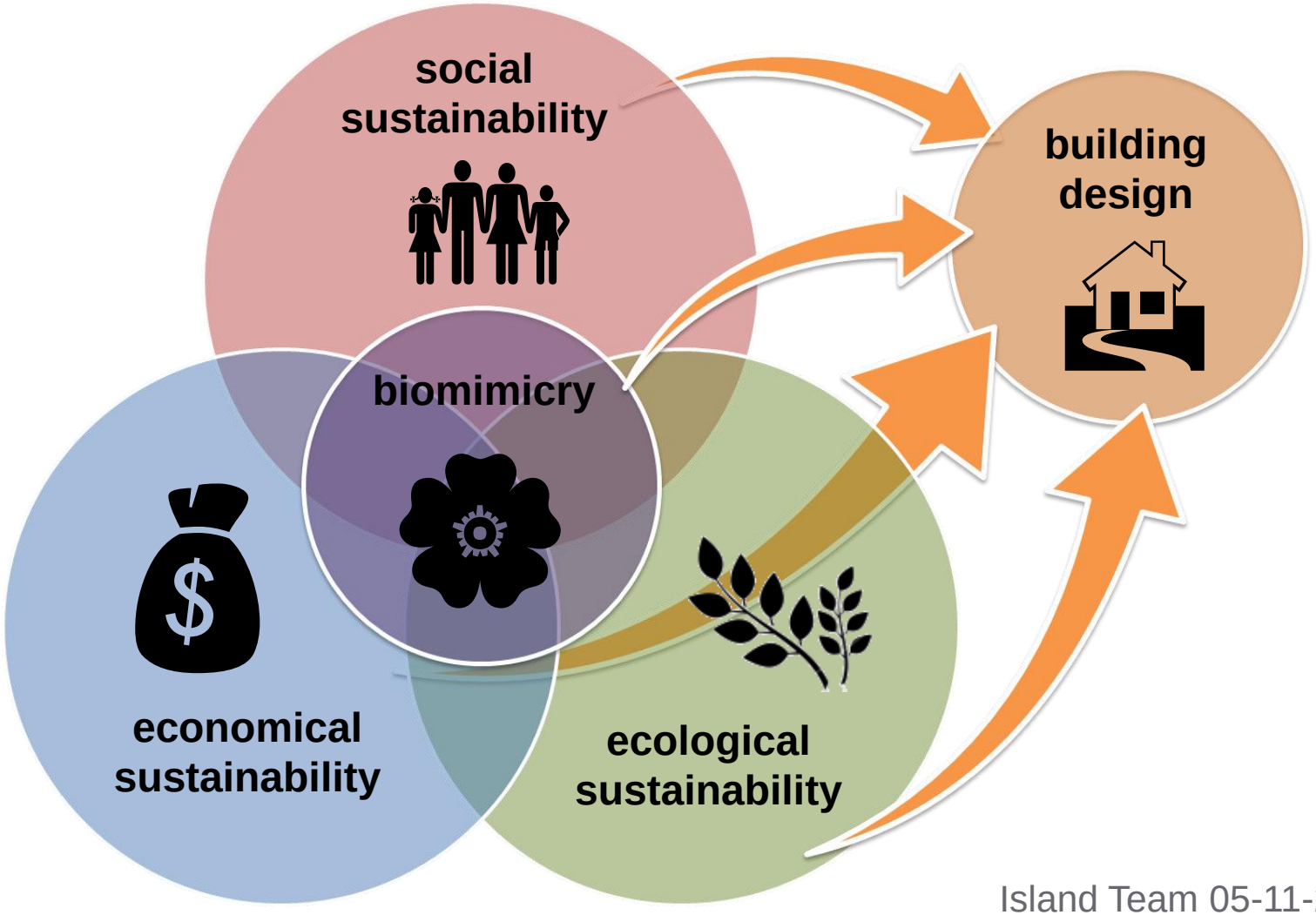
	Helpful	Harmful
Internal origin	**Strengths** • Social building • Integrated into environment • Adapted to weather conditions • Local production • Low construction costs	**Weaknesses** • Rather high o&m costs (energy, cleaning, etc.) • Rather low flexibility
External origin	**Opportunities** • Good opportunities to improve sustainability • Natural ventilation • Educating building (e.g. biomimicry and sustainability)	**Threats** • Hurricanes and heavy rain endanger construction and operation • Rather low sustainability over lifetime

POP Challenge

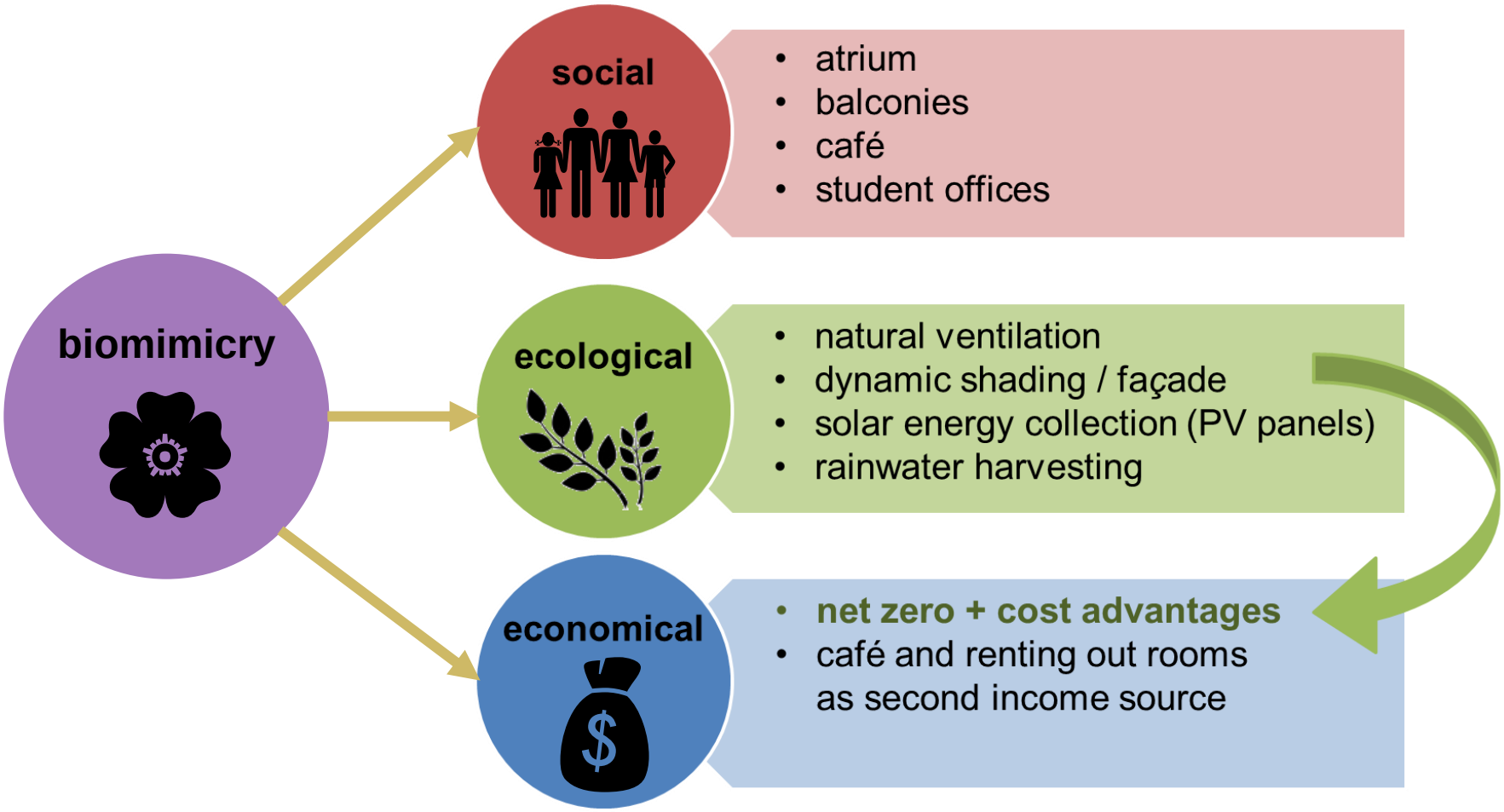
- **P**roduct – aspects of the building
- **O**rganization – who is proactive/reactive?
- **P**rocess – team process



Biomimicry Challenge



Biomimicry Challenge

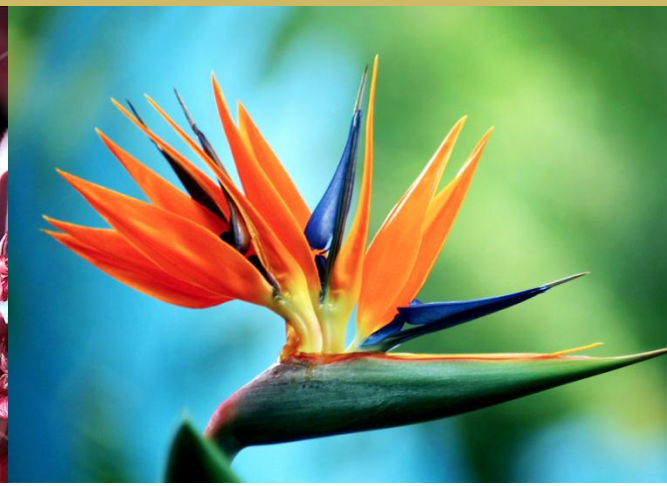


Architectural Inspiration



- Comfortable space in tropical climate.
- Provides Natural illumination
- Maximizes Natural Ventilation
- Provides a sense of security and visual comfort.

Biomimicry Inspiration



- Tropical American plants with a deeply cleft calyx.
- They are common in Puerto Rico
- Chosen for their ability to collect water in the central core and in between leaves; this provides a source of water for other organisms.
- In the case of the Bird of Paradise, its leaves move according to humidity levels and temperature.

Structural Ideas

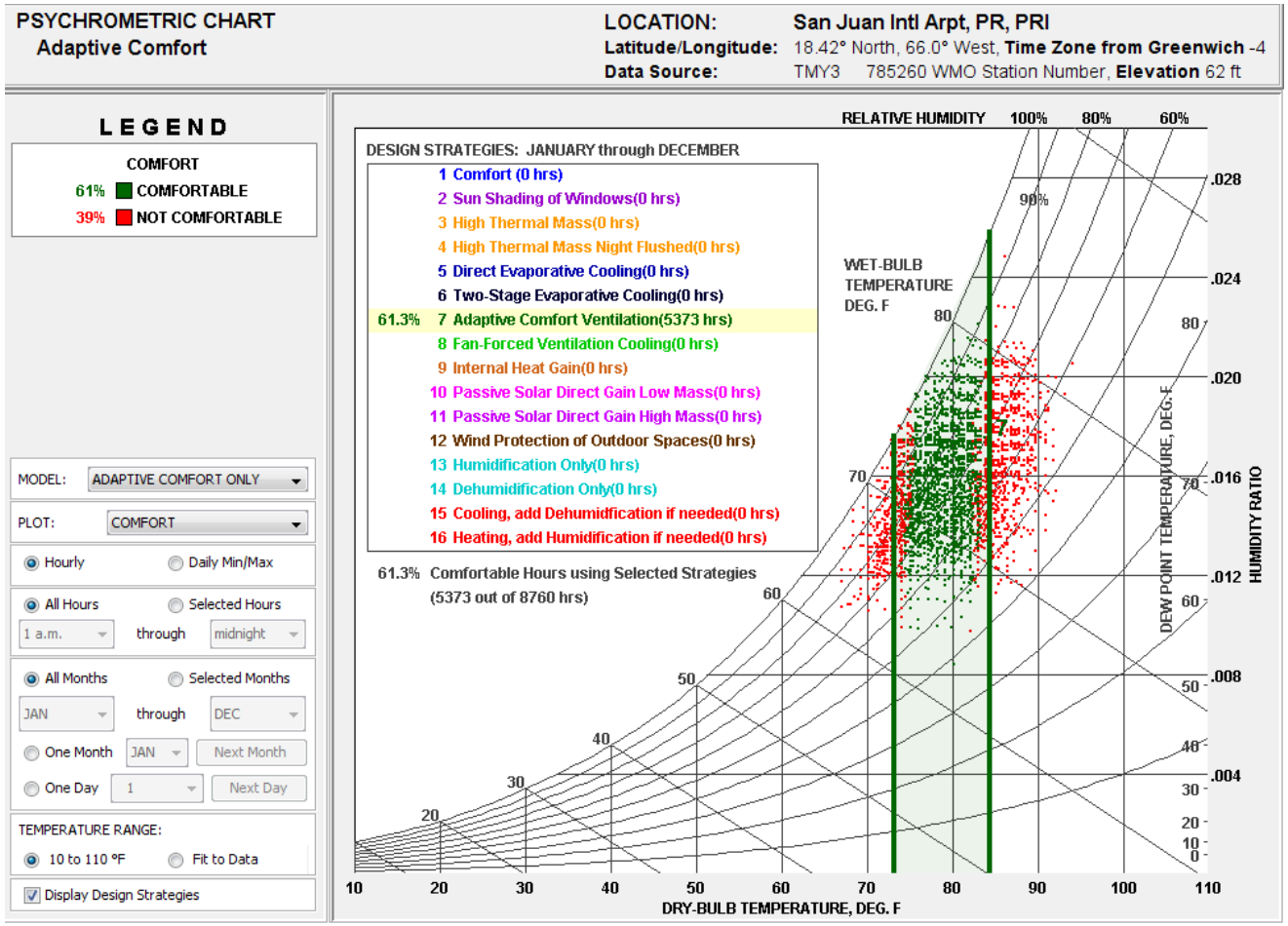


- How do we prepare for Mother Nature?
- Use of developing technology
  - Shear Splices
  - Rocking Frames
  - Shear Walls

MEP Ideas

- Biomimicry: natural cooling and ventilation
- Adaptive comfort suitable for Puerto Rico
- Building management with some individual control
  - Enhanced social space
  - Resilient against future use and climate changes

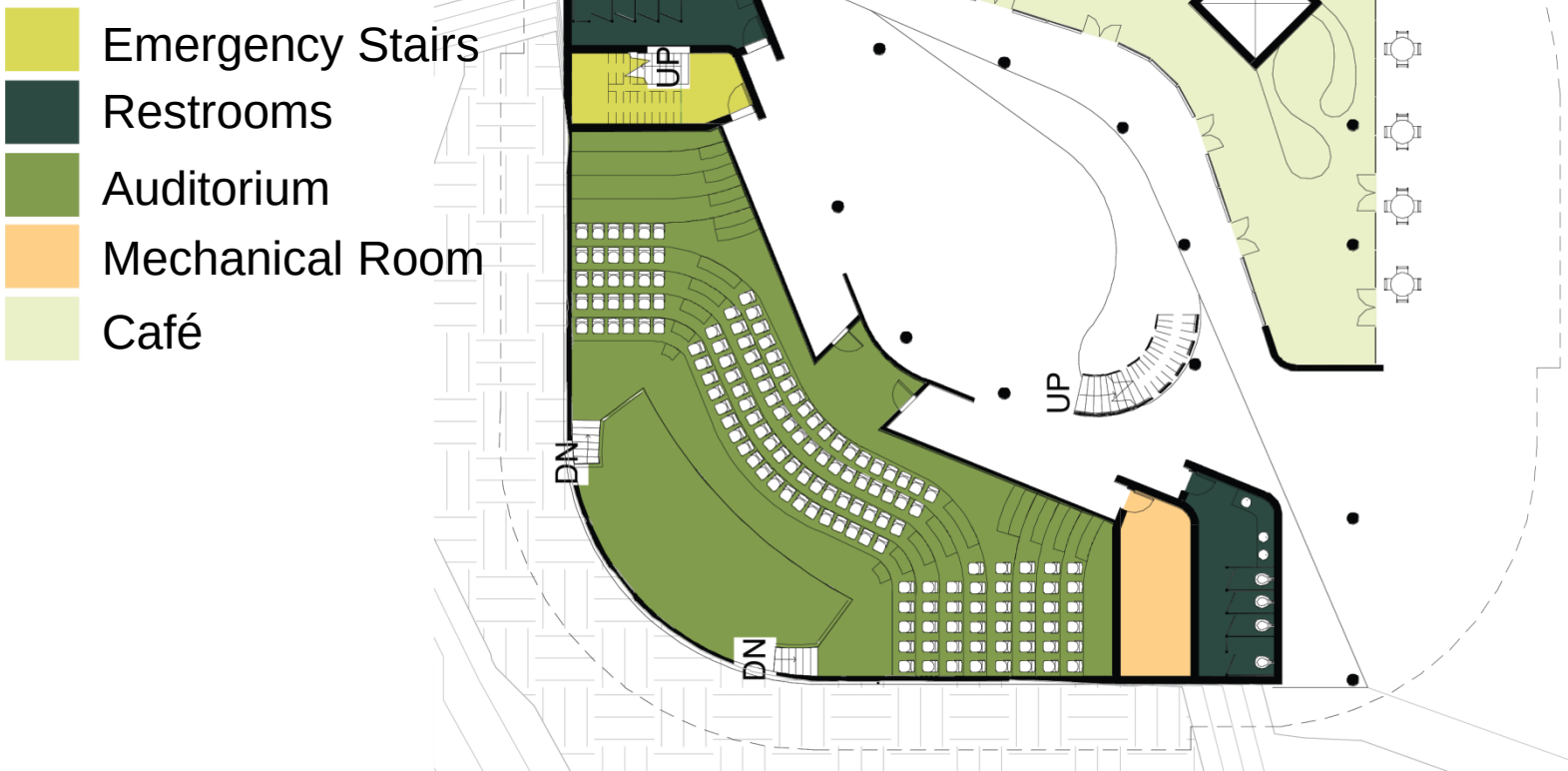
Natural Ventilation Potential



Site Plan

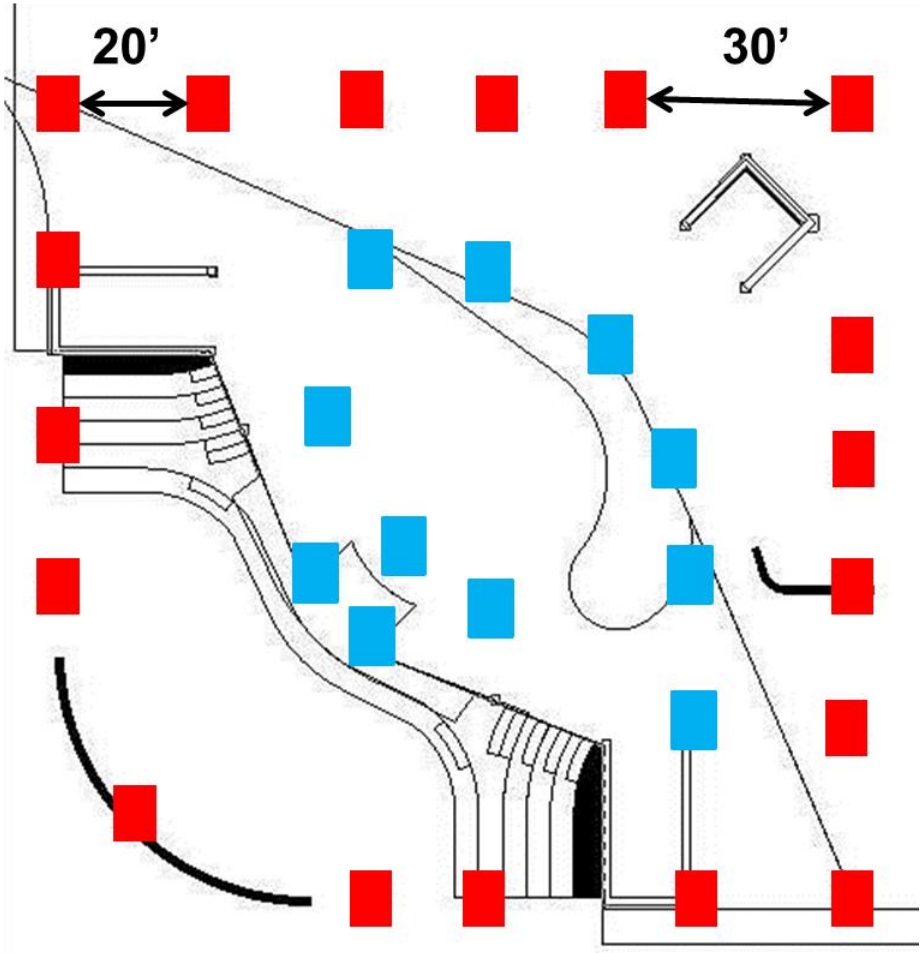

Campus Quad
Main Road Within Campus
Secondary Road
Student Center
Faculty of Education

Architectural Floorplan 1



Structural Floorplan 1

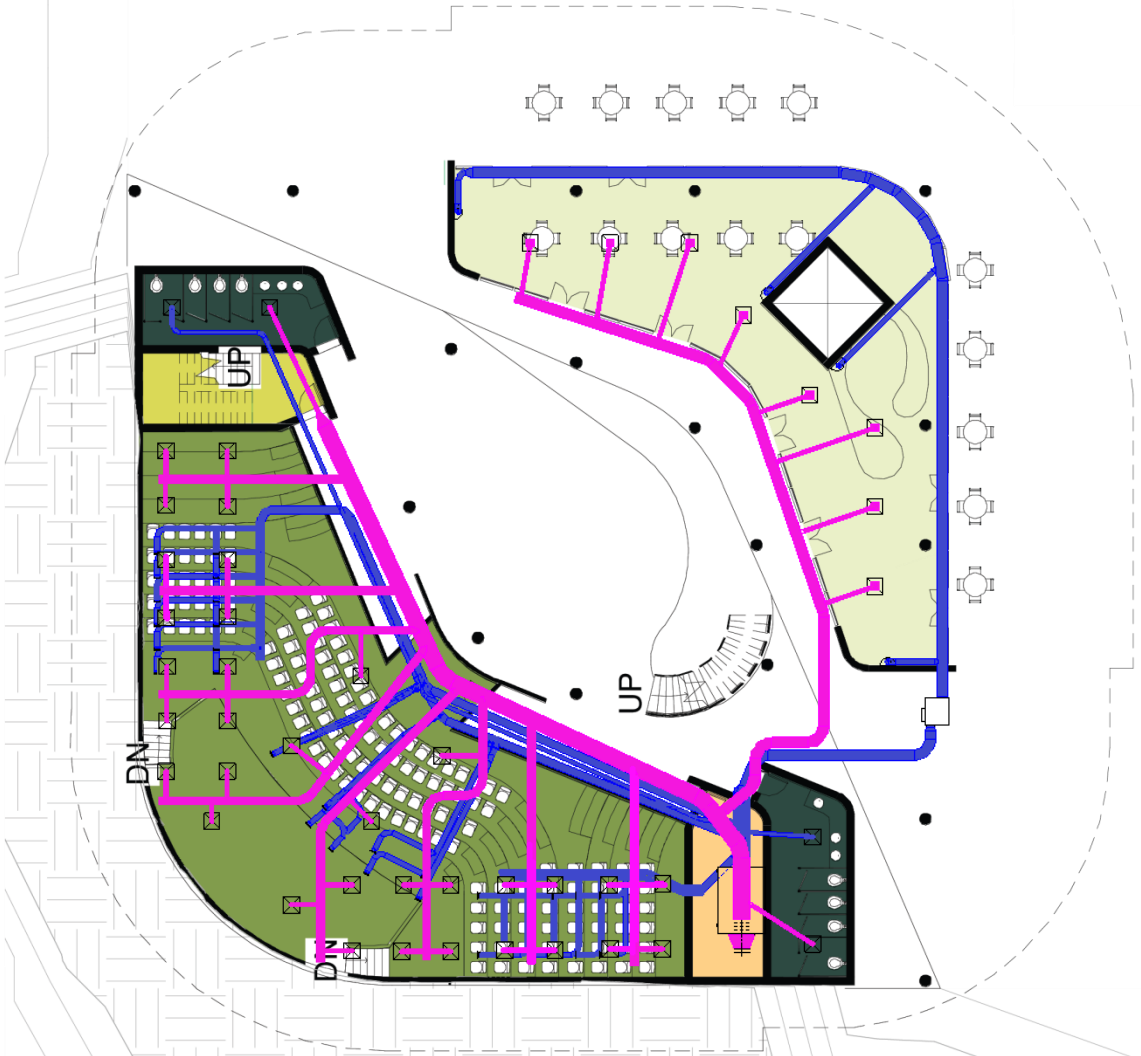
Columns	Member Size
Exterior	24” x 24”
Interior	14” x 14”



MEP Floorplan 1

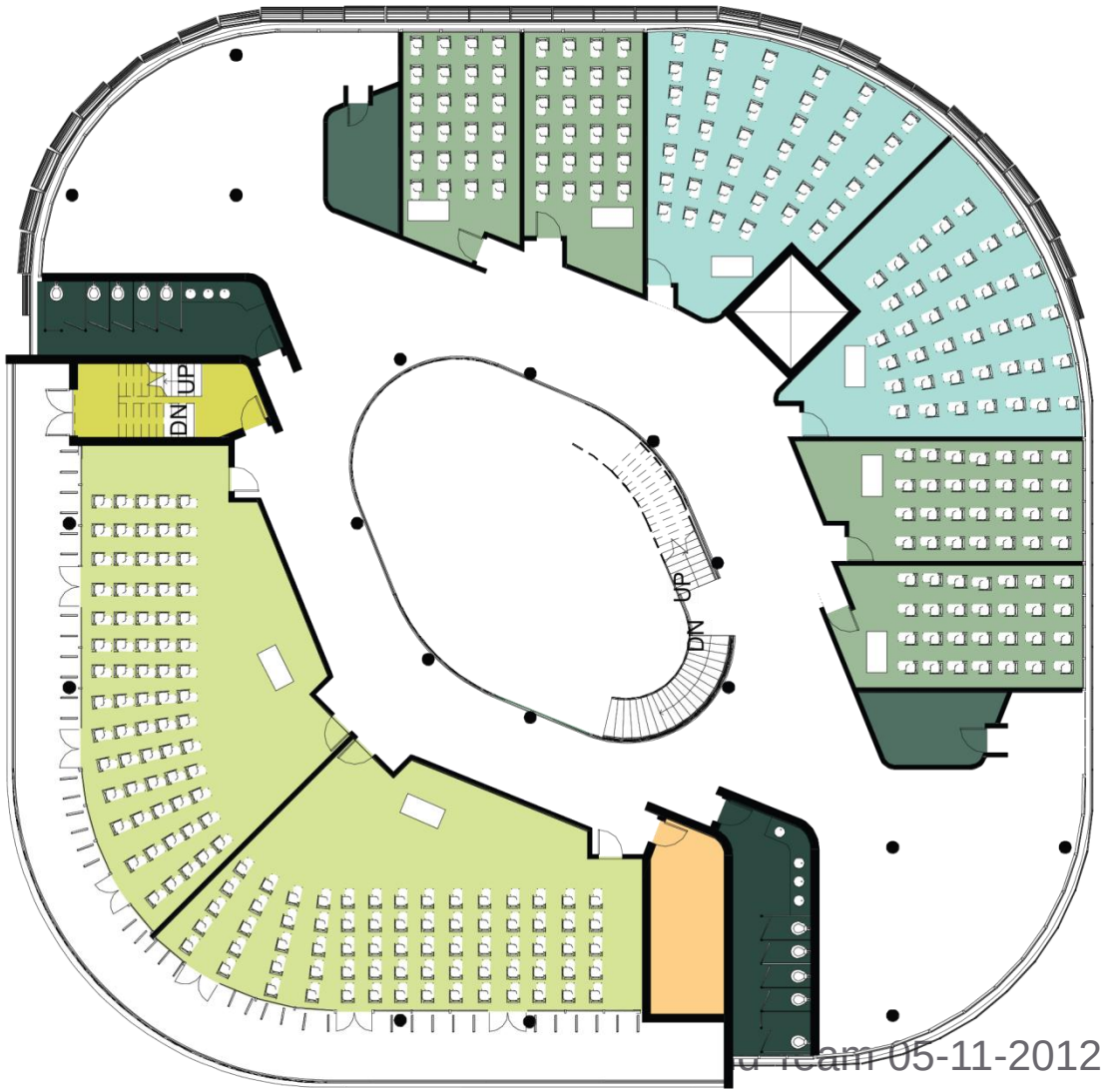
Supply Duct

Return Duct



Architectural Floorplan 2

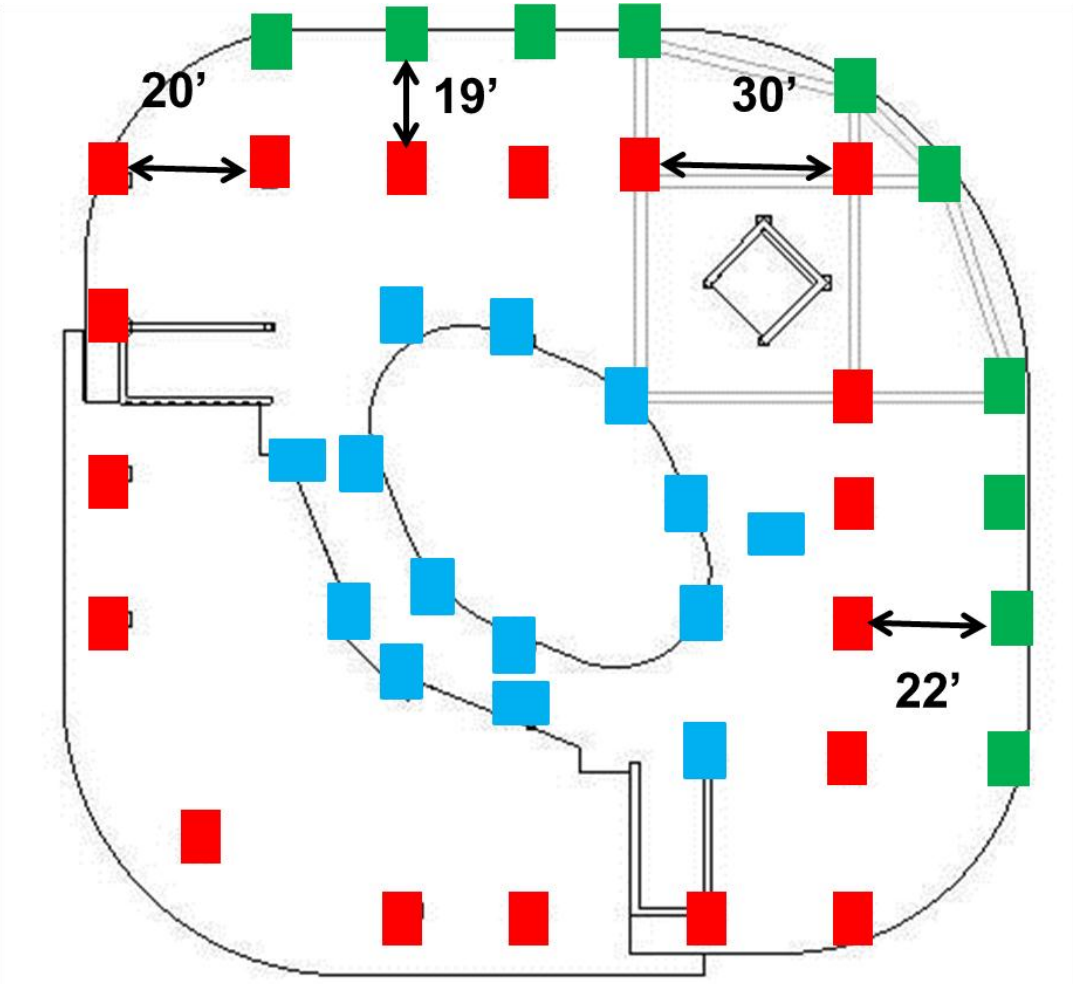
- Emergency Stairs
- Large Classrooms
- Small Classrooms
- Tech. Office
- Restrooms
- Mechanical Room
- Instructional Labs



Structural Floorplan 2

Columns	Member Size
Exterior	24” x 24”
Interior	14” x 14”
Cantilever	20” x 20”

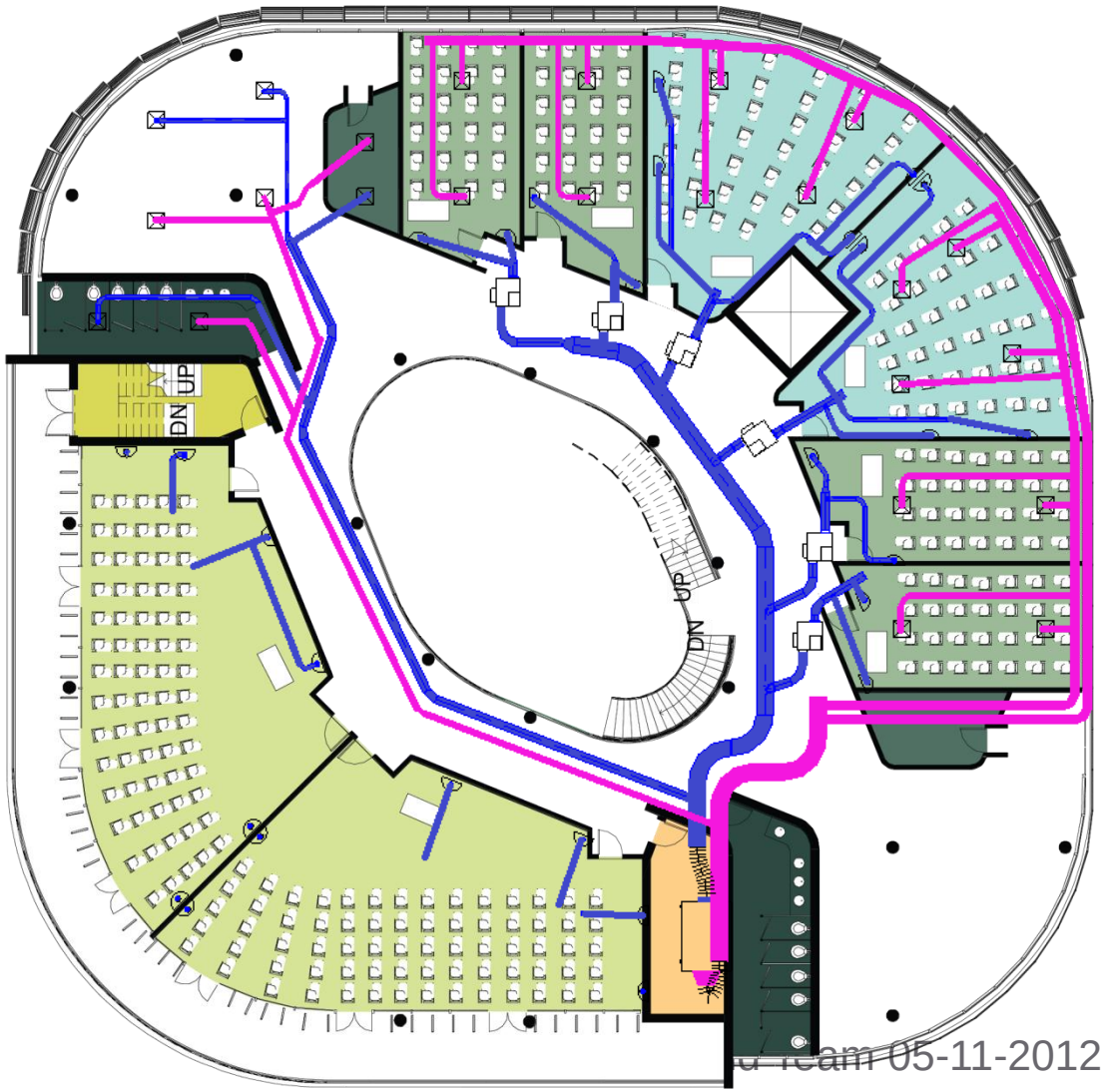
Beams	18” x 22”



MEP Floorplan 2

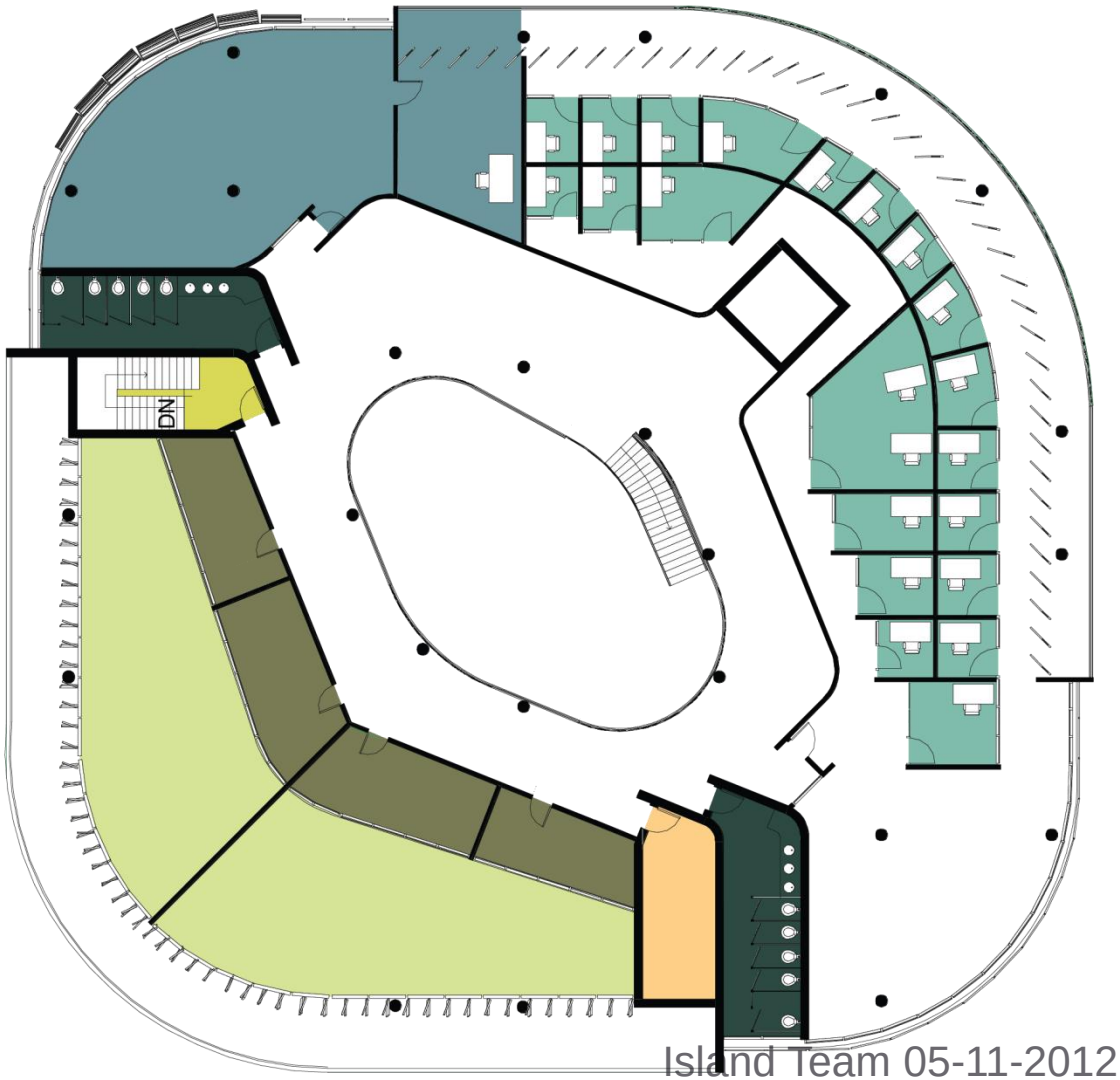
Supply Duct

Return Duct



Architectural Floorplan 3

- Emergency Stairs
- Restrooms
- Mechanical Room
- Instructional Labs
- Seminar Rooms
- Faculty Offices
- Administration



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Columns	Member Size
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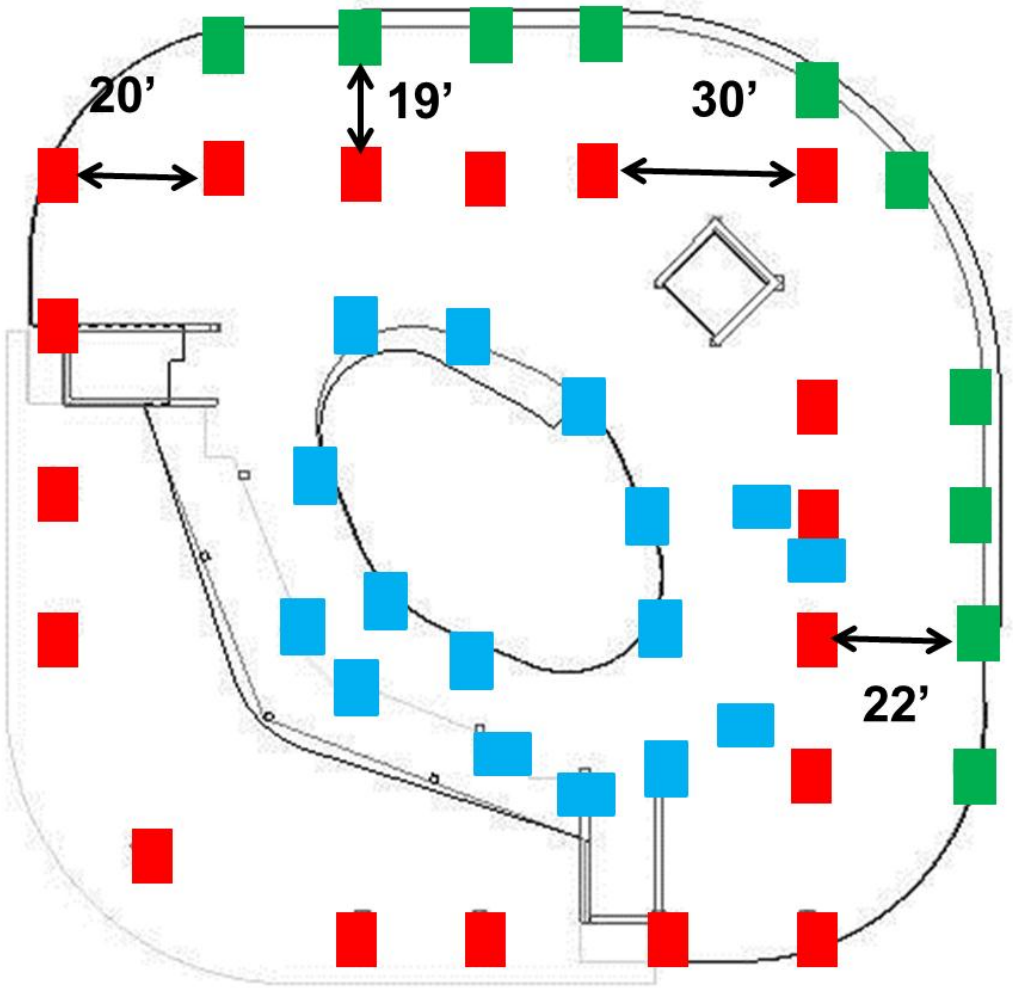
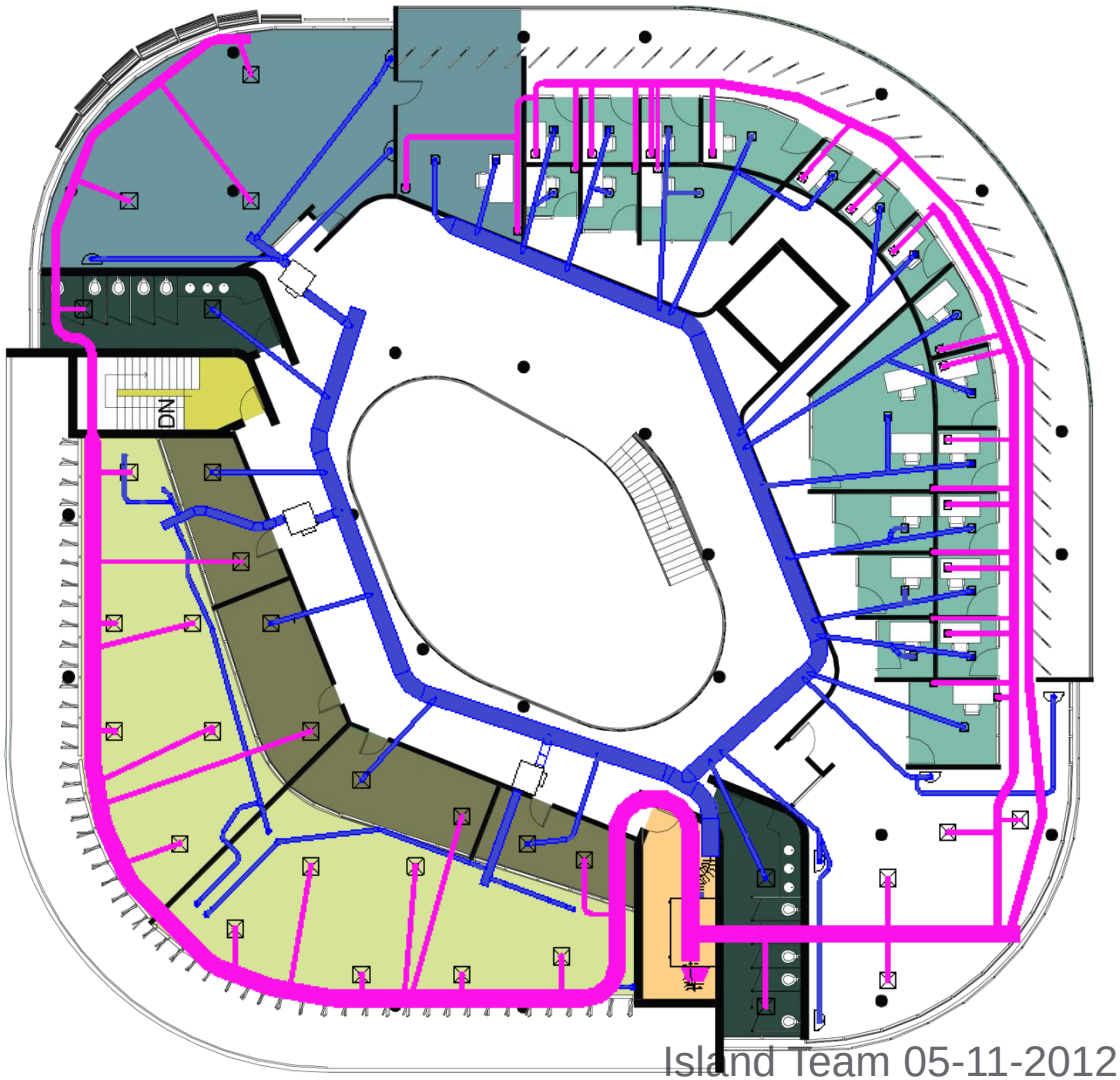


MEP Floorplan 3

Supply Duct

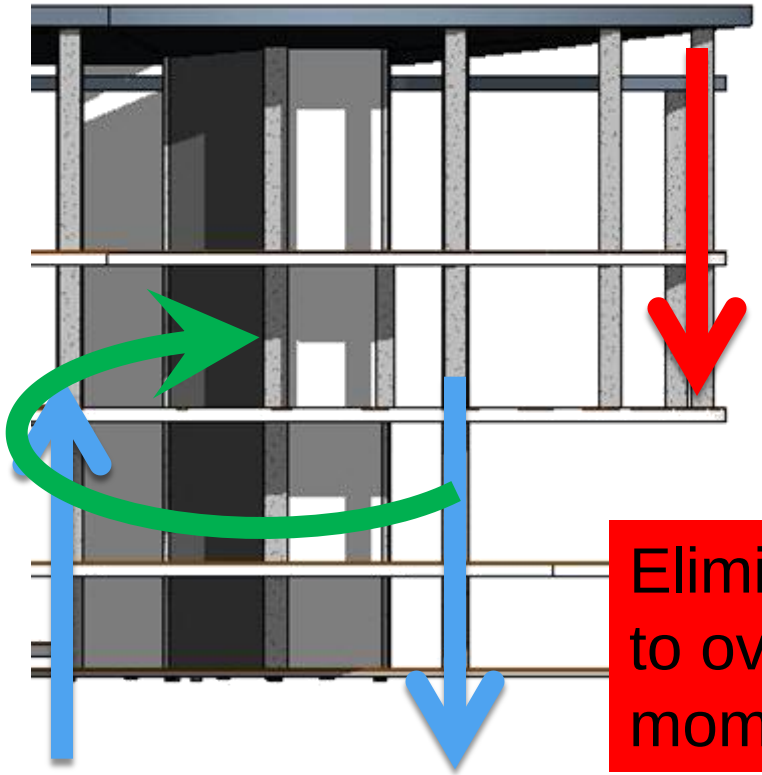
Return Duct



Section A-A

Section B-B

Evolution of the Foundations

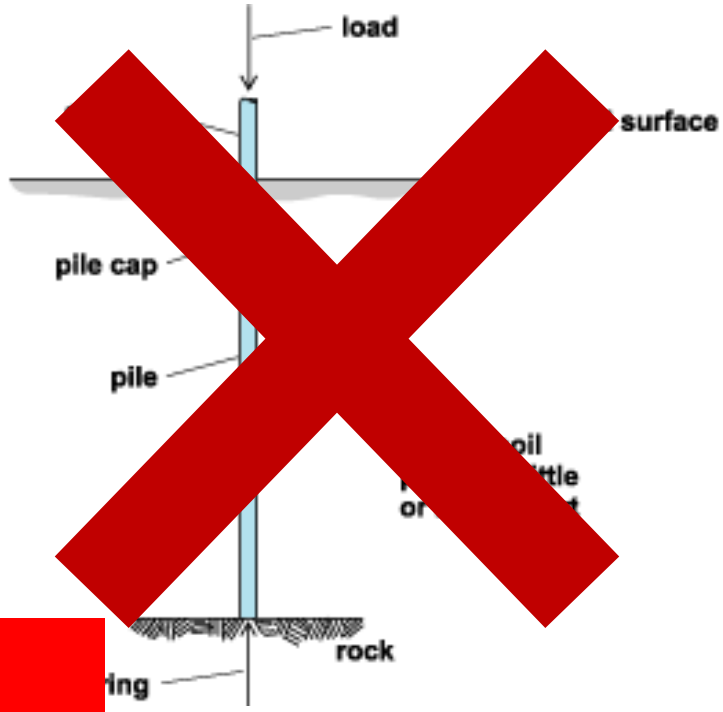


Eliminated due to overturning moment.

Spread Footings

Evolution of the Foundations

- Accounts for the tension force
- Interferes with the underground water tank used for water recycling.

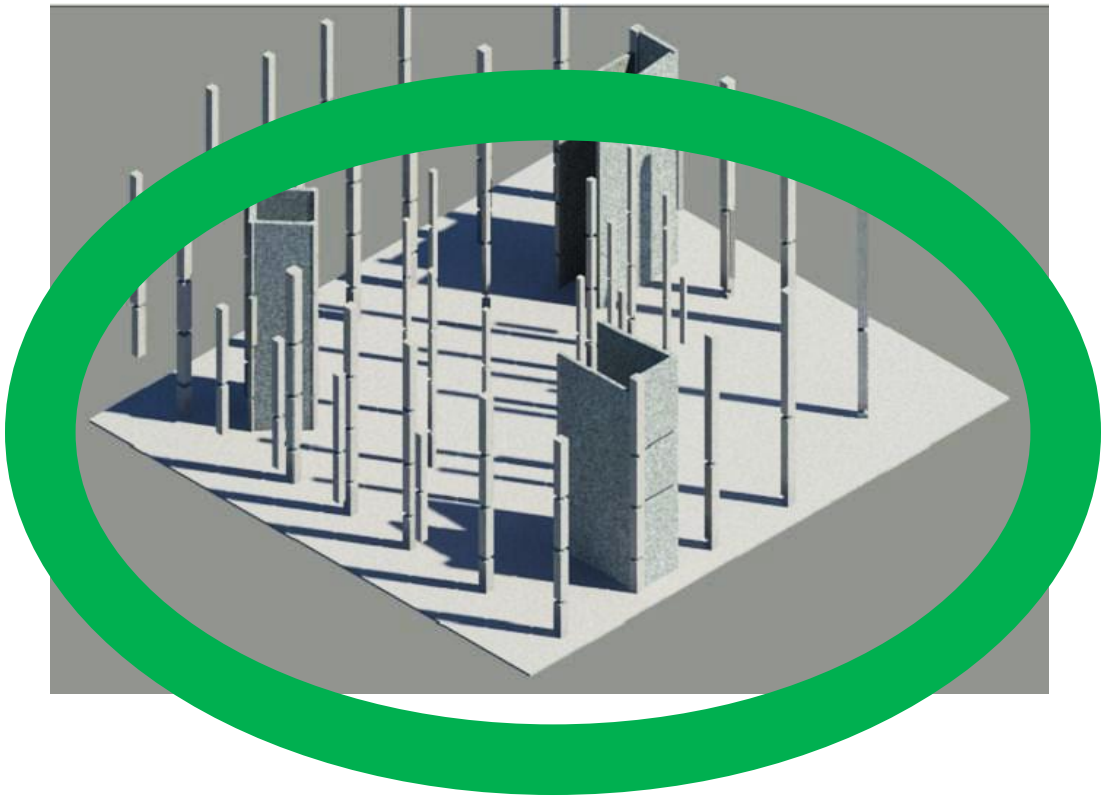


Eliminated due to water tank placement

Pile Footings

Evolution of the Foundations

- Shallow foundation
- Accommodates the water tank
- Time and cost is comparable to pile foundation

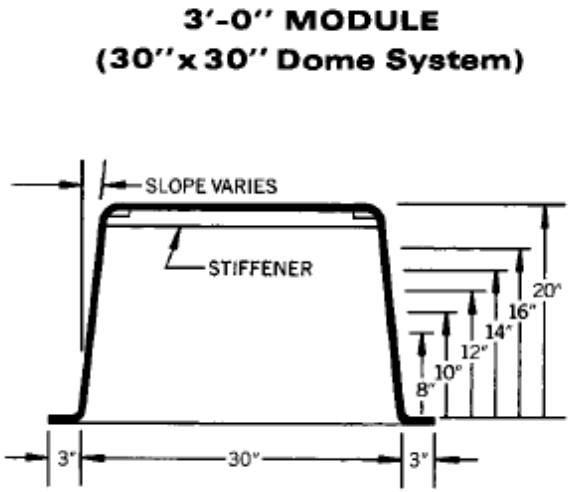


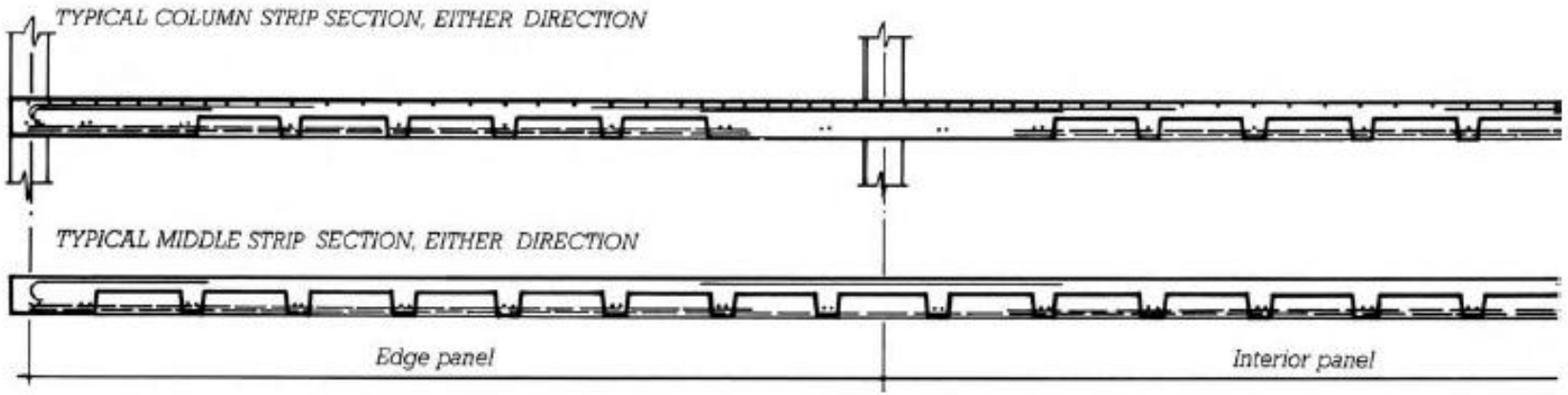
100’ by 100’
30” thickness

Mat Foundation

Evolution of Roof

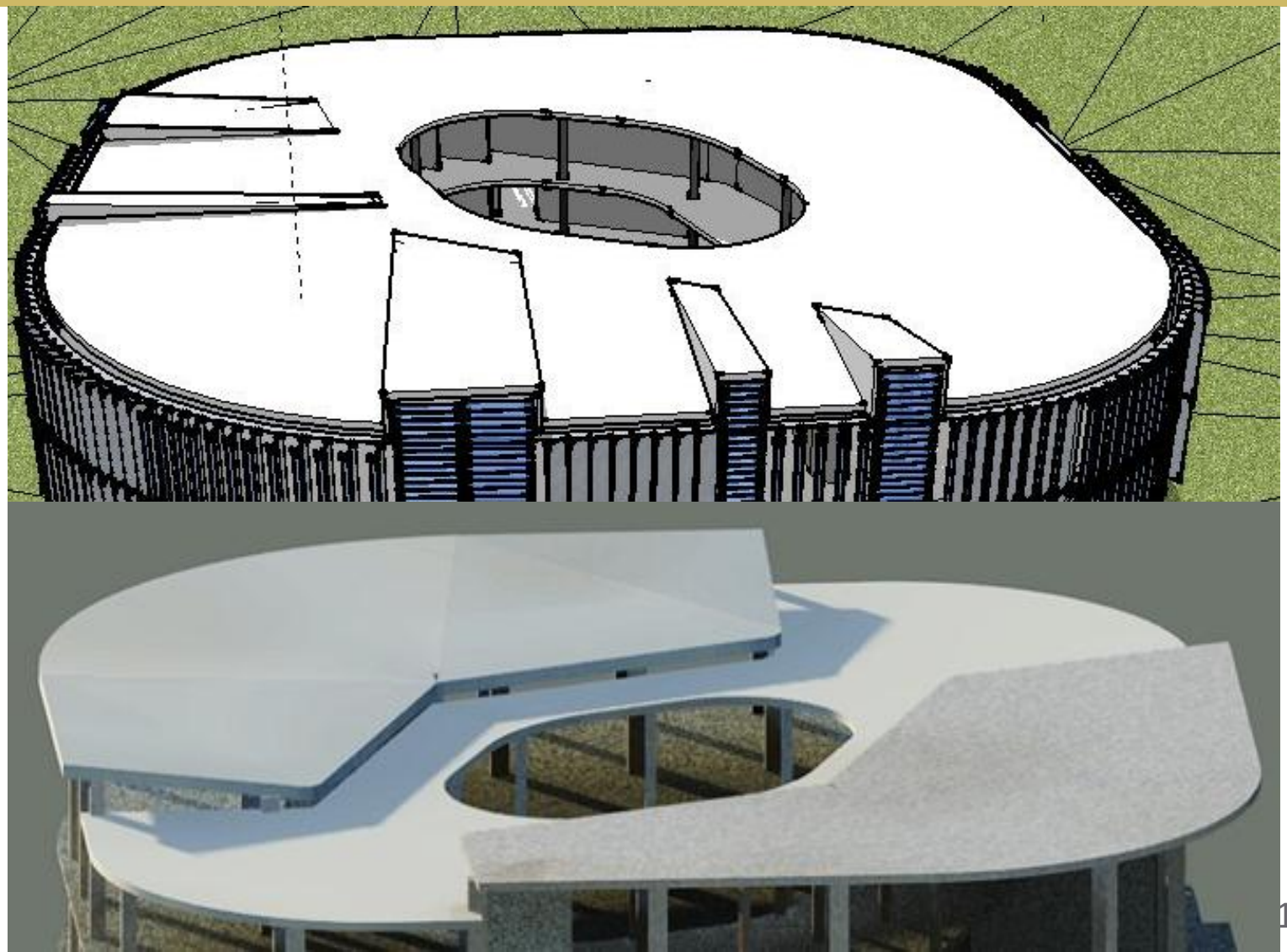
Post-Tensioned
Waffle Slab
Depth: 20 inches





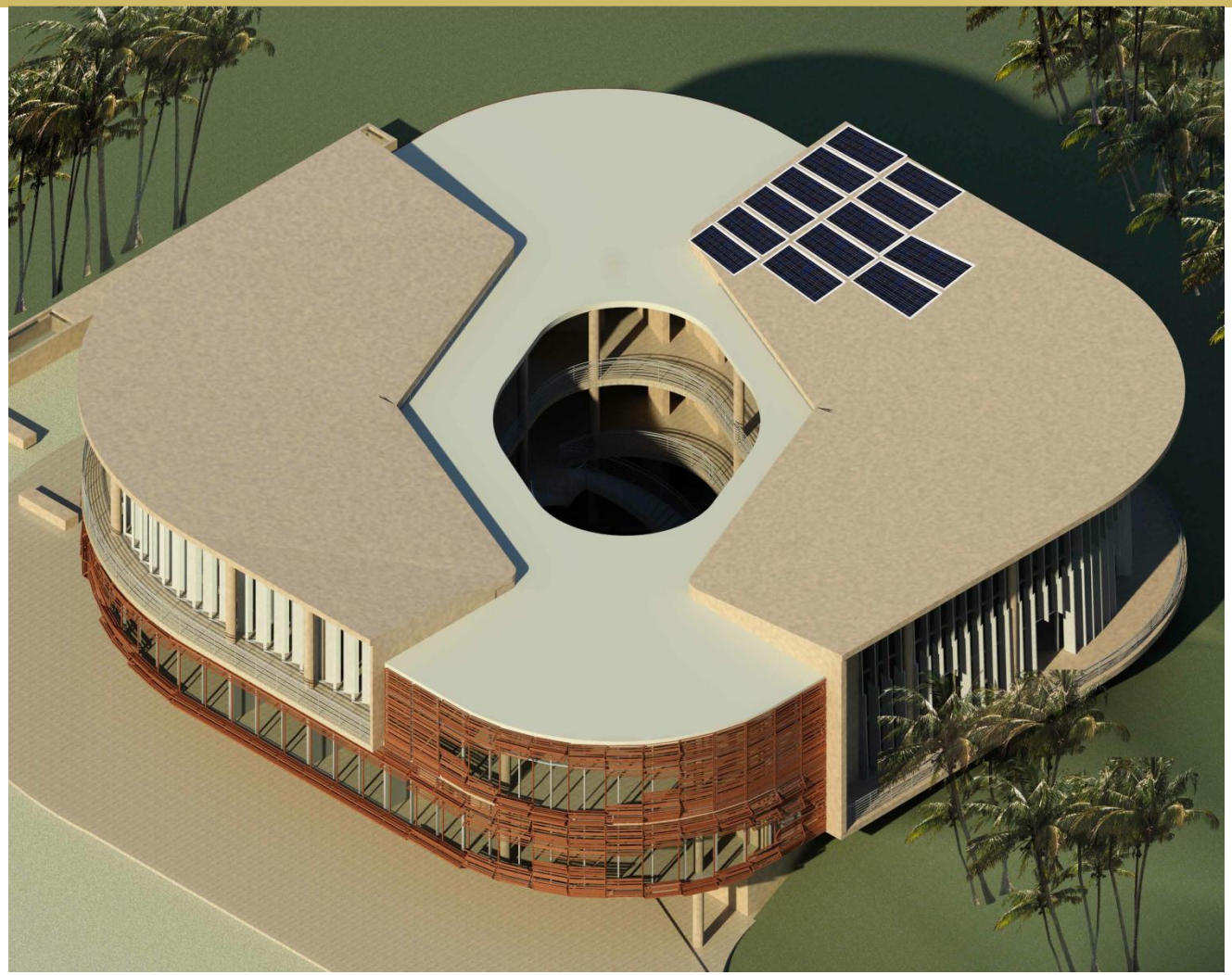
Images Courtesy of Fundamentals of Building Construction

Old and New Roof

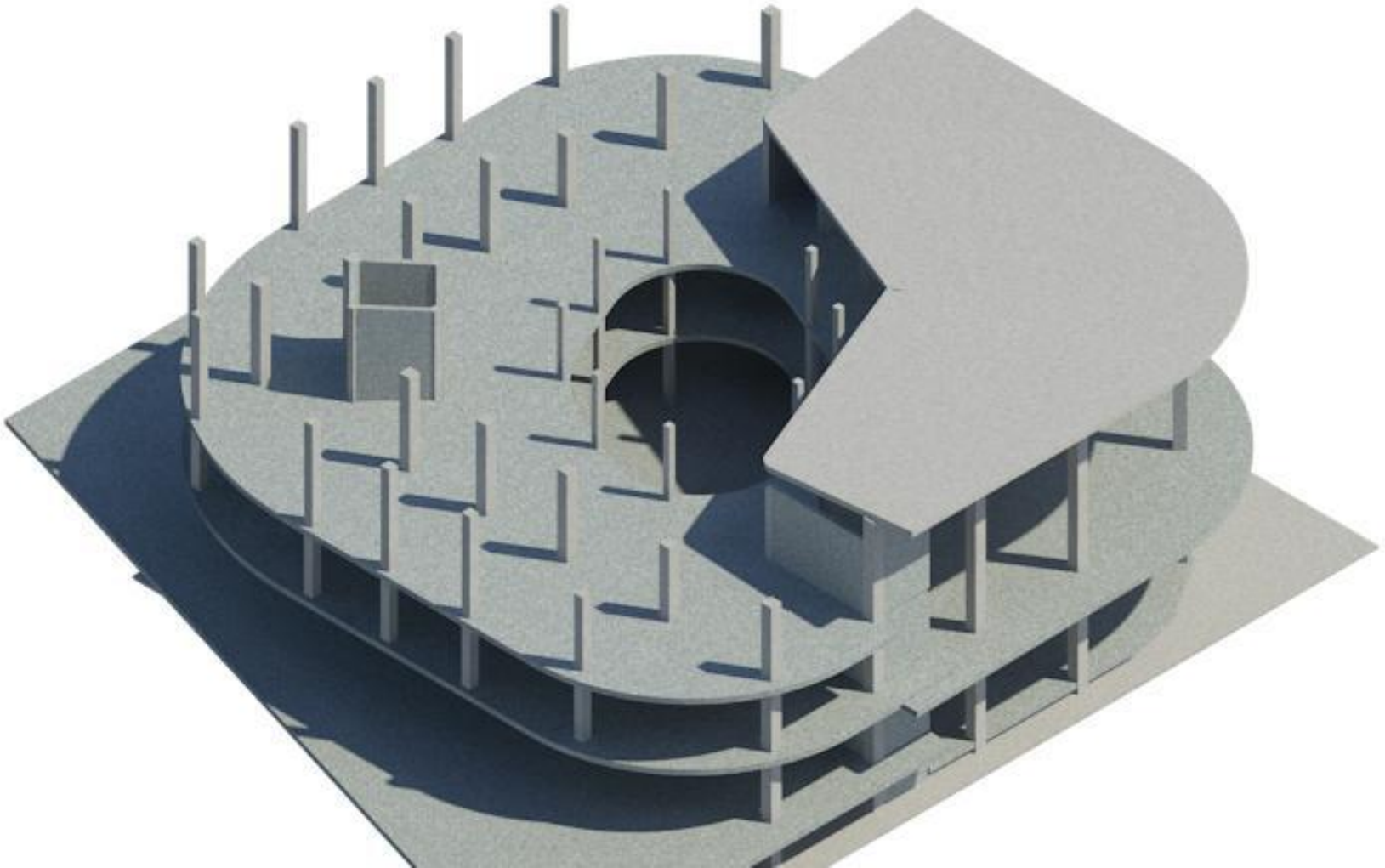


Architectural Model 3D

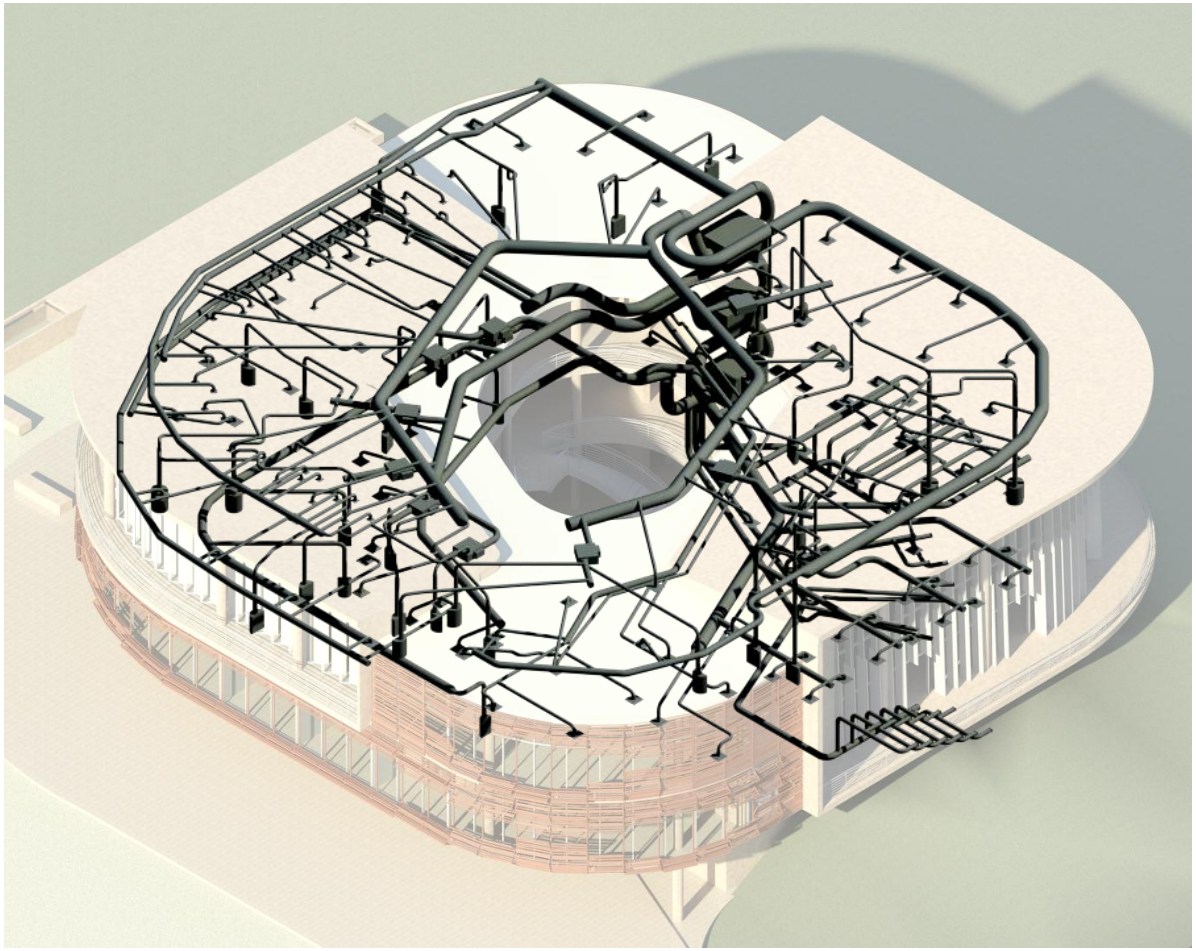
Architectural Model 3D



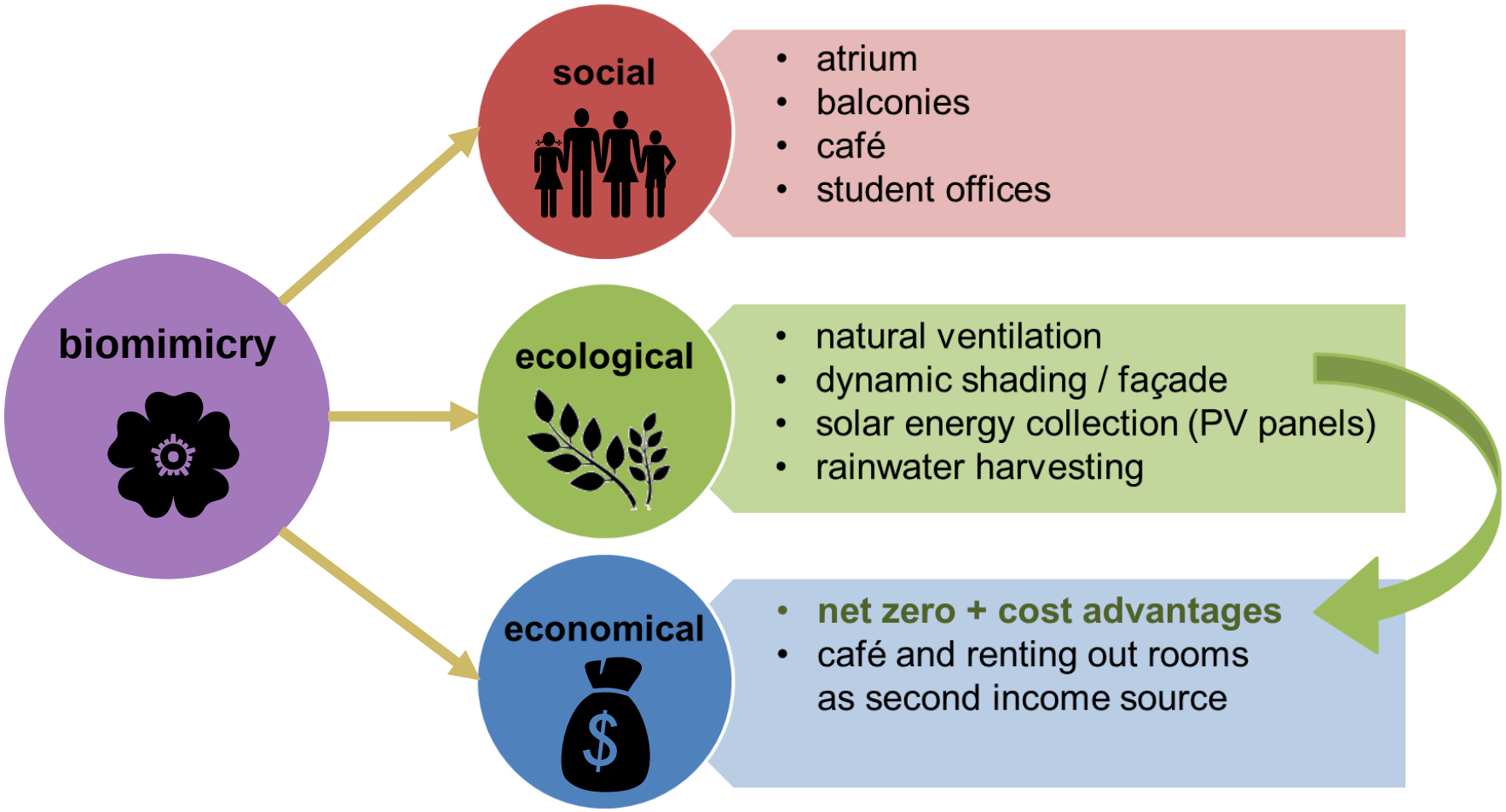
Structural Model 3D



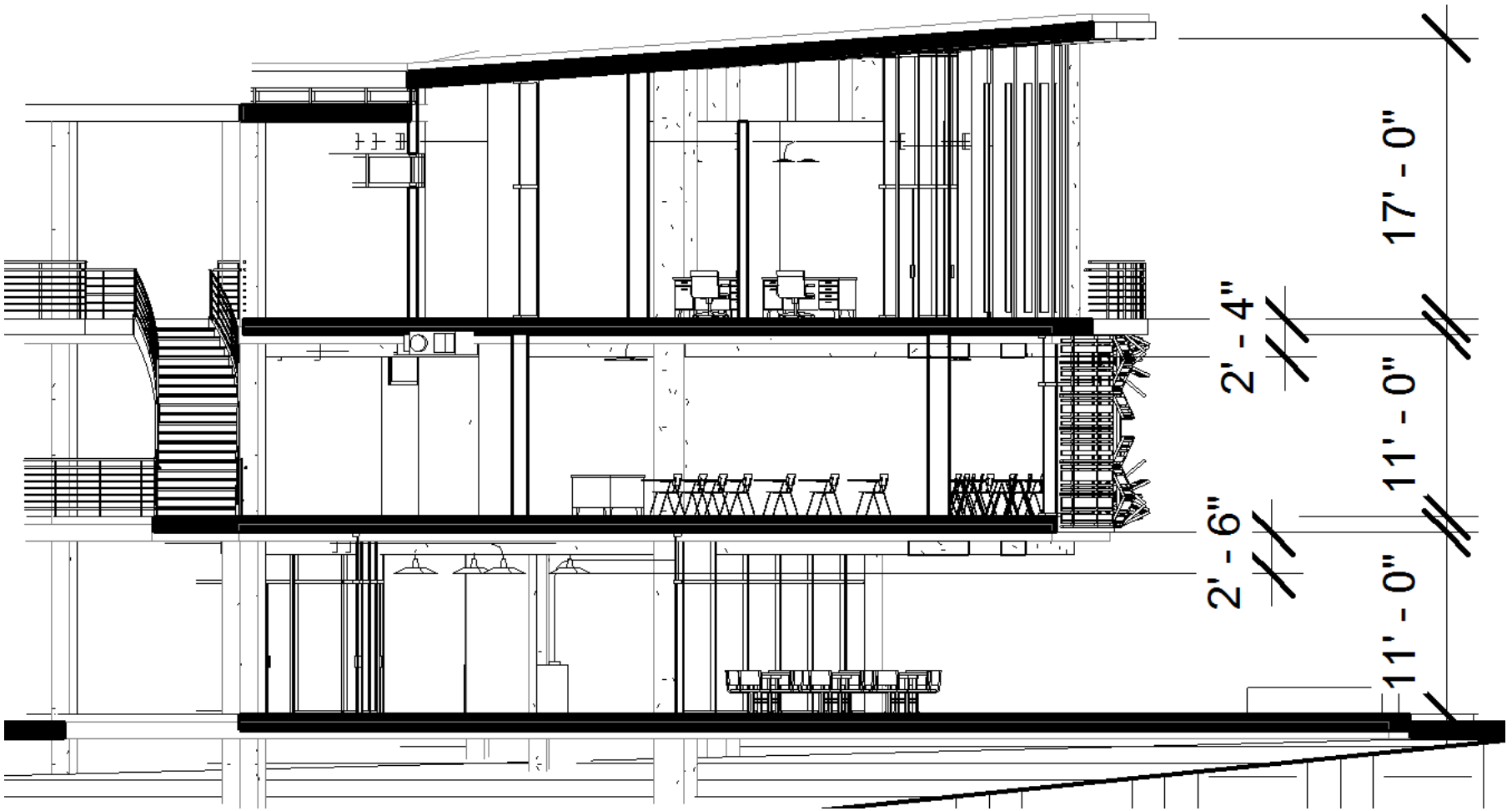
MEP Model 3D



Challenges


biomimicry
social
• atrium
• balconies
• café
• student offices
ecological
• natural ventilation
• dynamic shading / façade
• solar energy collection (PV panels)
• rainwater harvesting
economical
• net zero + cost advantages
• café and renting out rooms as second income source

Floor Sandwich / Ventilation

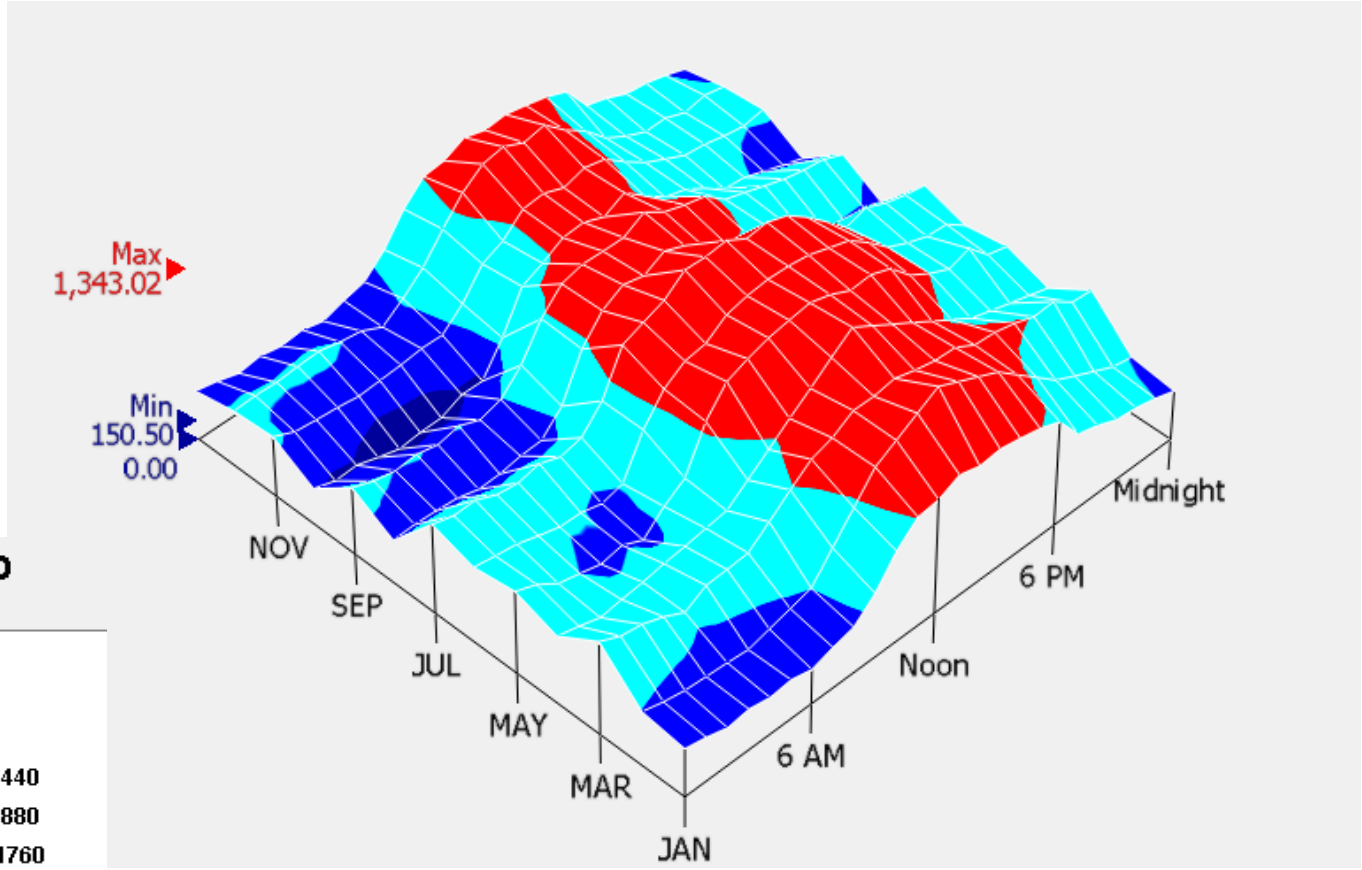


Wind Availability

- Sea breezes from east across site
  - Naturally cooler than stagnant air
  - Westward side receives some wind exposure
- Average wind speed:700 fpm
  - Typically varies between 150 and 1600 fpm
- Wind speed highest in afternoon when hottest

Wind Speeds

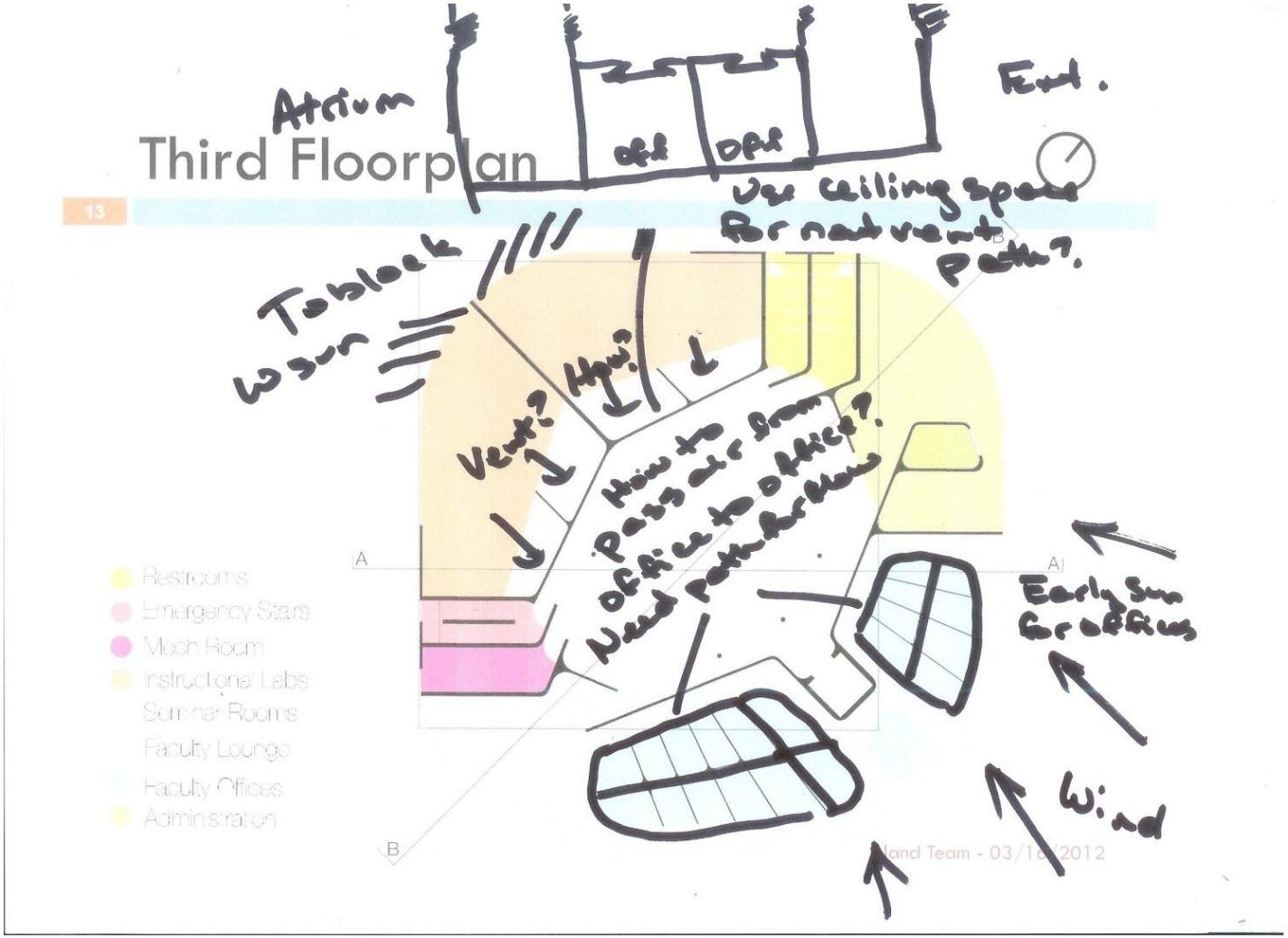
- Wind Speeds (fpm)



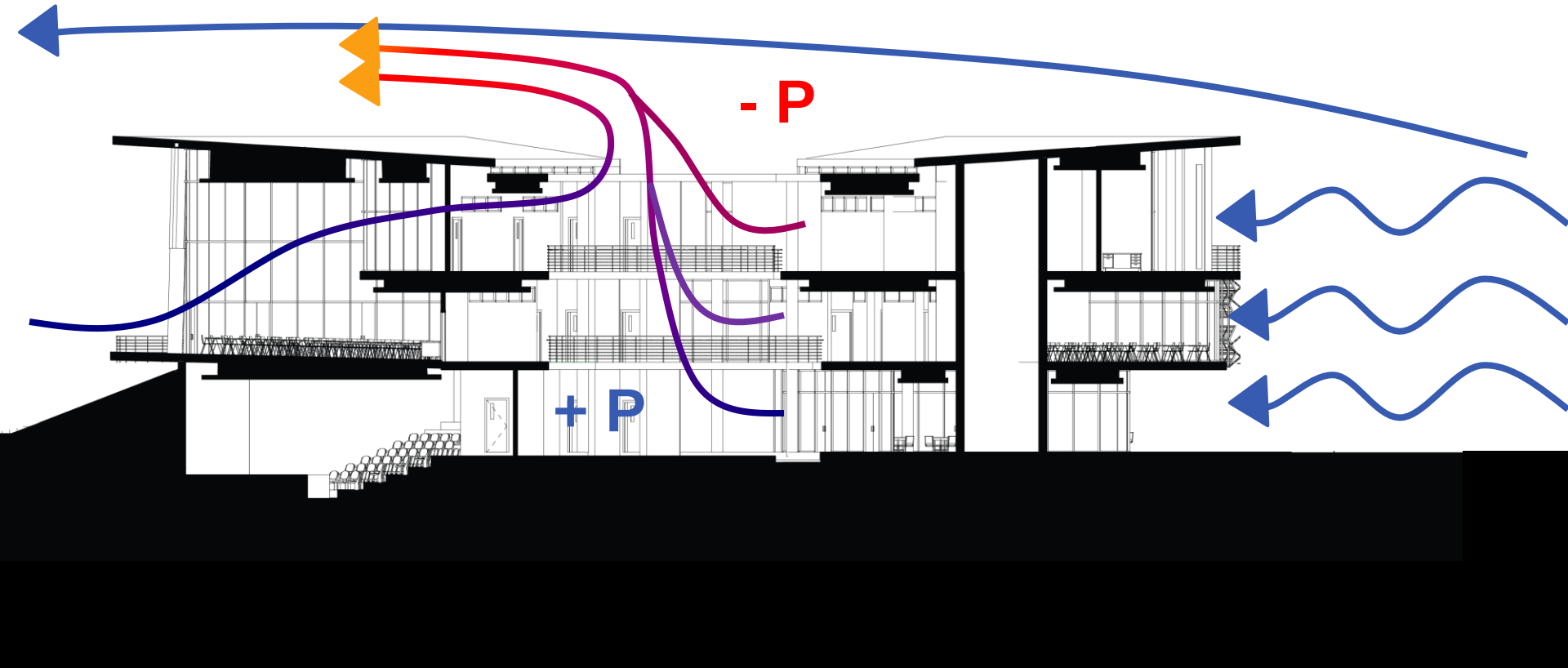
Natural Ventilation Strategy

- Size for no more than 3F rise across room
  - 300 fpm in most spaces
  - Achievable most hours of year
- Maximum 700 fpm for ventilation in rooms
  - Achievable many hours of year
  - Less than 1 F rise
- Strategies:
  - Operable windows and grilles on both sides of room of at least 5% of floor area
  - Interior return fans to draw air inward

Review with Mentors



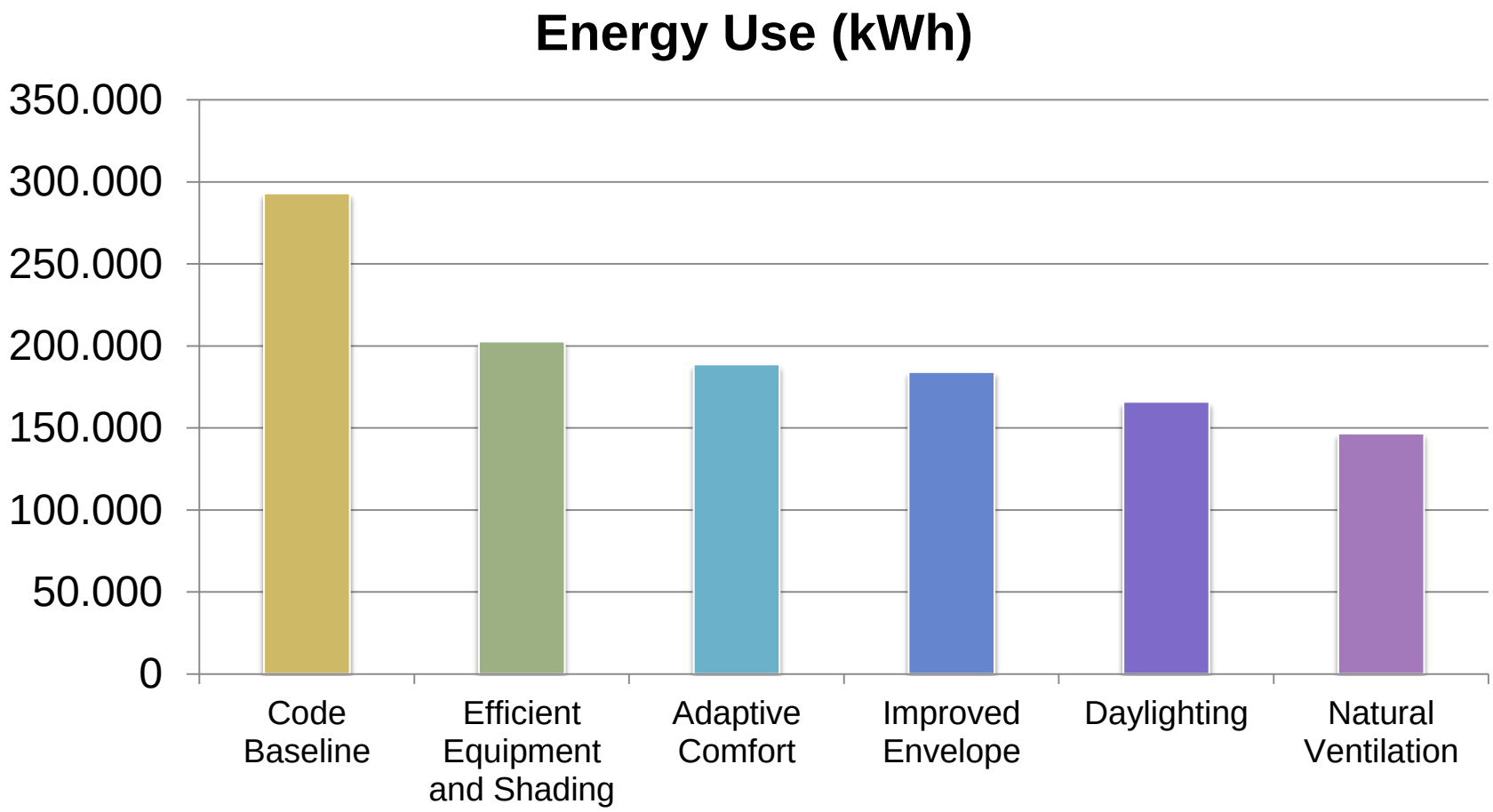
Natural Ventilation



Strategy to Achieve Net Zero

1. Baseline building according to IMC
2. Window shading and efficient fans
3. Setpoint to upper limit of ASHRAE standard
4. Improved insulation and windows
5. Photosensors for daylighting
6. Switch to adaptive comfort with natural ventilation

Energy Saving Strategies

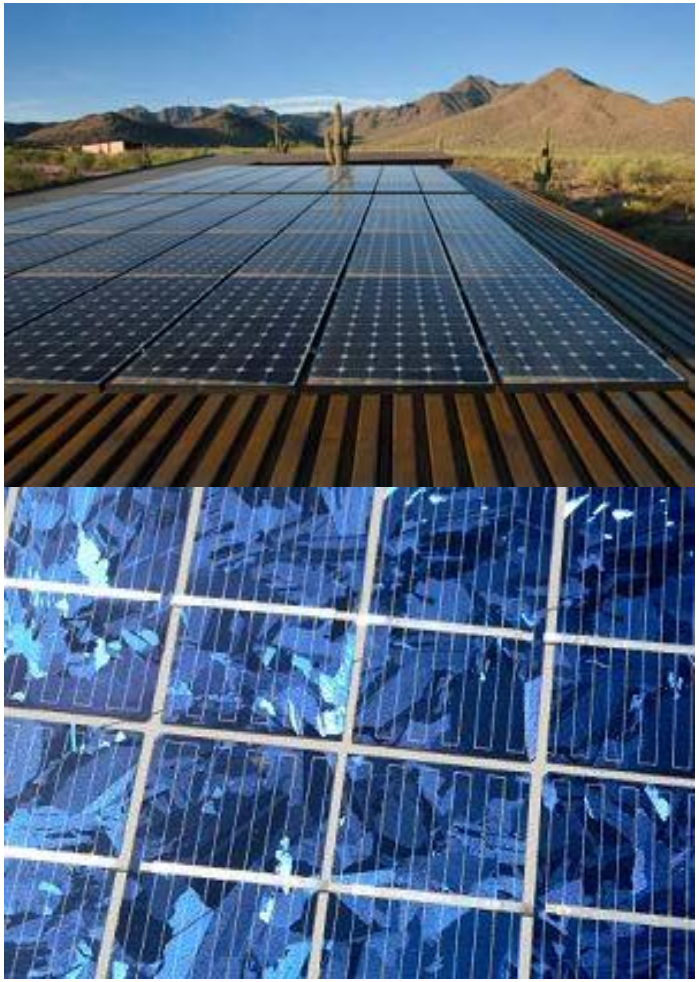


eQuest Results

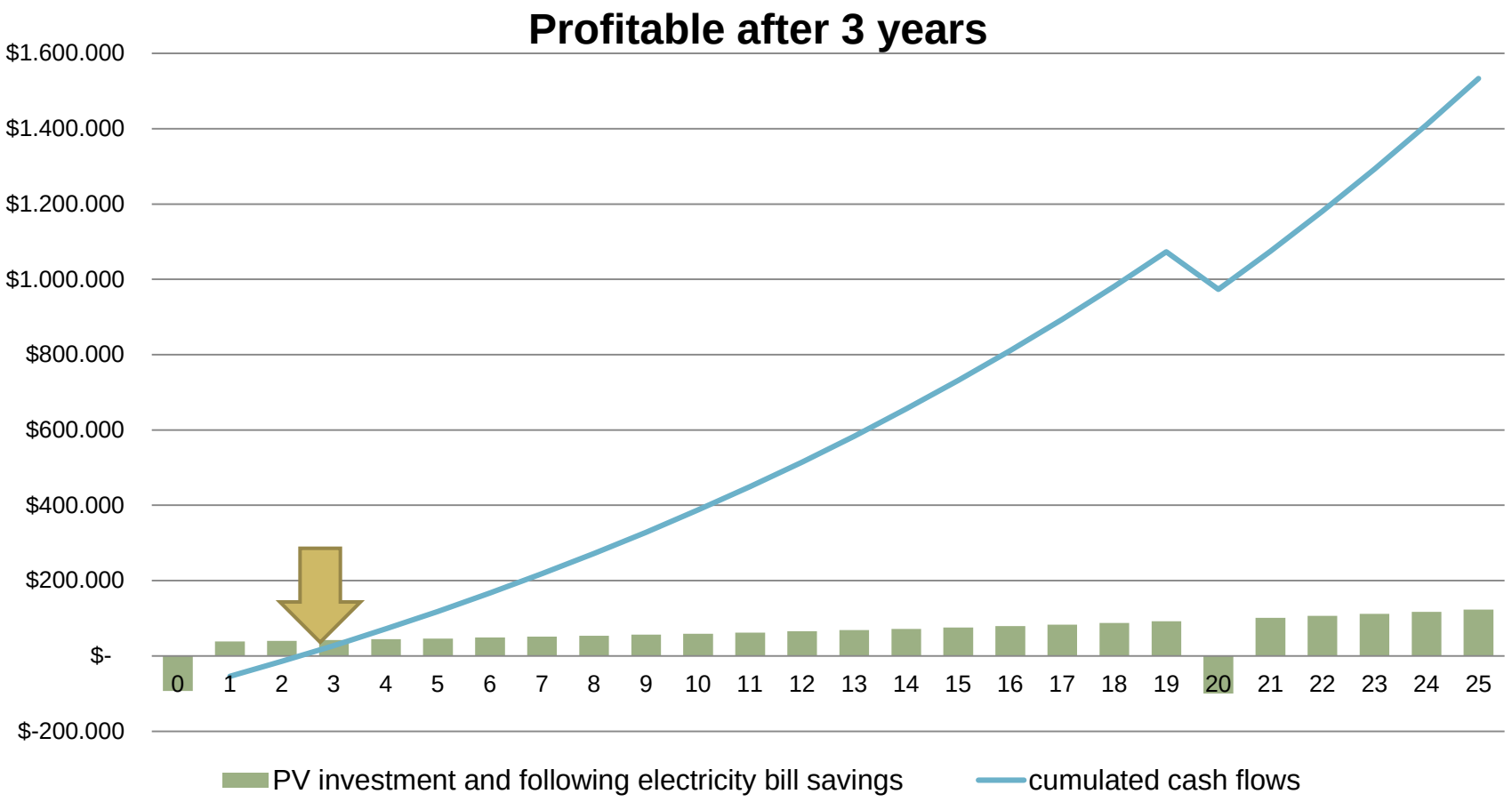
- 146,610 kWh on-site energy per year
  - Design temperature of 83F (limit of acceptability with adaptive comfort standard)
  - 184,400 kWh at design temp. of 76F (ASHRAE)
- 44 tons maximum cooling load
  - Occurs on October 19, 4 pm
  - Reduced from 60 tons with change in setpoint
- 49% percent reduction from baseline

PV Panels

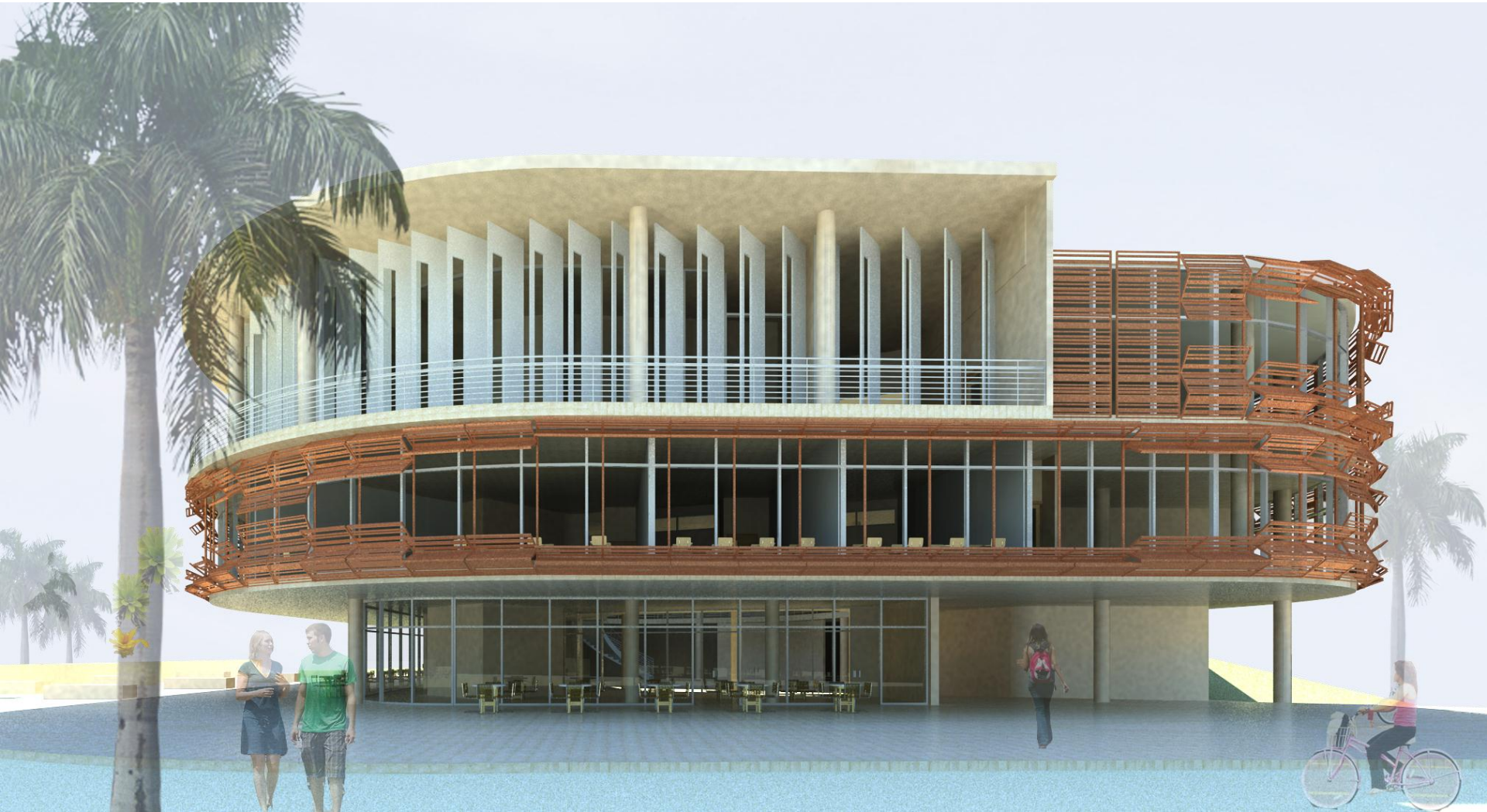
- Polycrystalline silicon PV panels
- Most common, less expensive
- Not tilted to be more resistant during hurricanes
- Energy gained: 194,293 kWh/year
- Energy needed: 184,840 kWh/year
- Investment costs: $ 92,600



Trade-off PV Panels



Dynamic Façade



Façade Override

Enclosed Façade

Façade Material



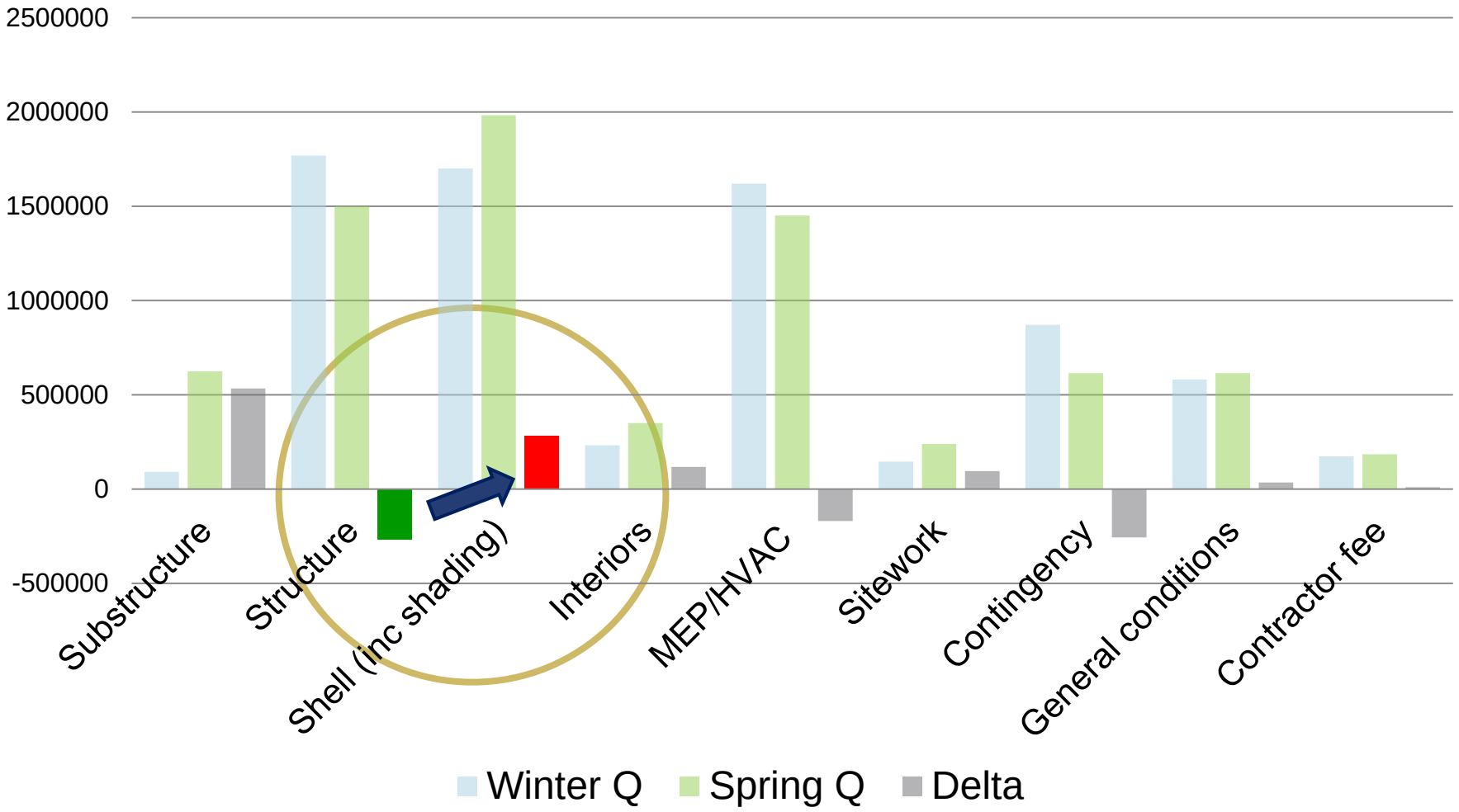
- corten steel
  - high strength
  - weather resistance
  - strong enough to protect windows
  - nice appearance

http://www.dezeen.com/2011/01/25/the-wyckoff-exchange-by-andre-kikoski-architect/

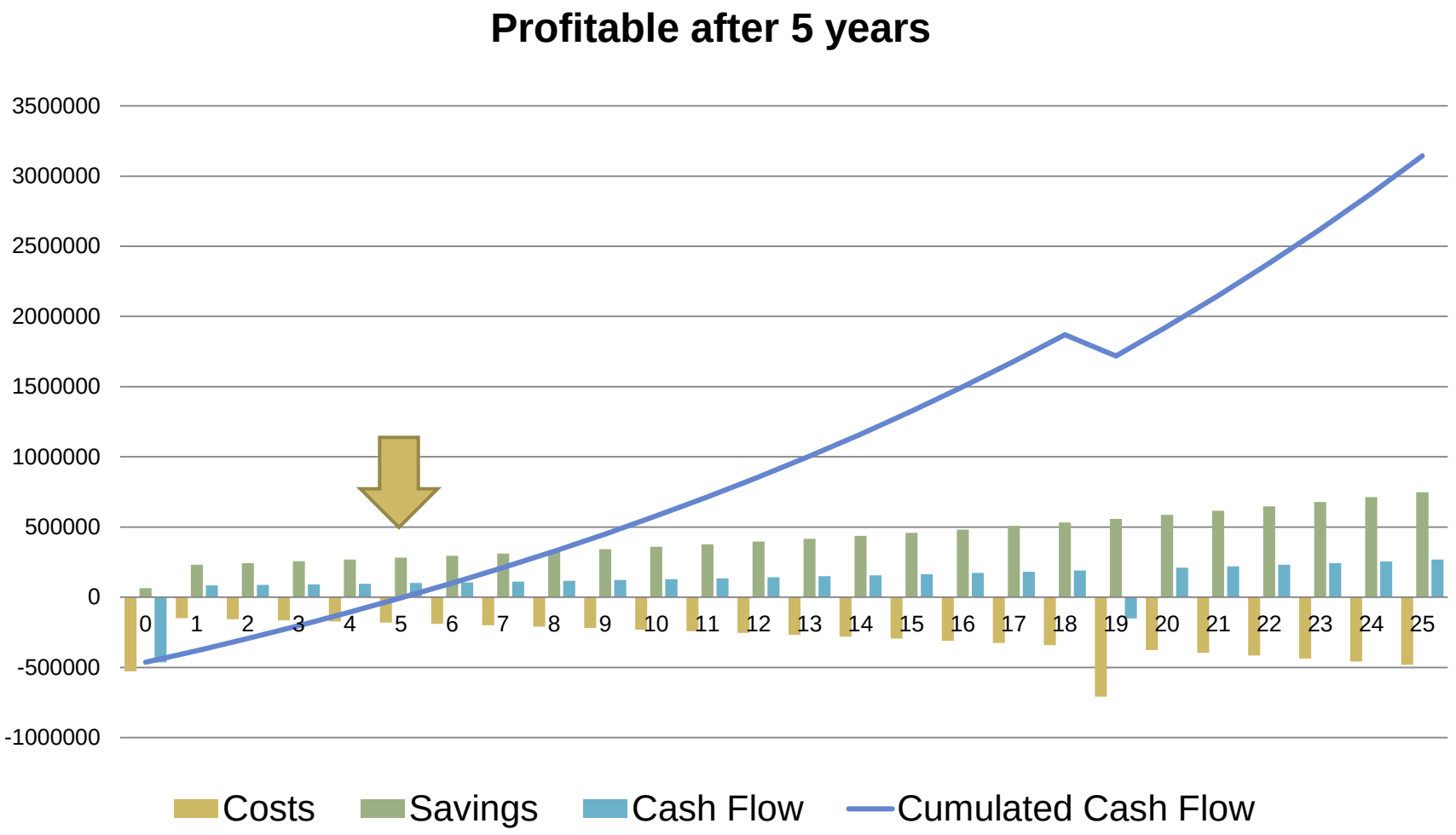
Strengths & Weaknesses Façade

	Strengths	Weaknesses
Quantitative	• Saves energy costs • Smaller HVAC system possible • Protects glass windows in hurricanes • Lower cleaning costs for windows	• Construction costs • Operation costs • Maintenance and regular replacement costs for motors • Hurricane risk buffer
Qualitative	• Aesthetical beauty • Perfect shading • Advances natural ventilation • Local / biomimicry solution • Material perfect for humid and rainy climate	• Motors and sensors quite sensitive

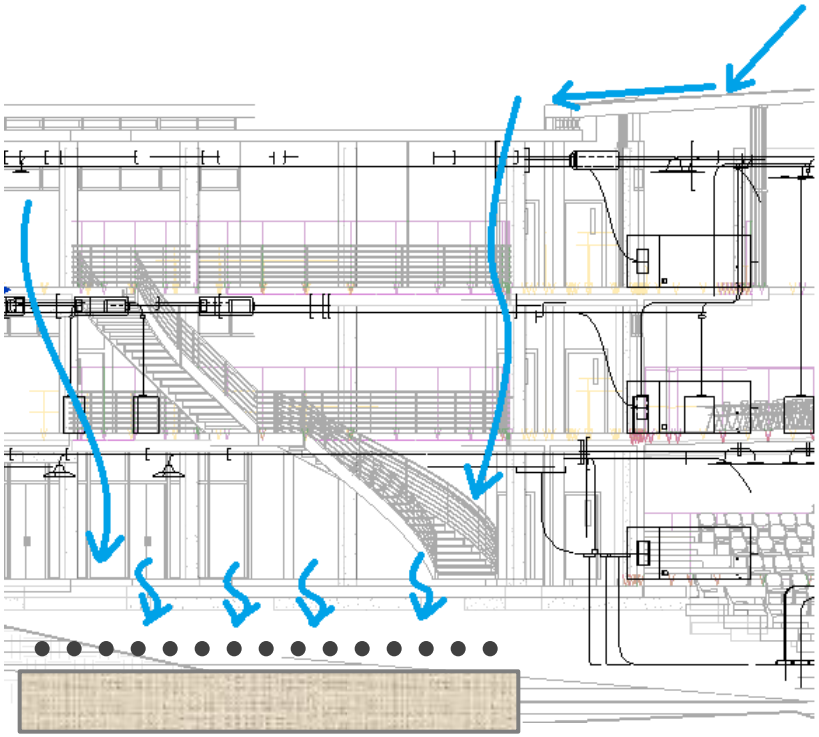
Façade Financing Possibility



Trade-off Façade



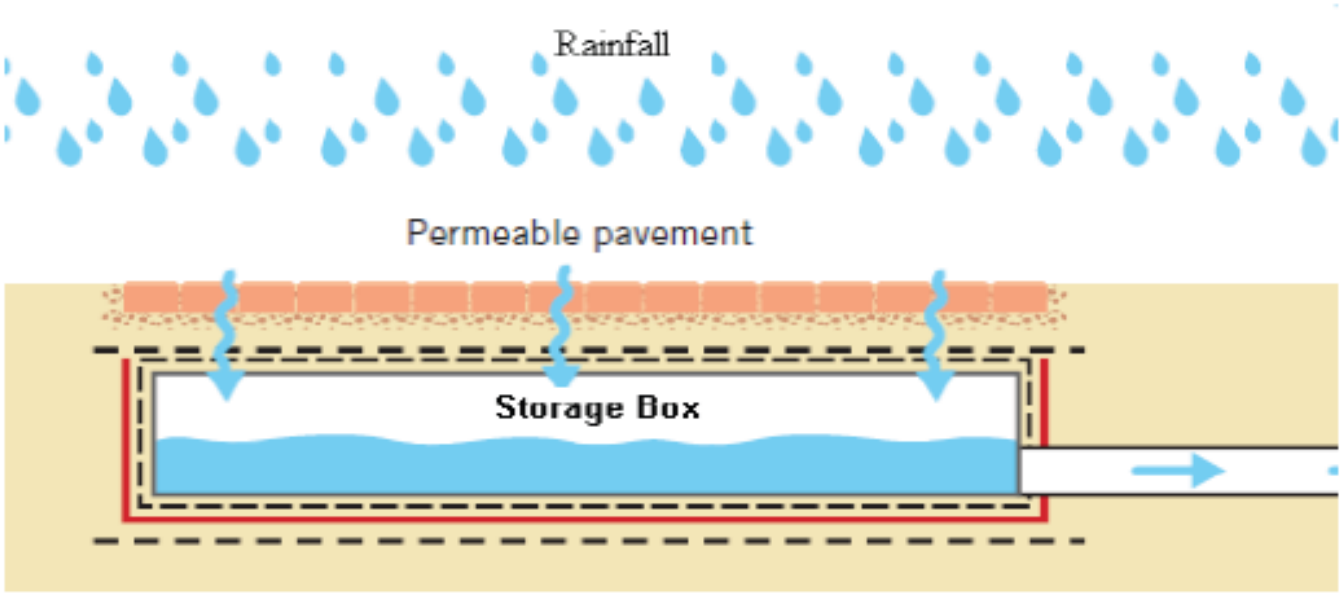
Rainwater Harvesting



10,000 gallon tank fed by permeable PVC pipe

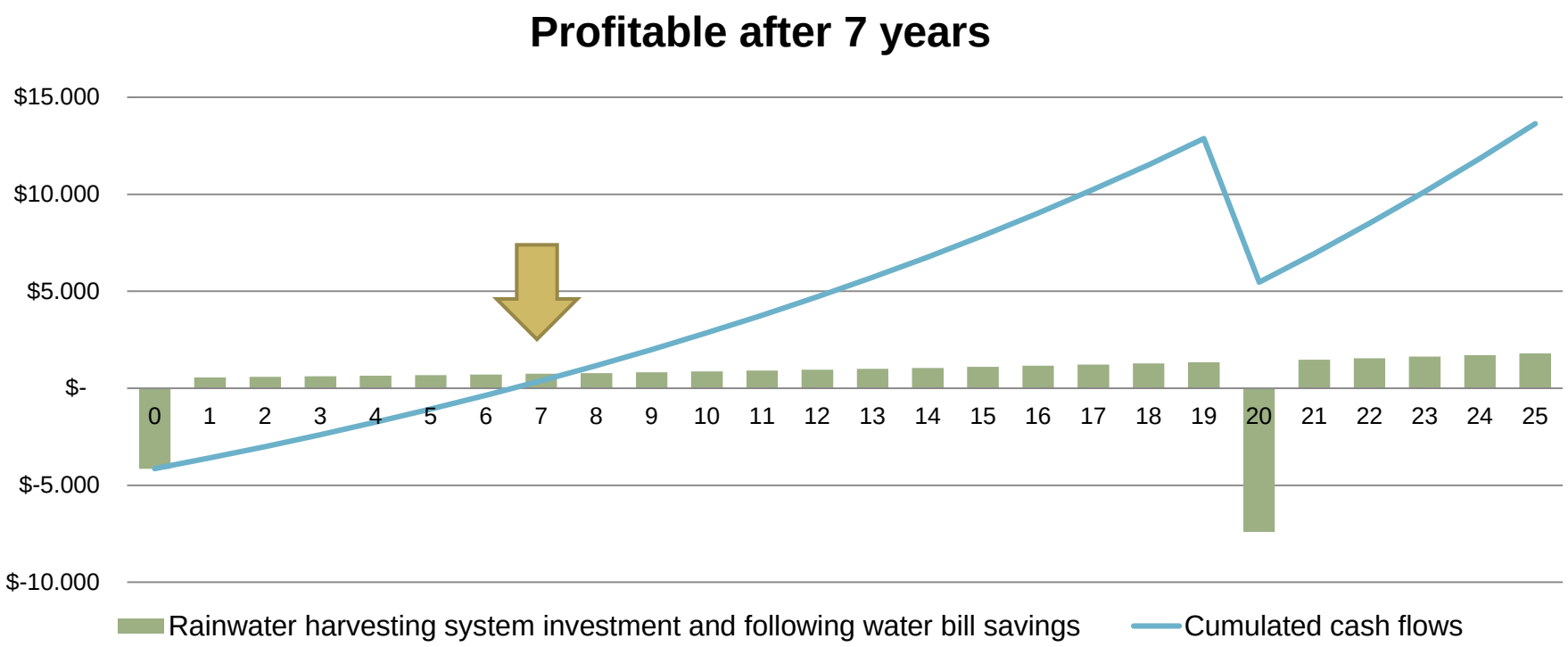
Rainwater Harvesting

- Can harvest 80,000 gallons/year
- Non-potable use: 73,800 gallons/year
- Conclusion: rainwater harvesting beneficial

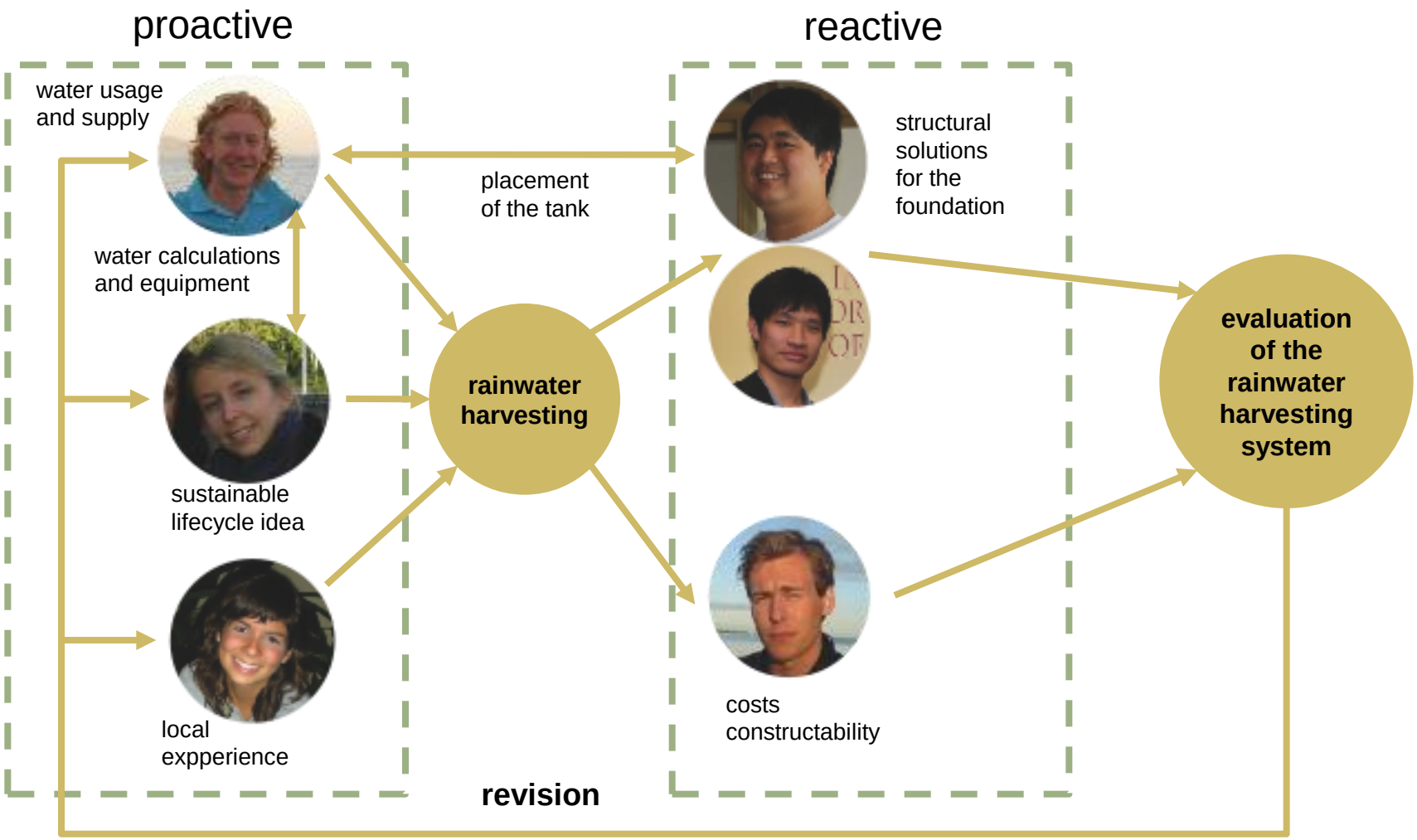


Trade-off rainwater harvesting

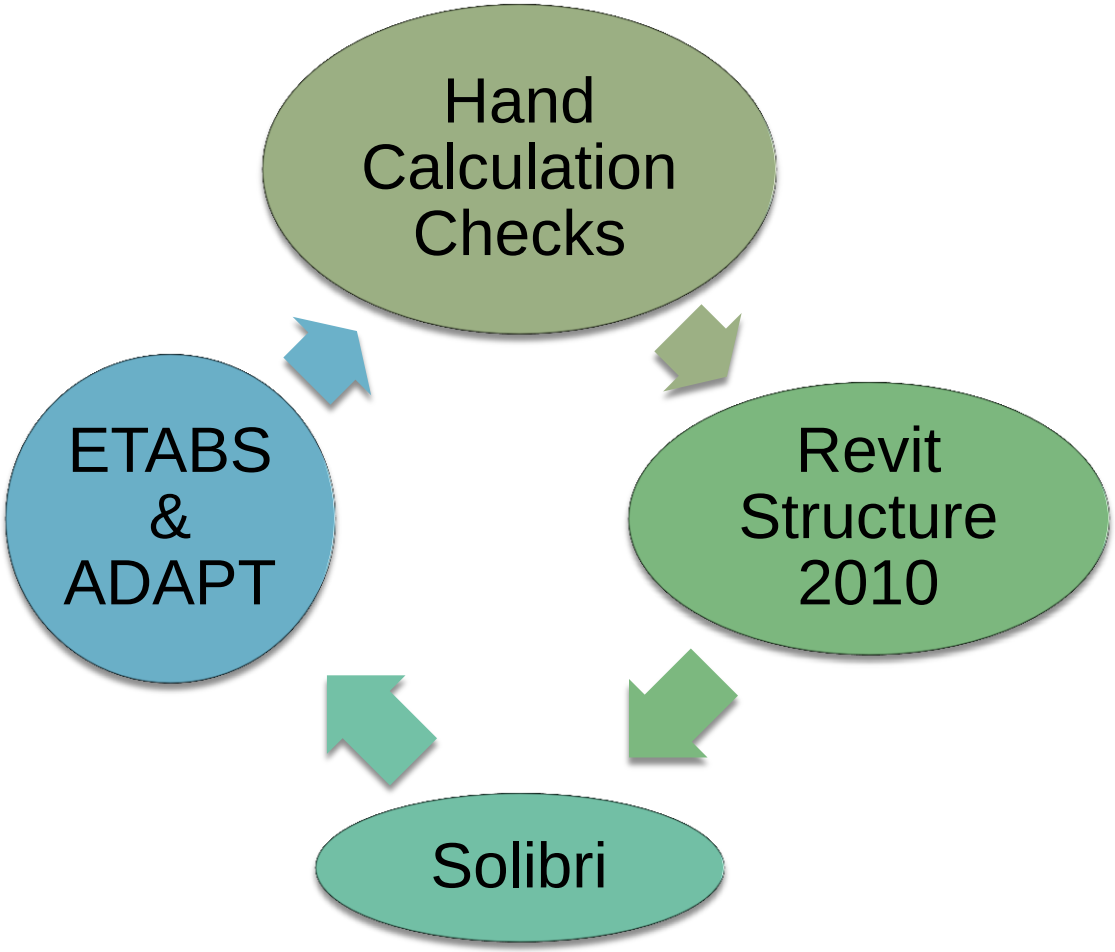
- Rainwater gained: 80,000 gal/year
- Non-potable water needed: 73,800 gal/year
- Potable water needed in addition: 66,960 gal/year
- Investment costs: $ 4,150



Development Organization & Process



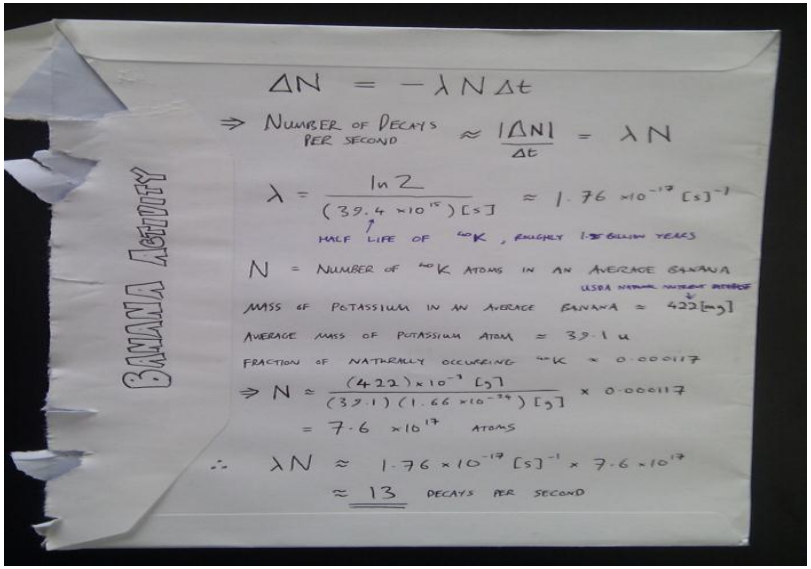
Structural Analysis Process



Hand Calculations

Back of Envelope Calculation

- Used for initial and major changes in the product

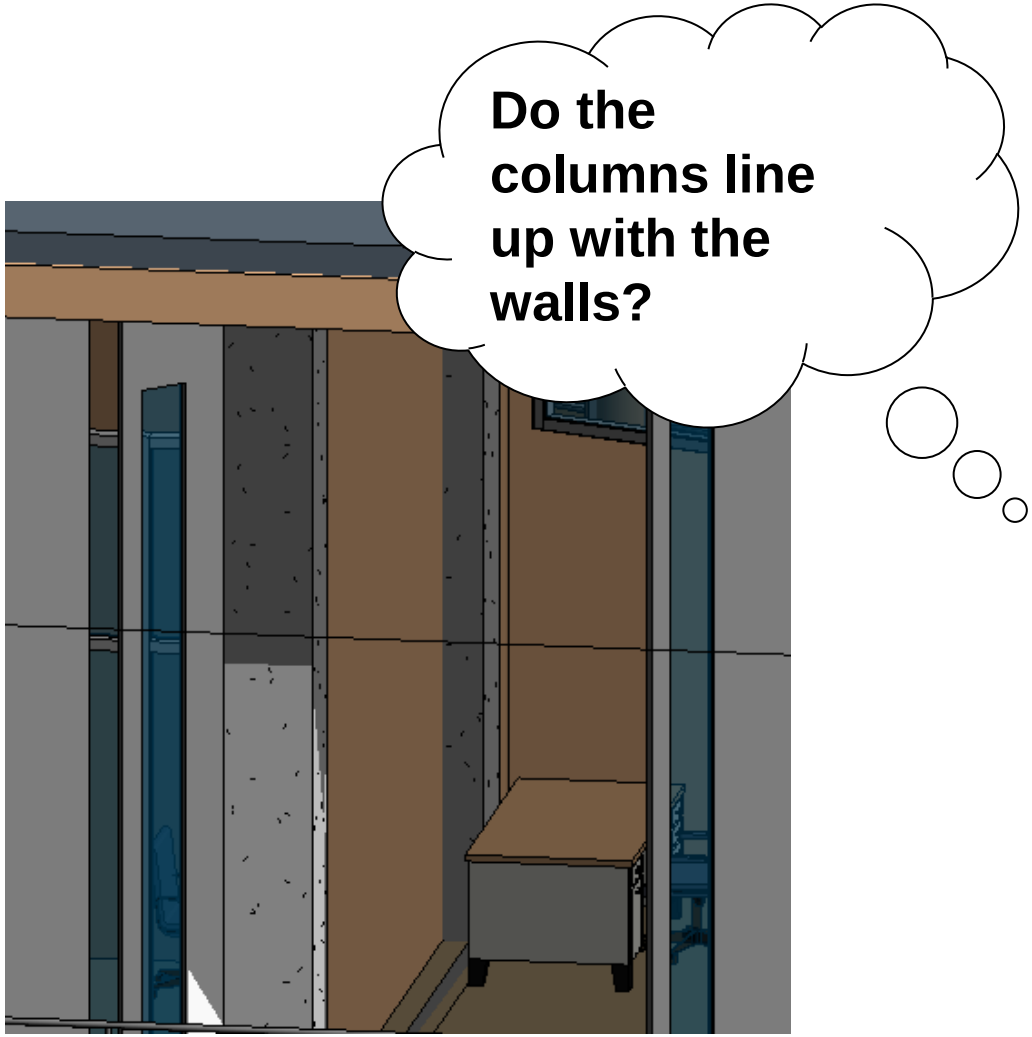


What is a reasonable size to get the process to start with?

What sizes should the team expect to allow them to move forward with their processes?

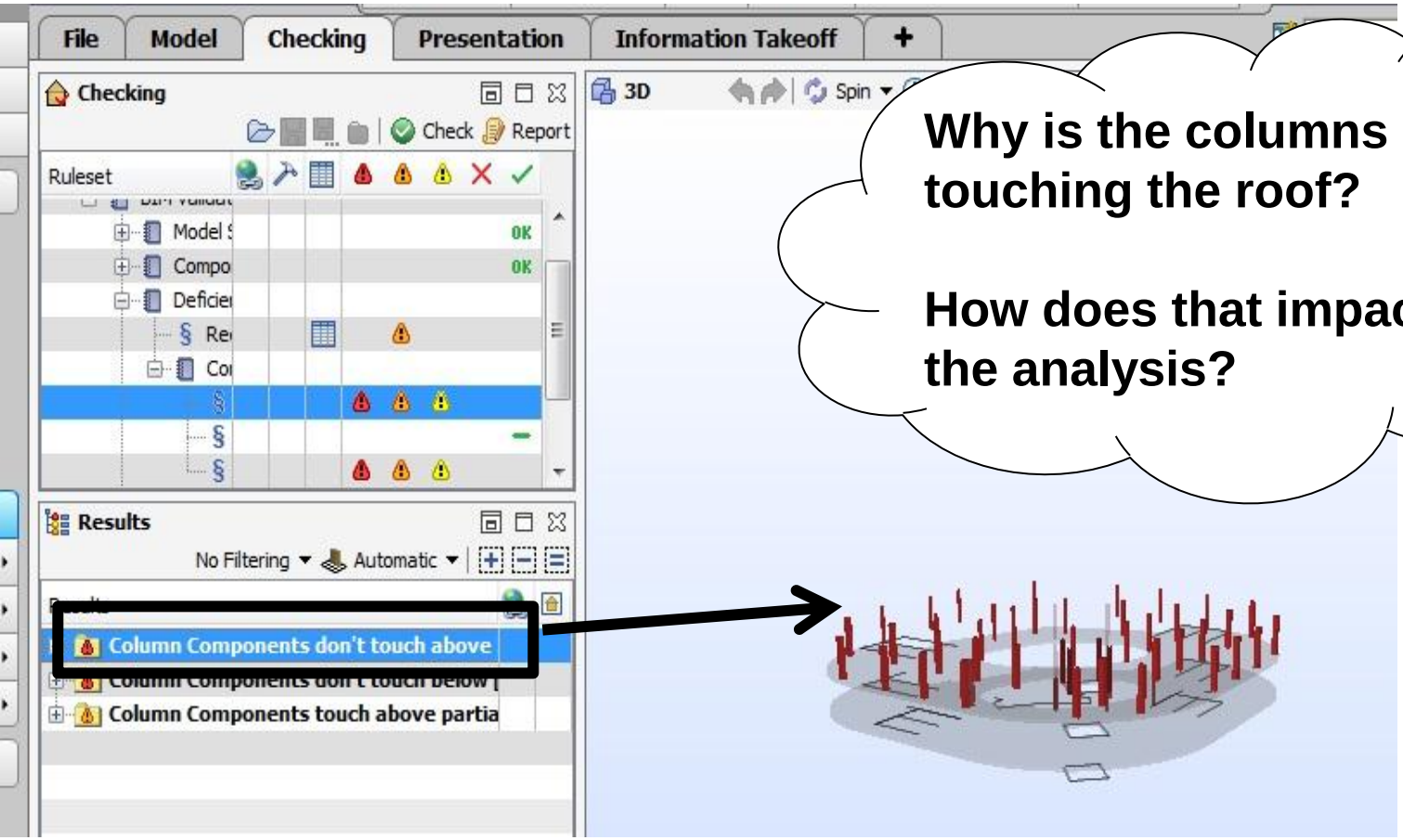
Revit Structure 2010

- Integration with Architecture and MEP
- Used for clash detections
- Enables visual communication on the product



Solibri

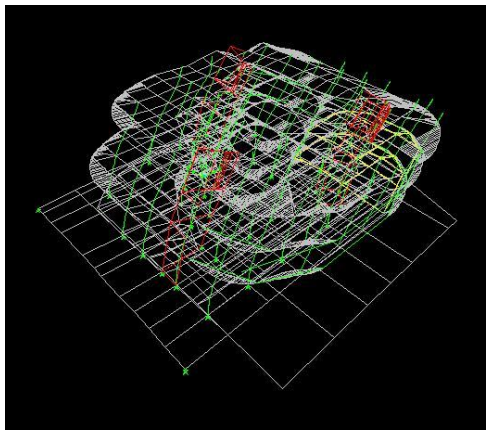
BIM Validation checks the BIM for completion.

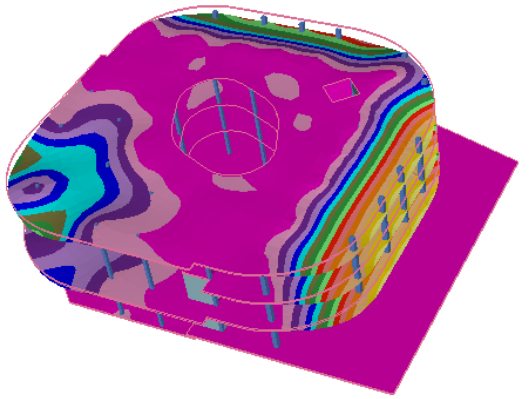


ETABS/ADAPT

- Structural Analysis Modeling Program
- Used to analyze:
  - Gravity Loading
    - IBC 2009 Design Combination
    - Post tensioned Concrete Tendons
  - Lateral Loading

What does the software tell us?



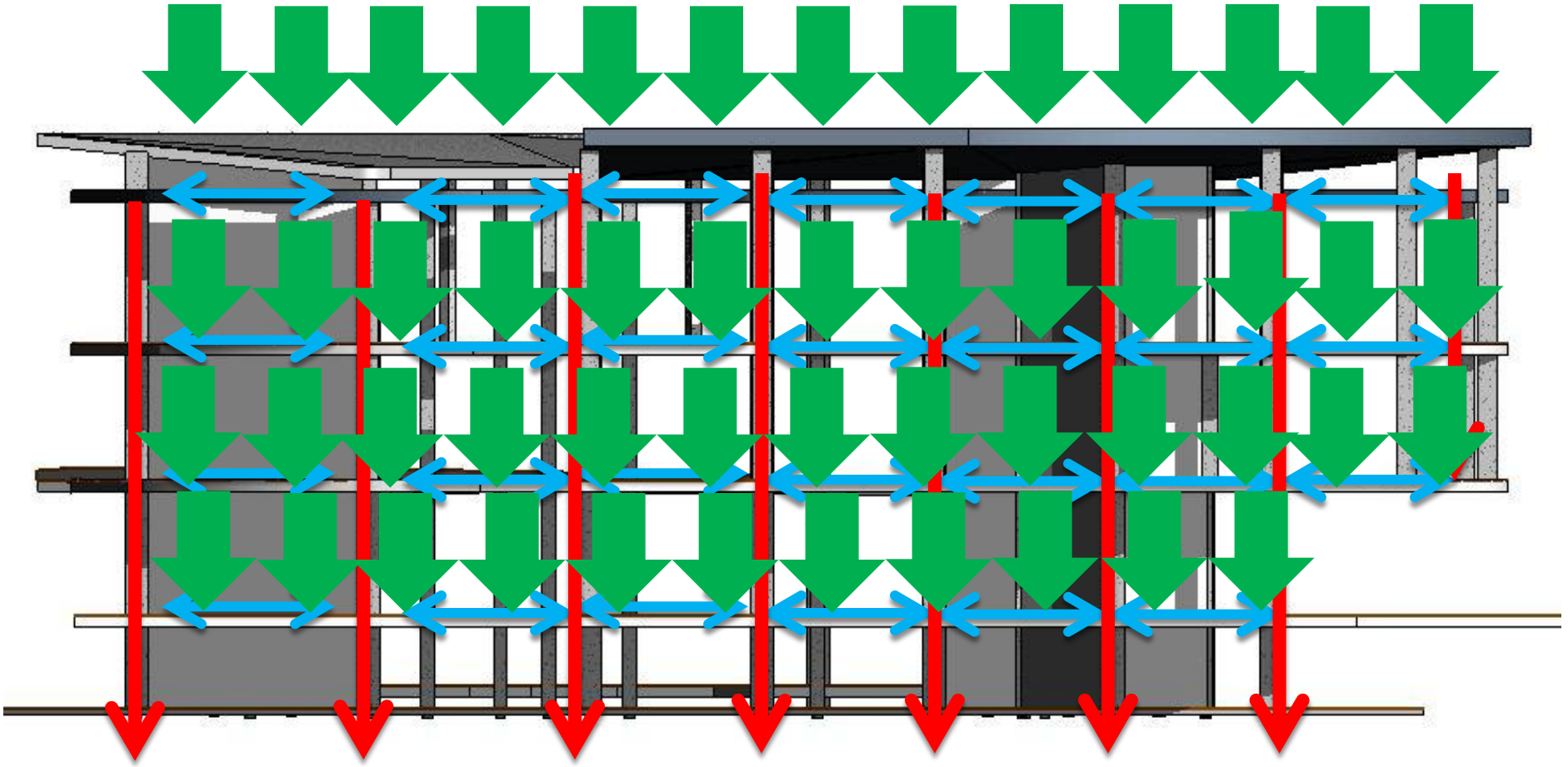


Hand Calculation

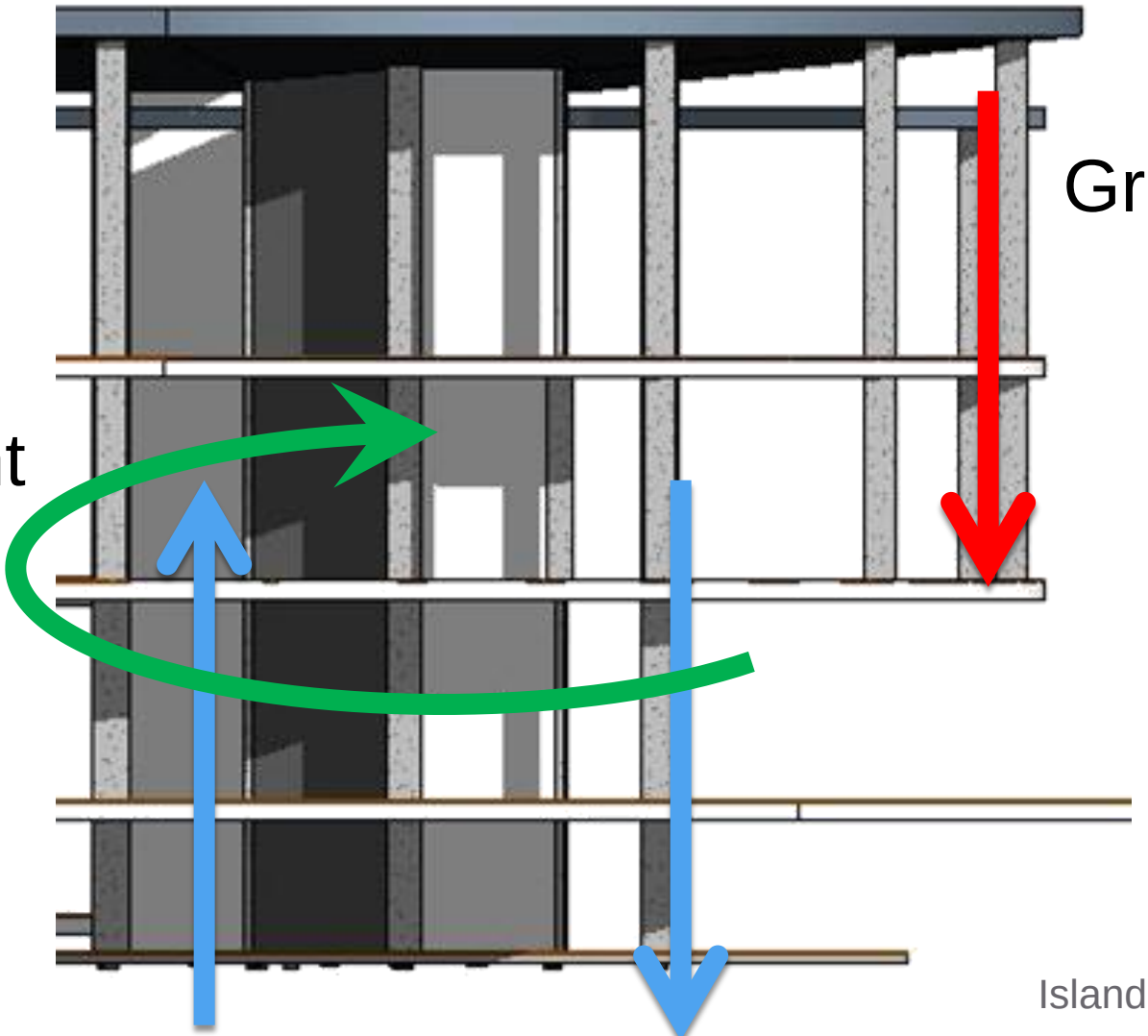
Spot Checking

- Validates the process
- Ensures that the whole “Garbage In, Garbage Out” syndrome did not happen.

Gravity Load Path

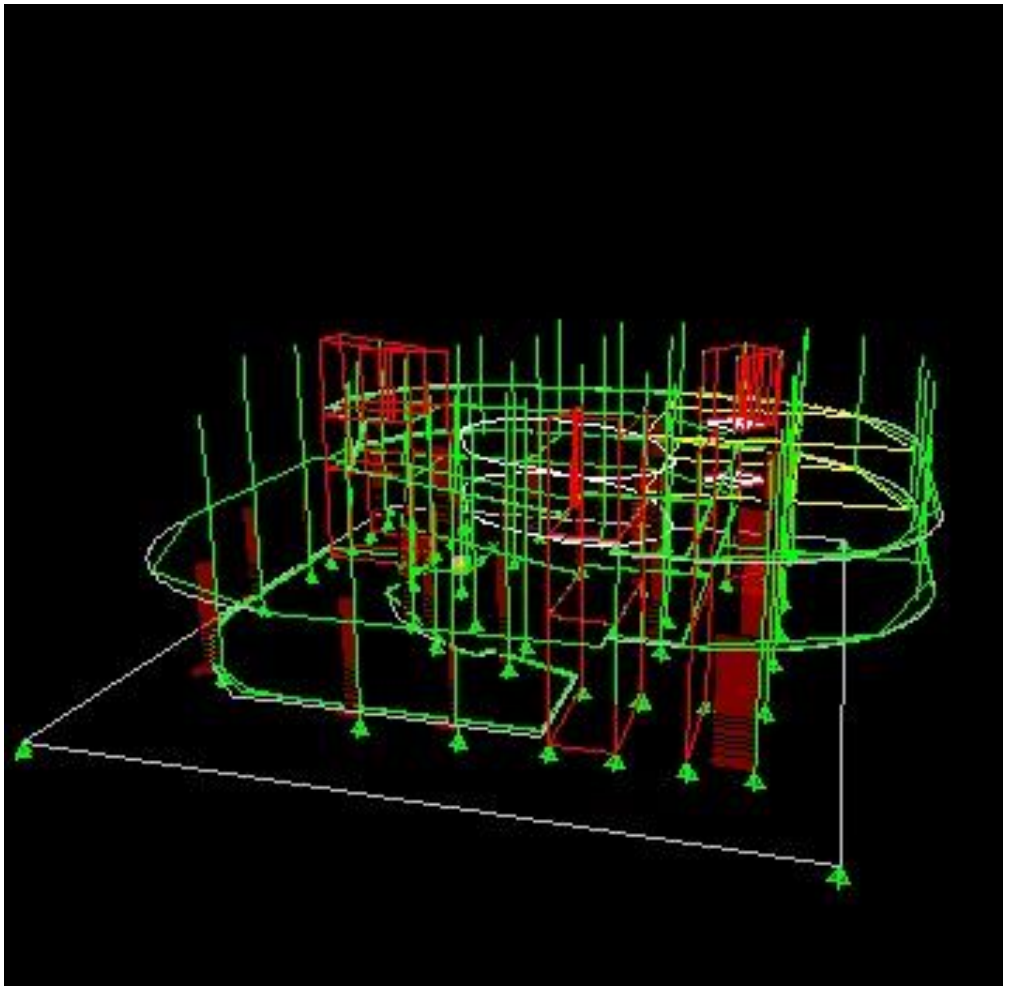


Gravity Load Path



ETABS Analysis

- ETABS Animation!



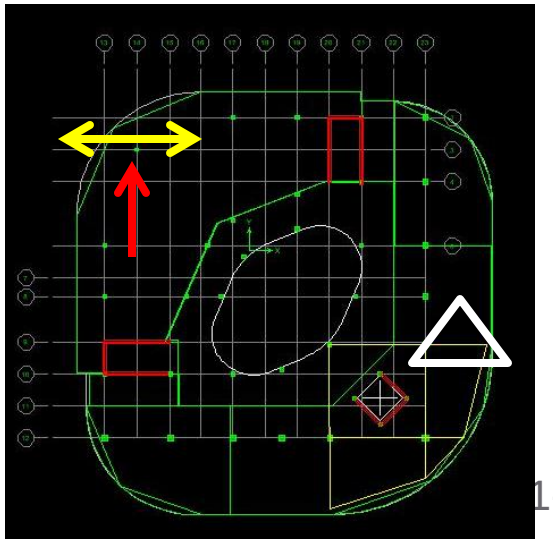
ETABS Data

Input Loading Data

Load Type	Floor	Values
Dead Load	Typical Floor	120 psf
	Roof	80psf
Live Load	Typical Floor	60 psf
	Roof	30psf
Wind Load	Typical Floor	43 kips
	Roof	25 kips
Seismic	Base Shear	765 kips

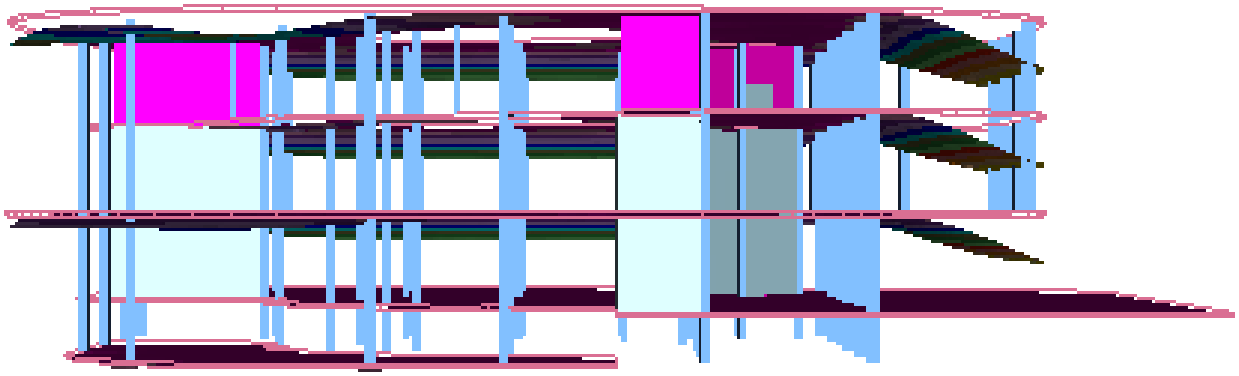
Data Result

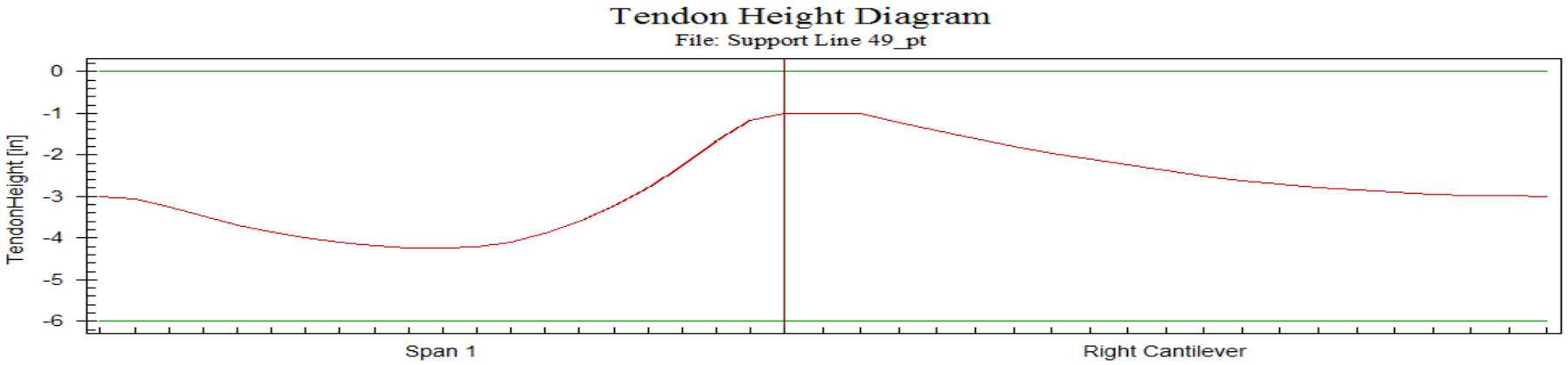
Maximum Beam Deflection	1.27 in
Axial Force @ Column C31	254 kips
Shear Force @ Column C31	330 kips



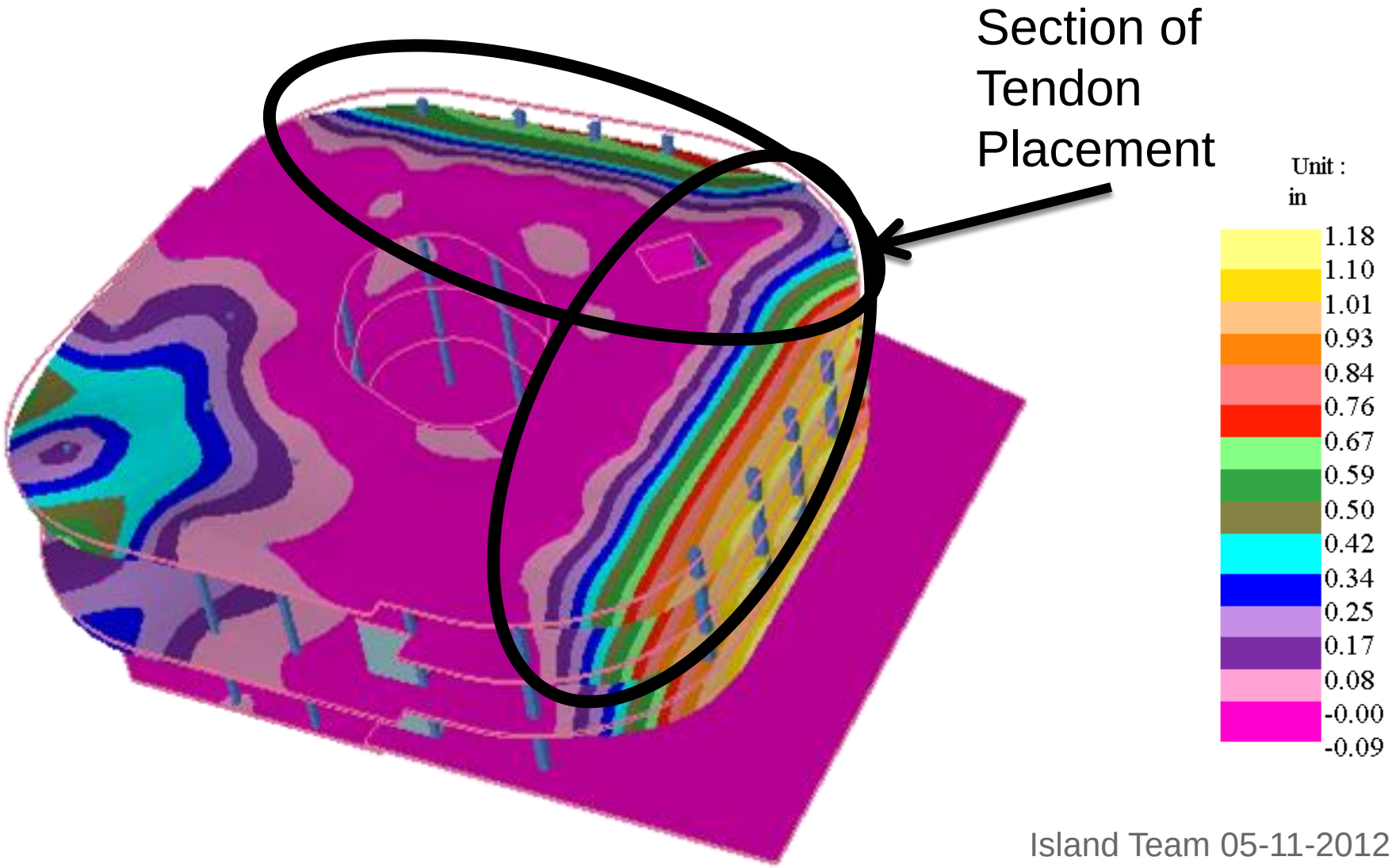
ADAPT Analysis

Max Deflection: 1.18”

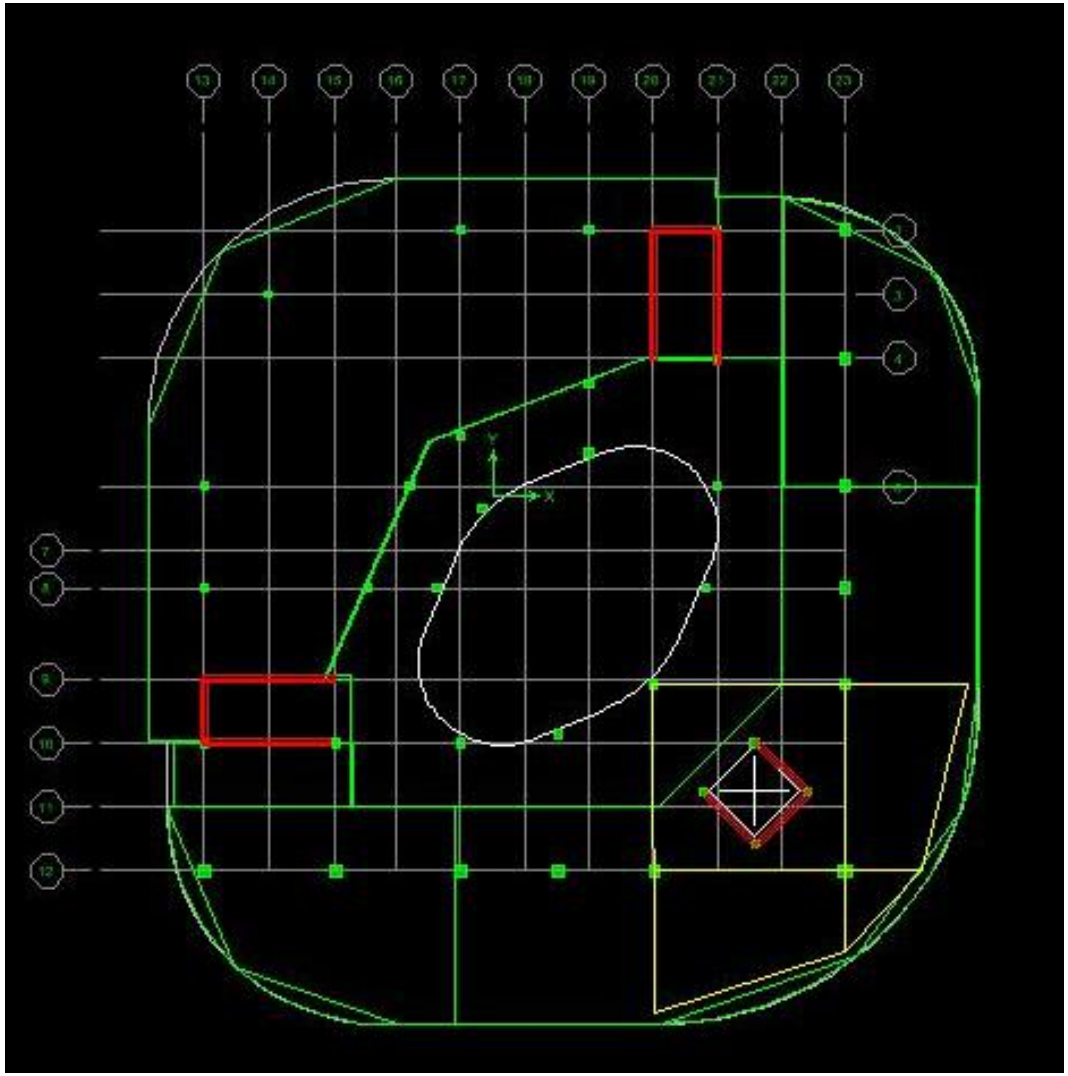




ADAPT Analysis



Lateral Resistance



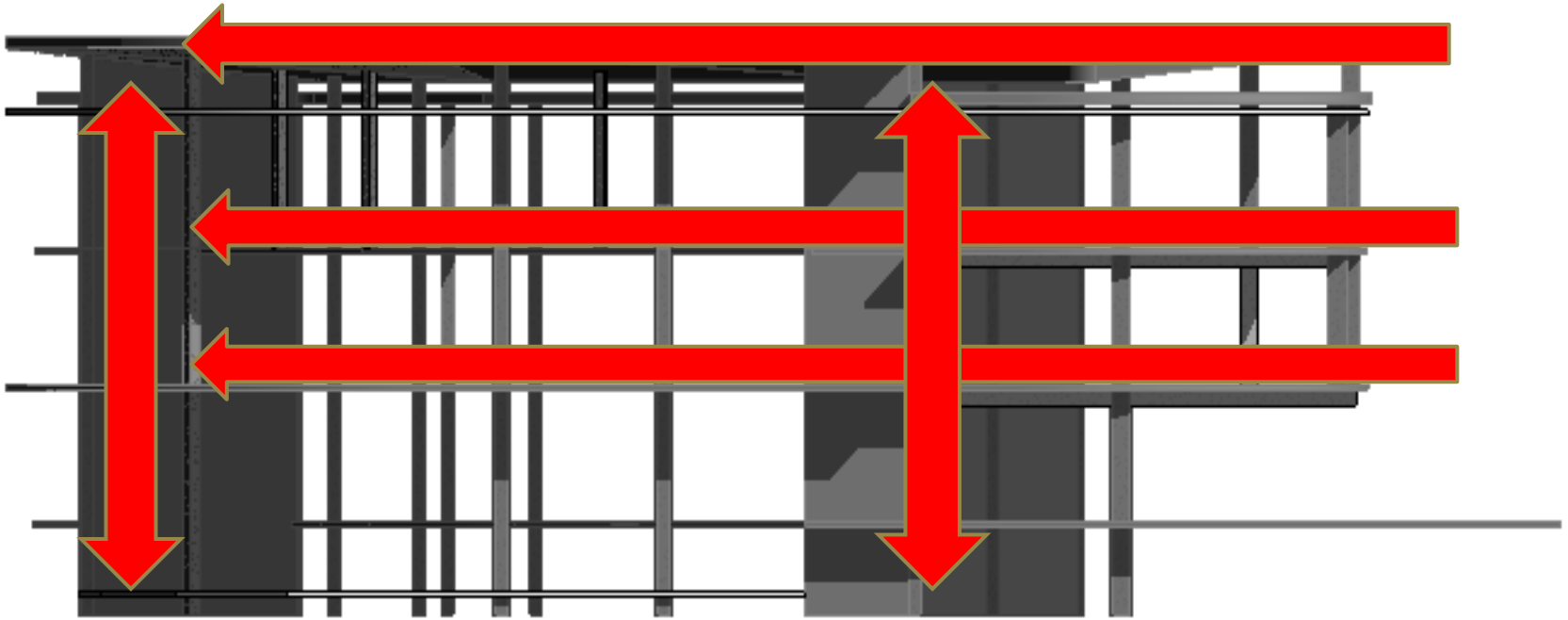
12” Shear Wall

Lateral Resistance

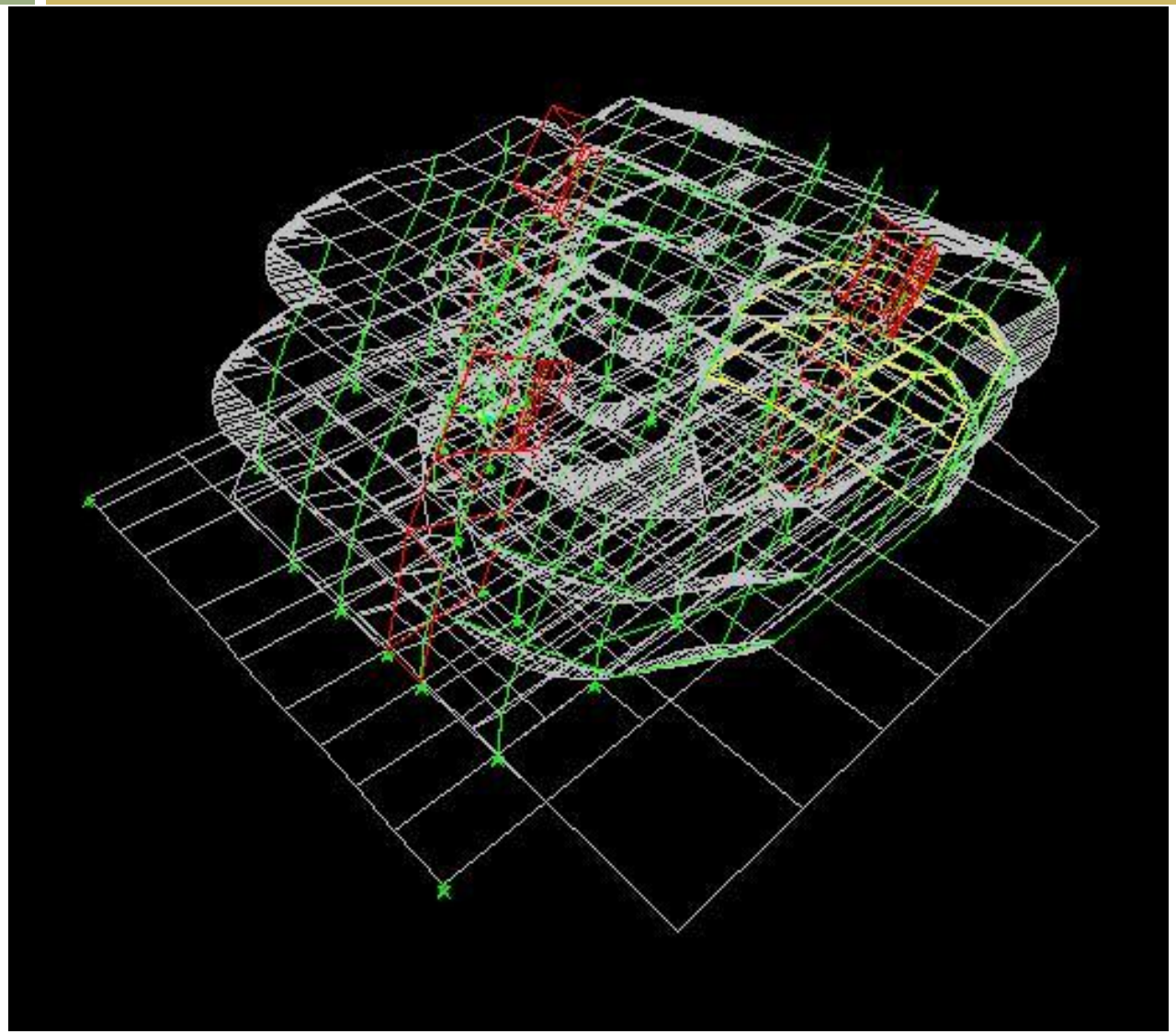
Criteria	Value
Site Condition	D
Ss	0.9
S1	0.31

Floor	Applied Load
Roof	192 k
3rd	383 k
2nd	192 k
Base	764 k

Lateral Load Path

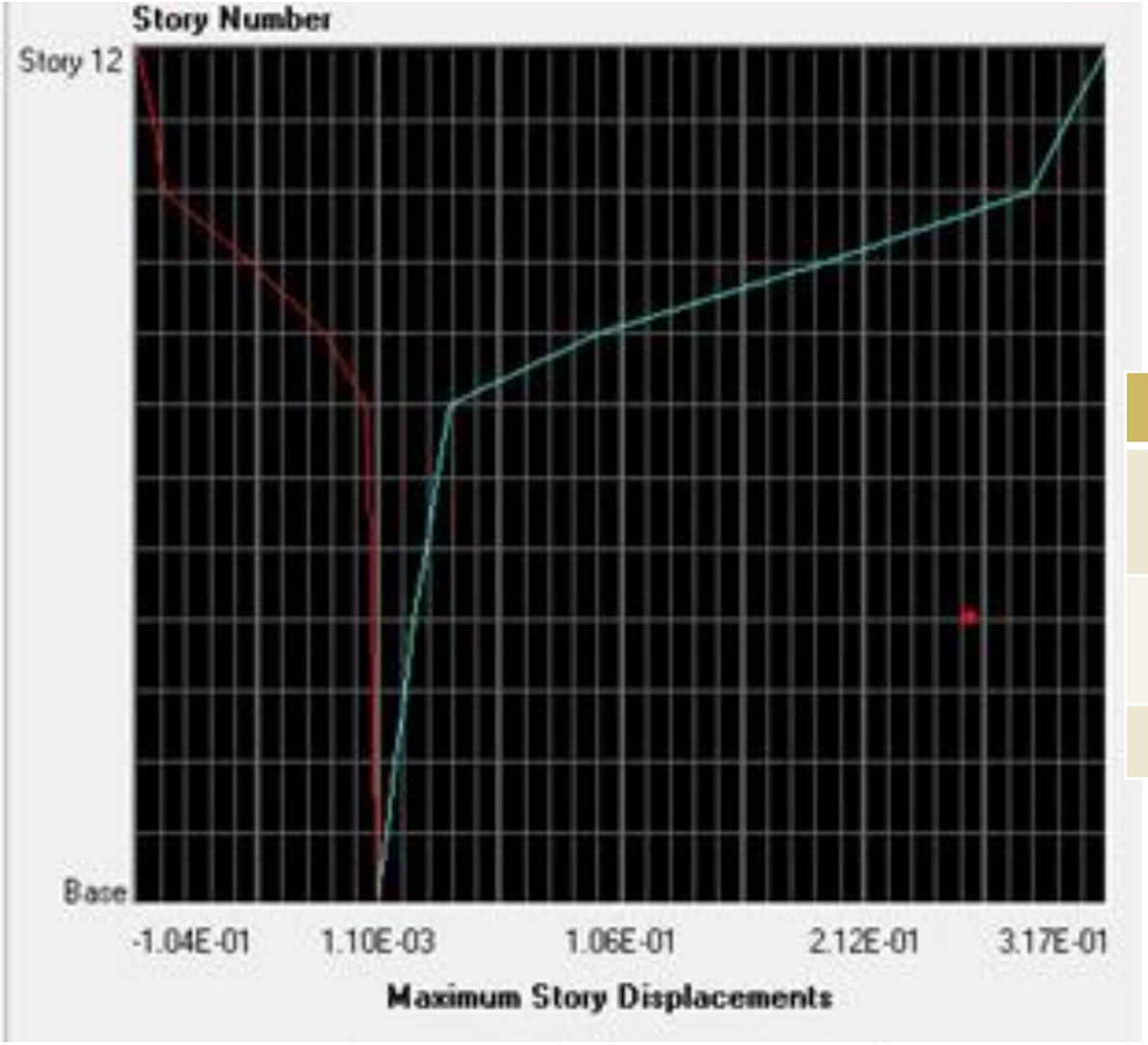


Lateral Analysis Results



Dominate Period: 0.358s

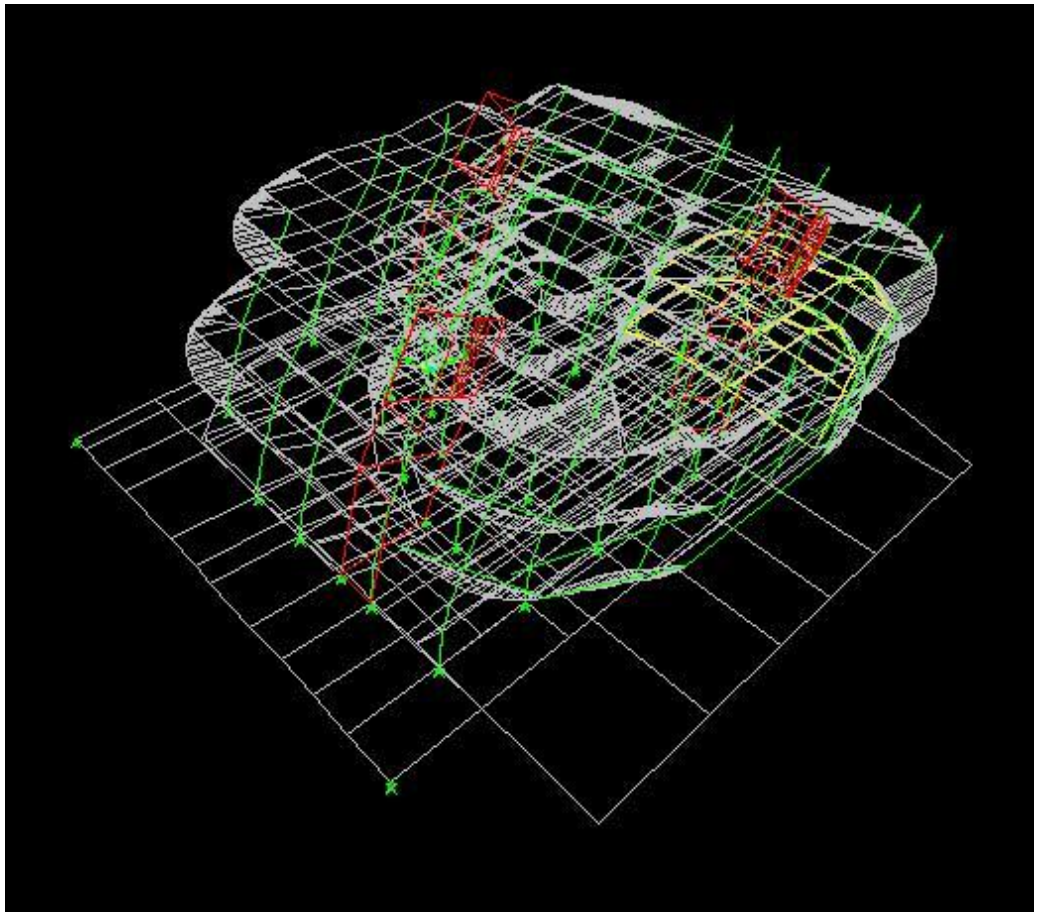
Lateral Analysis Results



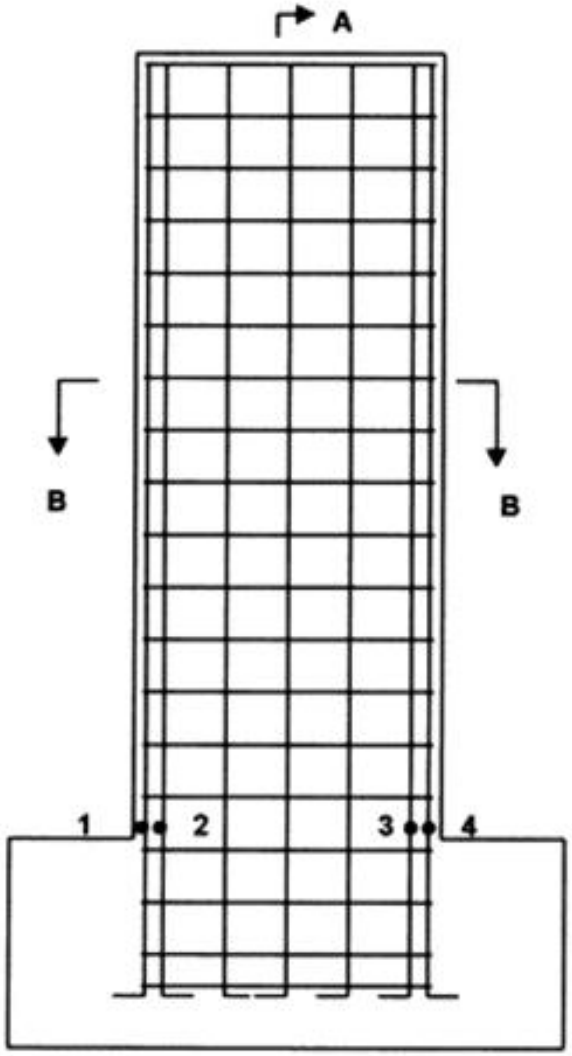
Cd	4
Max Elastic Defl.	0.32”
Code Amplified IDR	1.1%
Code Limit IDR	2%

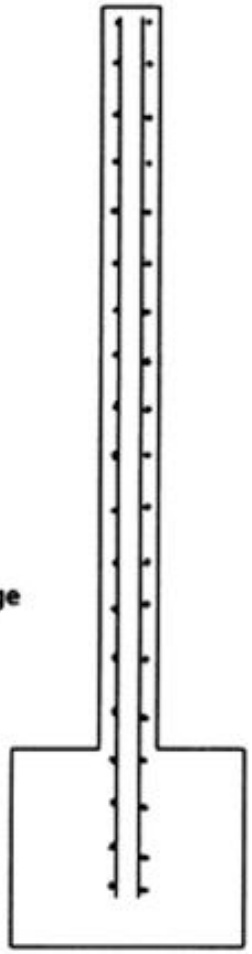
Lateral Analysis Results

- ETABS Animation!

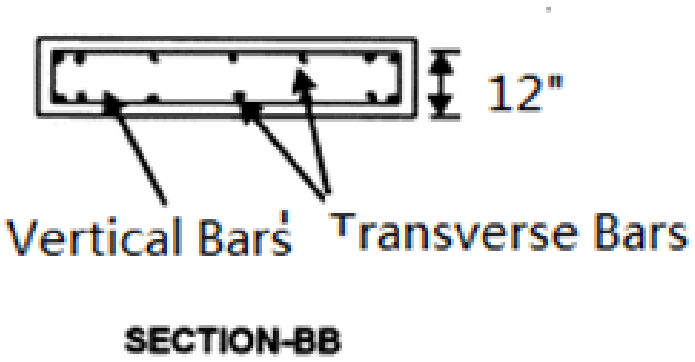


Shear Wall Design





SECTION -AA



SECTION-BB

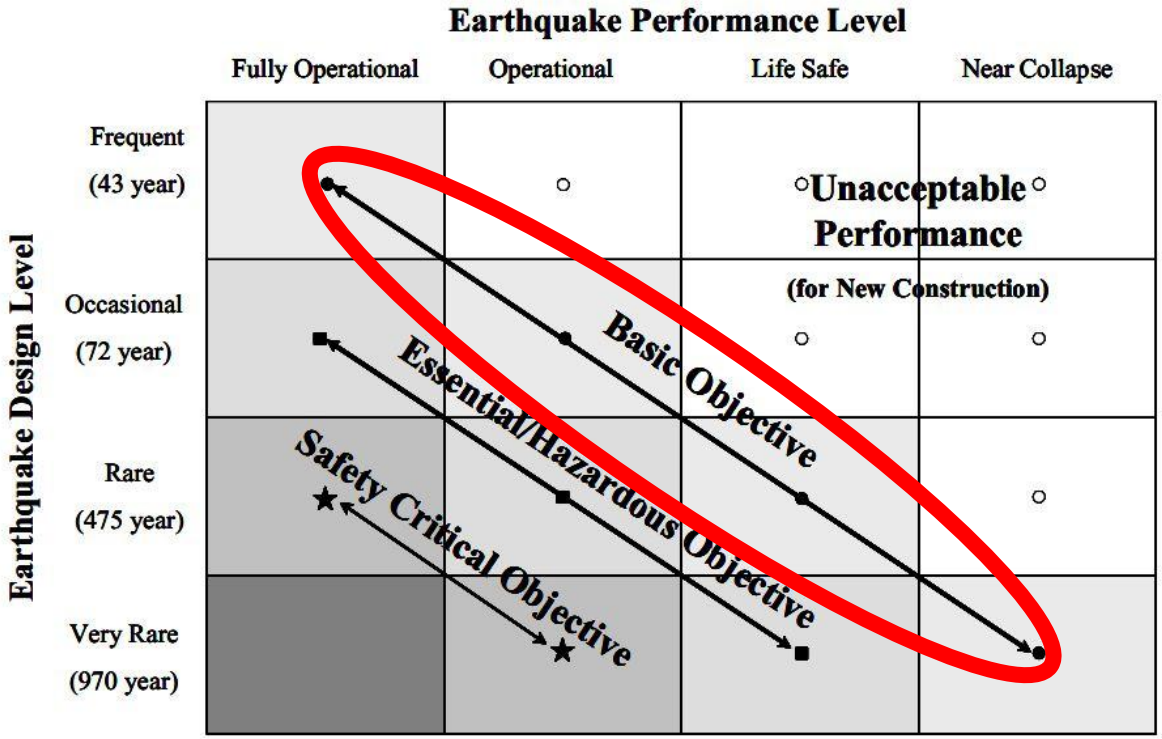
Foundation 's Reinforcement are not shown

Shear Wall design

Type	Reinforcement
Vertical: within 30” from the edge	#11 Bars @ 4”
Vertical: Others	#11 Bars @12”
Shear Reinforcement	# 6 Bars @8”

Earthquake Recovery

Applied Technology Council ATC-13 (1985)

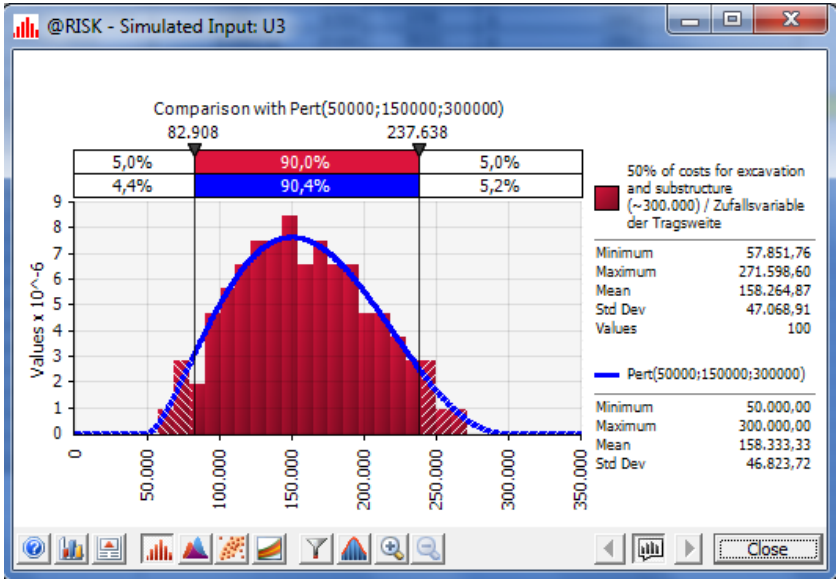


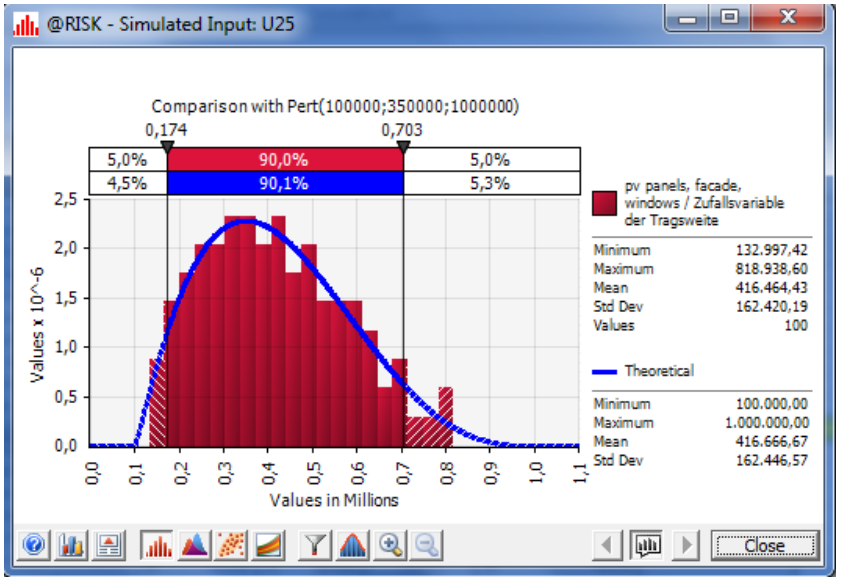
Result:
Probability of MMI 7 : ~ 2.3%

Damage State Level 4
10-80 Days for Repair

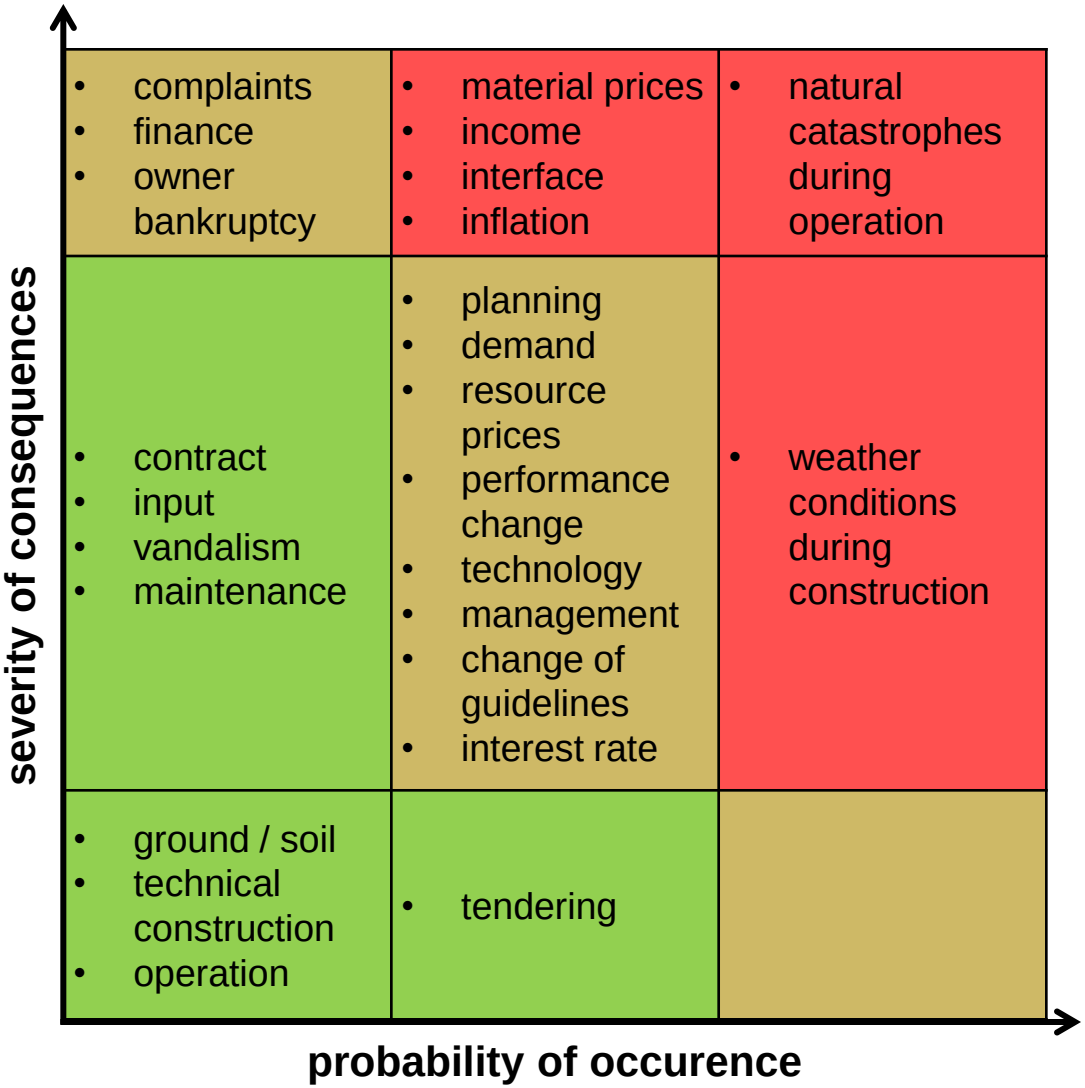
Hurricane Risk Surcharge

- Calculating the risk surcharge for hurricanes and natural catastrophes:
  - construction period
  - operation period



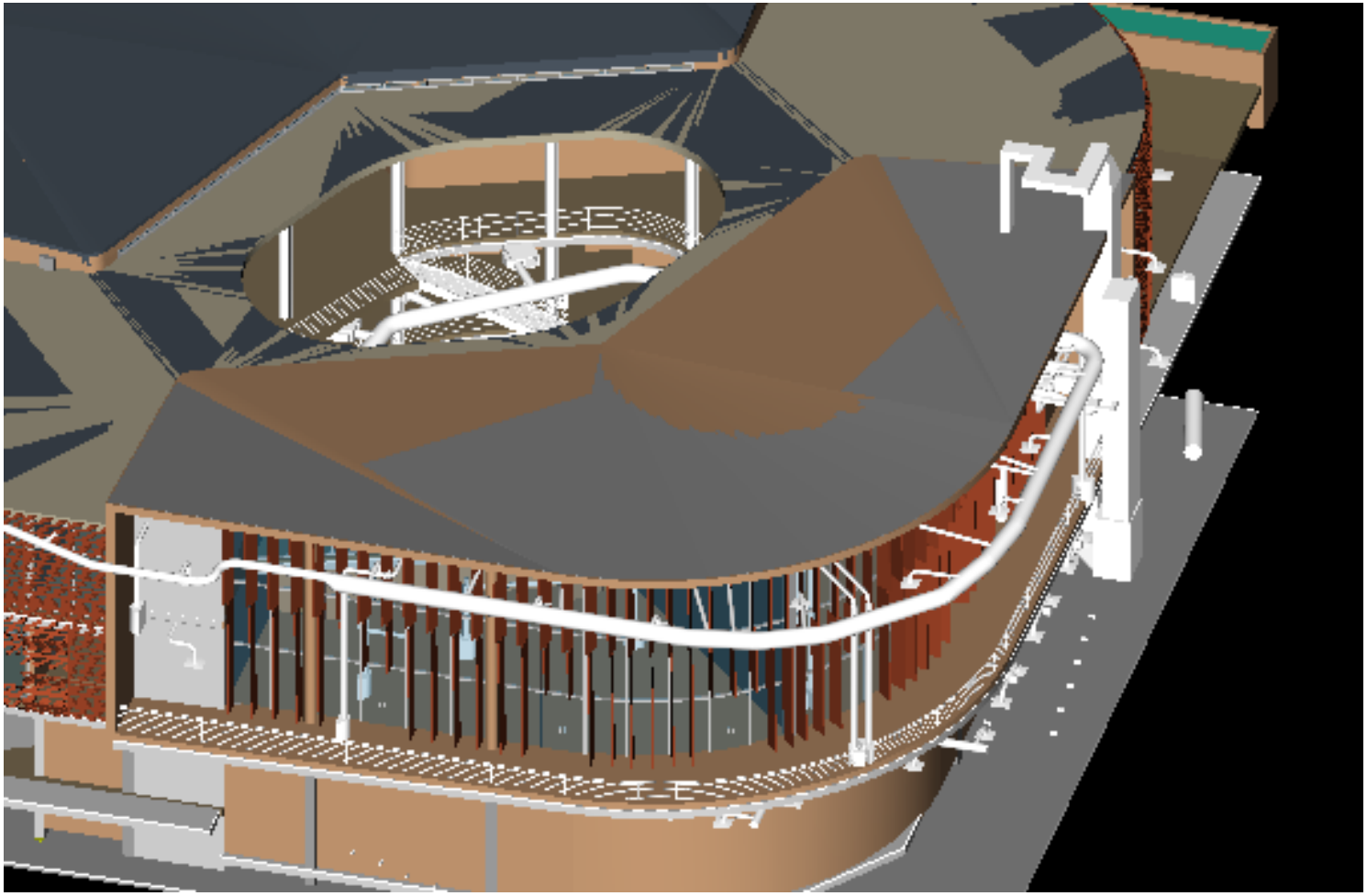


Risk Assessment Results

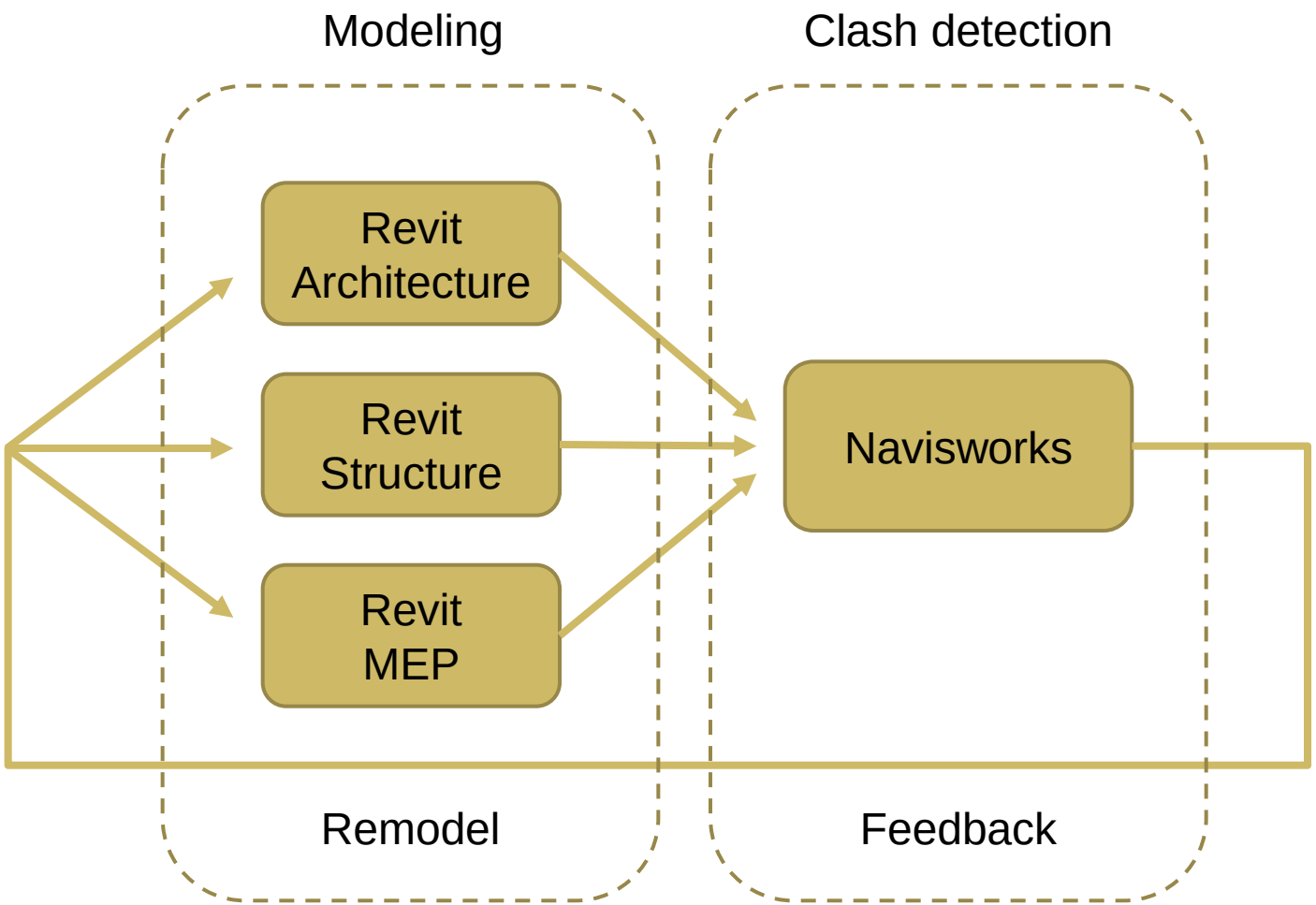


- Risk surcharges:
  - construction period: $ 250,000
  - operation period: $ 875,000

BIM Coordination



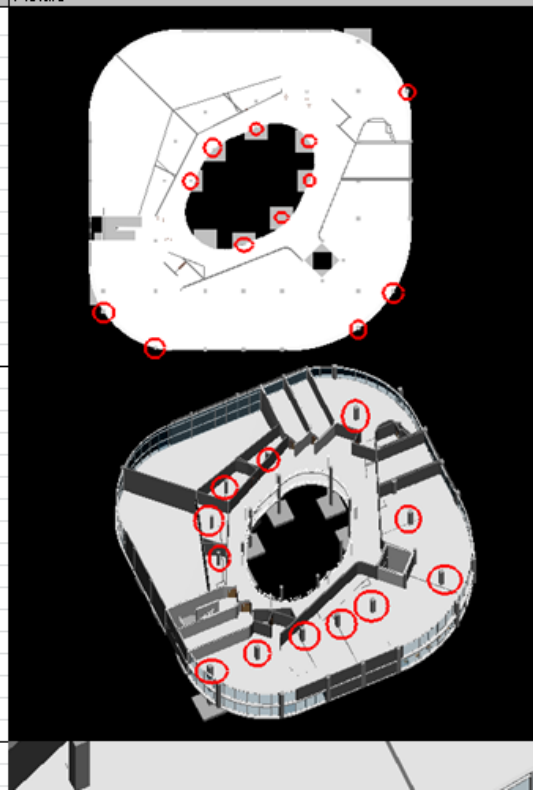
BIM Coordination



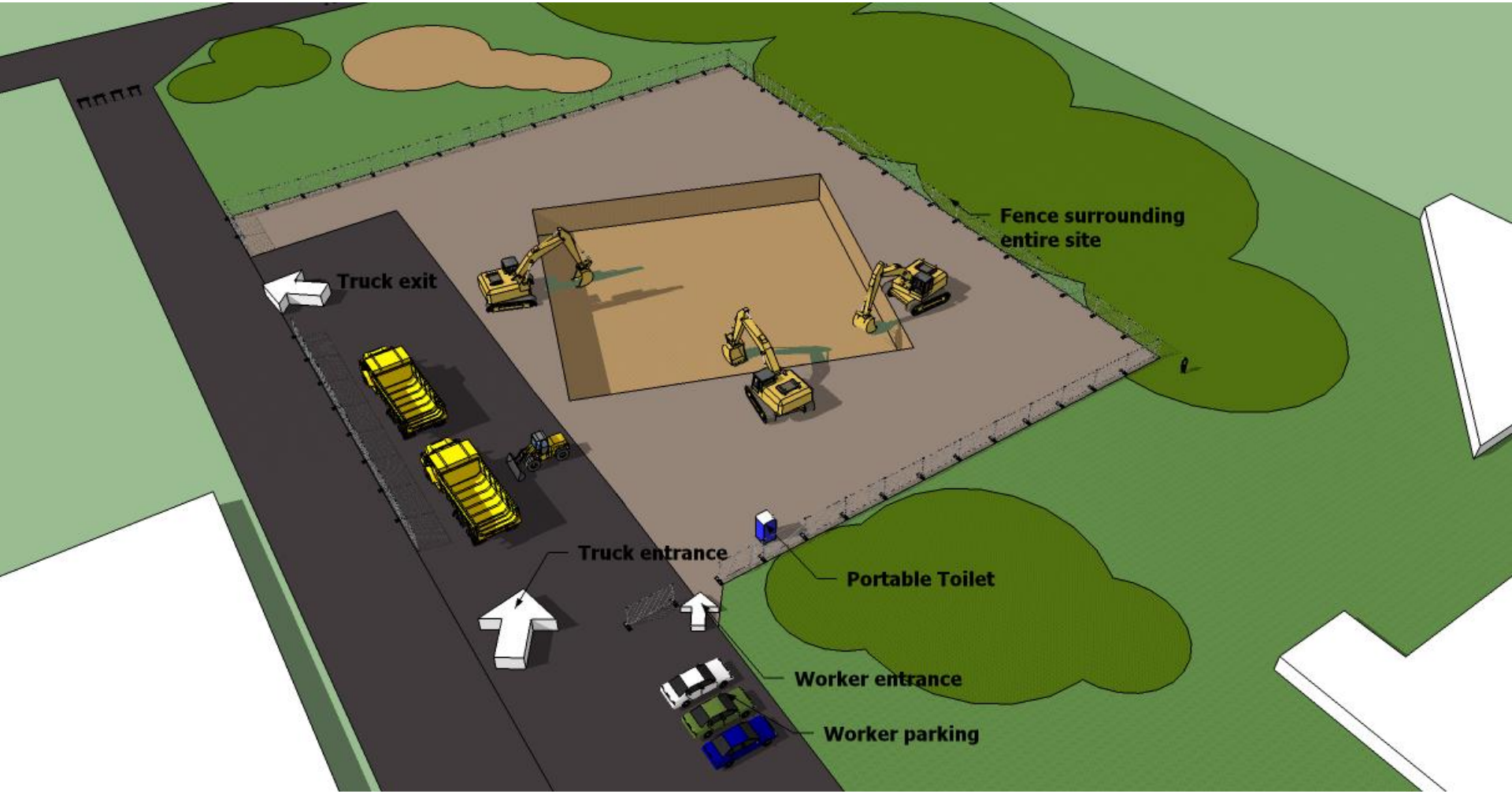
BIM Coordination

Clash detection 2012-04-12

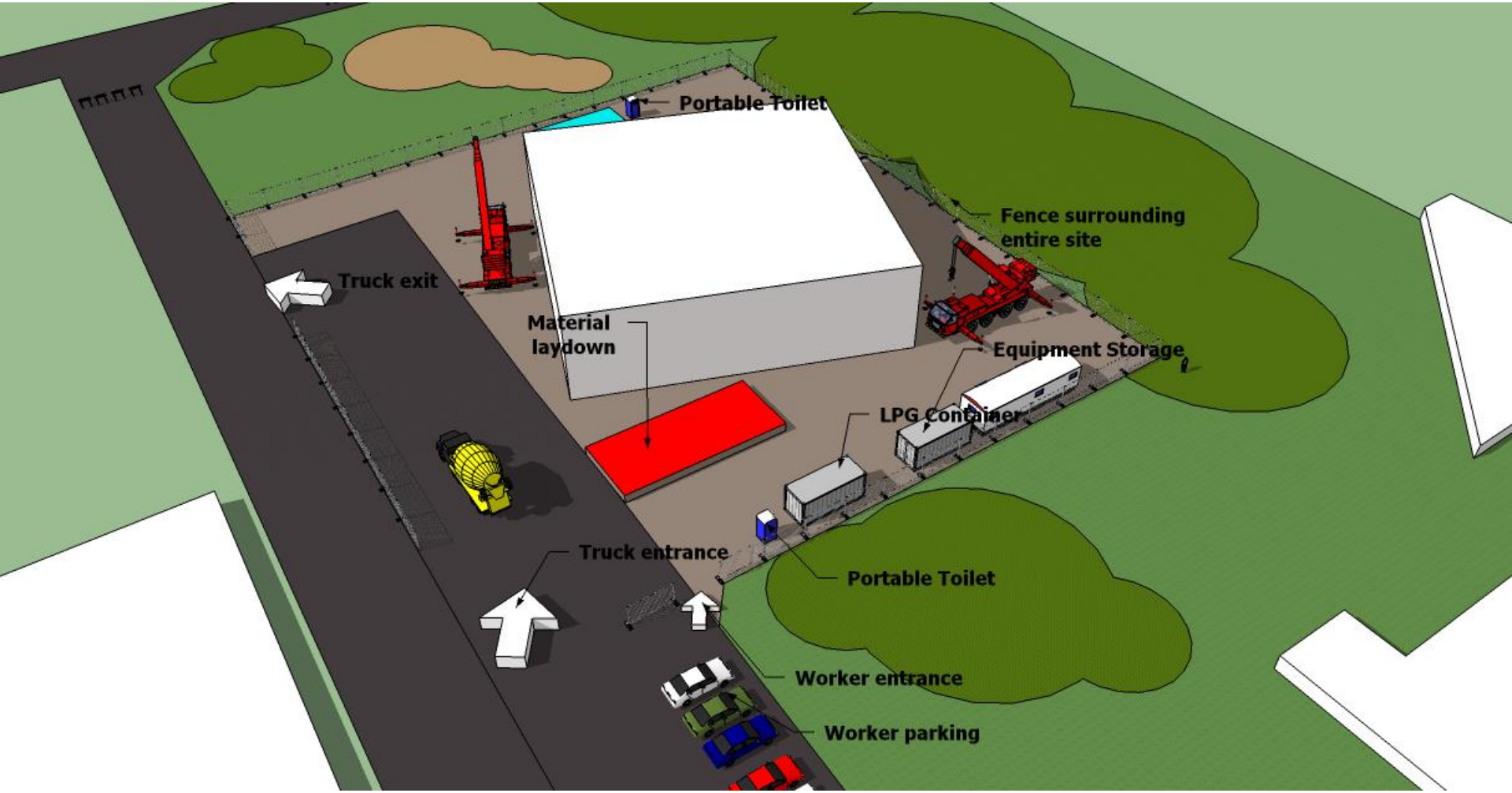
Resolved
Active
Accepted
In progress/partly resolved

Clash	Status	Detected on date	Comment/action	Picture
Missplaced collumns in facade	Resolved	2012-04-12	Correct placemet in autrium	
	In progress/partly resolved	2012-04-16	Atrium columns still wrong	
			Move architecture	
Missplaced collumns interior	Active	2012-04-12	Hide inside walls?	
			Some clash with open space	
Facede wall to thin	Resolved	2012-04-12	Make facede thicker?	

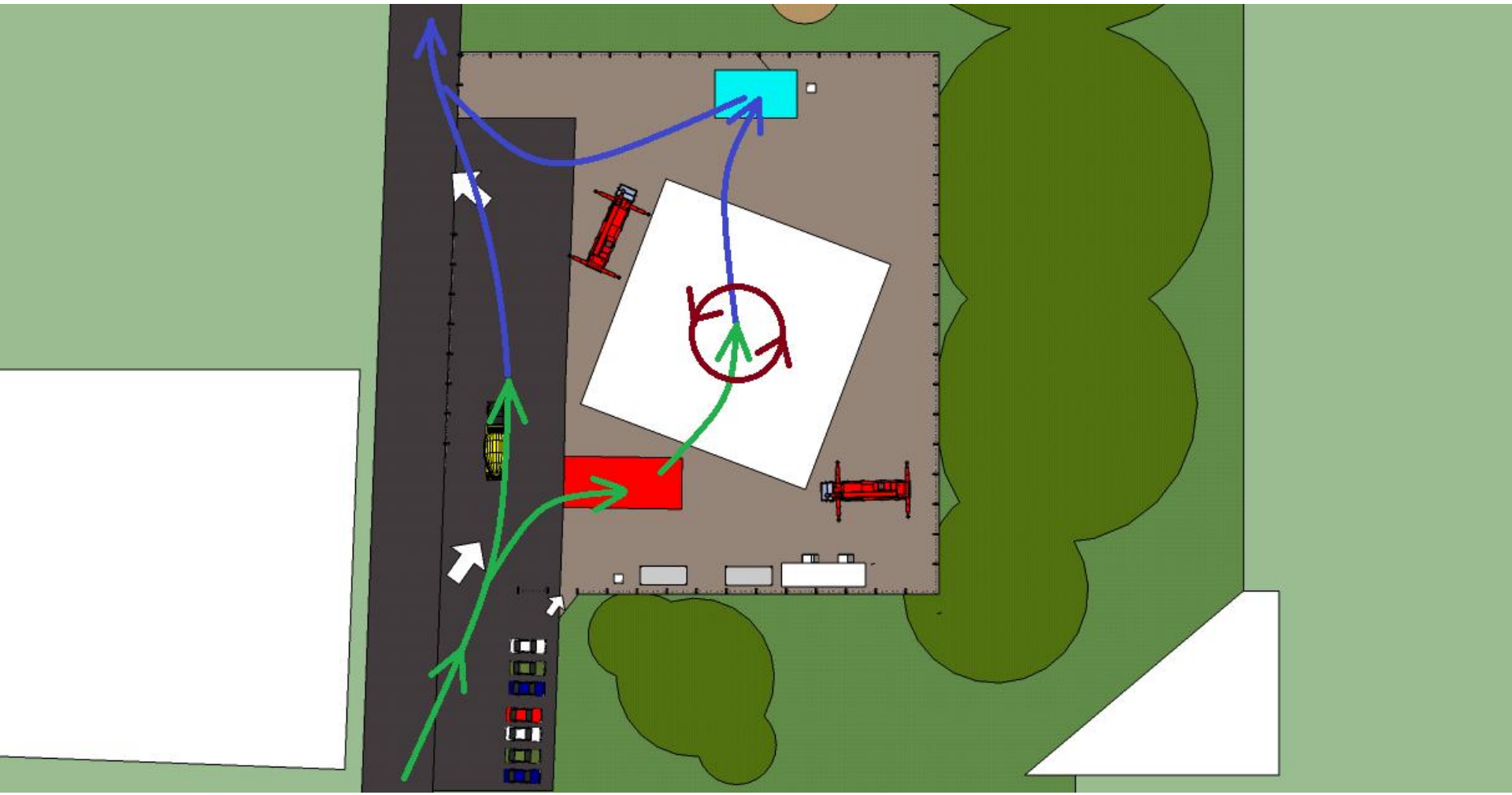
Site Logistics



Site Logistics



Site Logistics

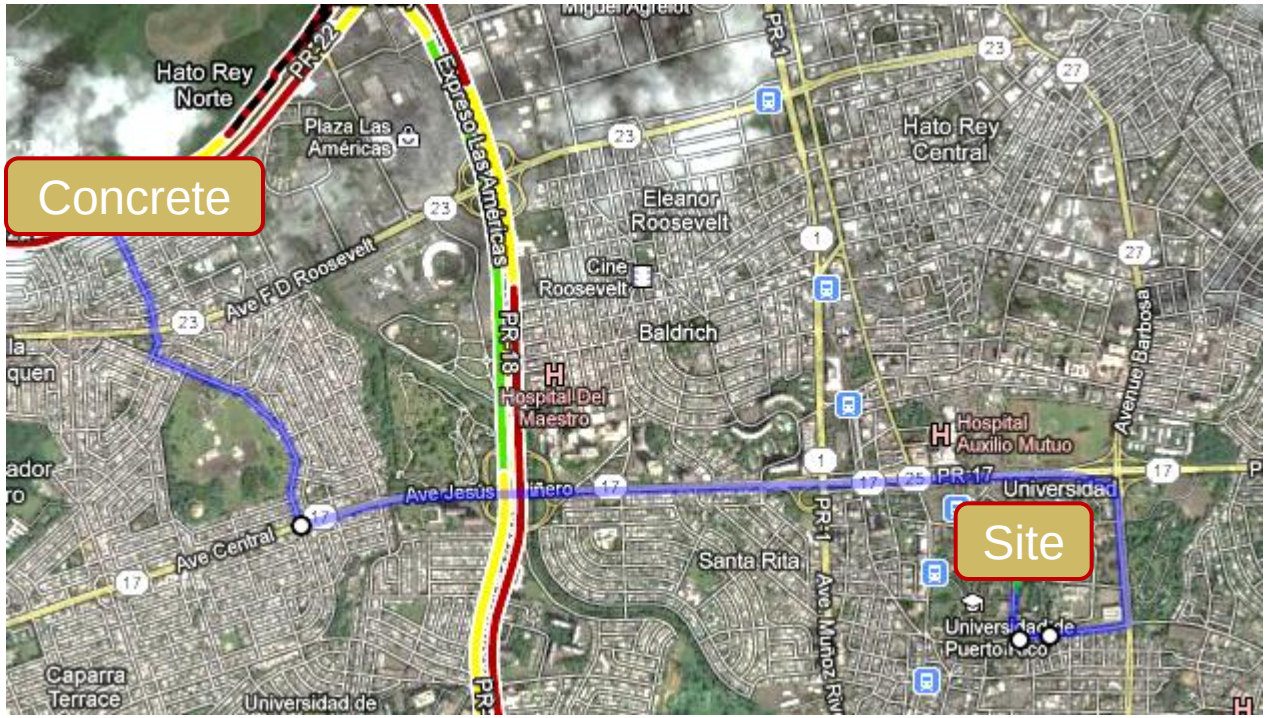


Truck Route

One way traffic

Off Site Logistics

- Concrete: 4.6 mi (map)
- Precast concrete: 8.7 mi
- Glazing: 7.0 mi
- Hospital: 0.7 mi
- Equipment rental: 6.3 mi
- Off site storage: 6.1 mi



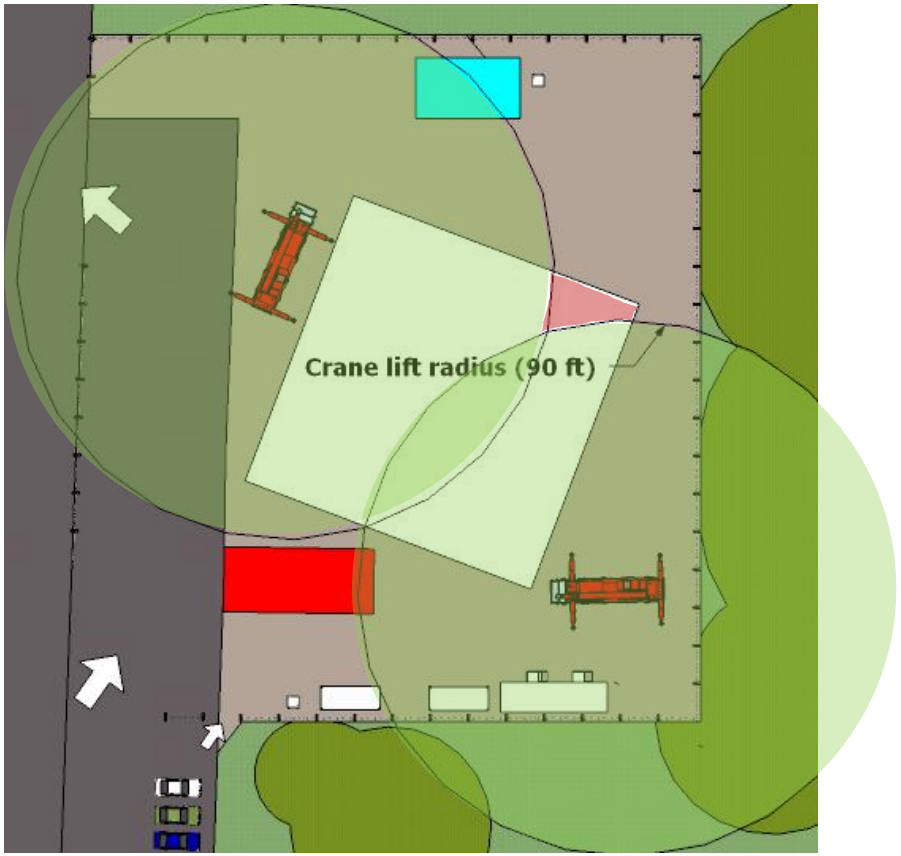
Equipment

- Excavator with high capacity
- Weight: 72 500 lb

- Small excavator for sewer etc.
- Weight: 7 800 lb

Equipment

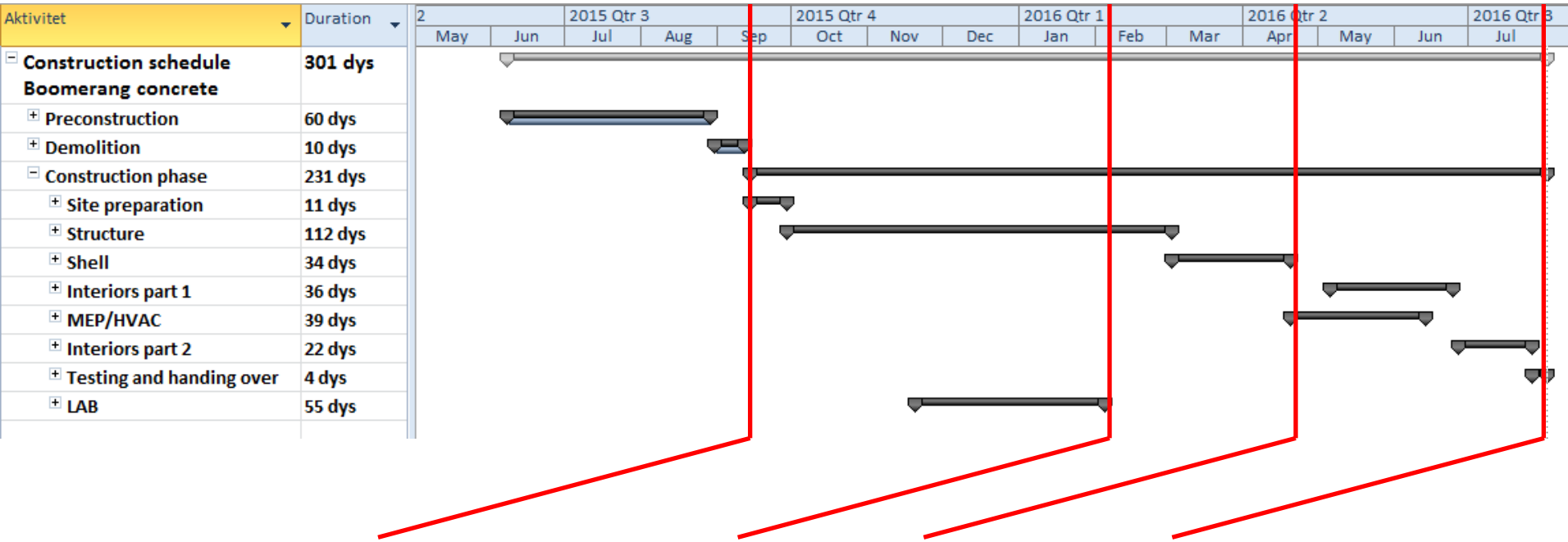
- Two mobile cranes suitable for slopes
- Load: 2 500 - 120 000 lb



Equipment

- Sky lift for fitting of windows and shading
- Used for material laydown

Schedule



9-14-2015
Construction start

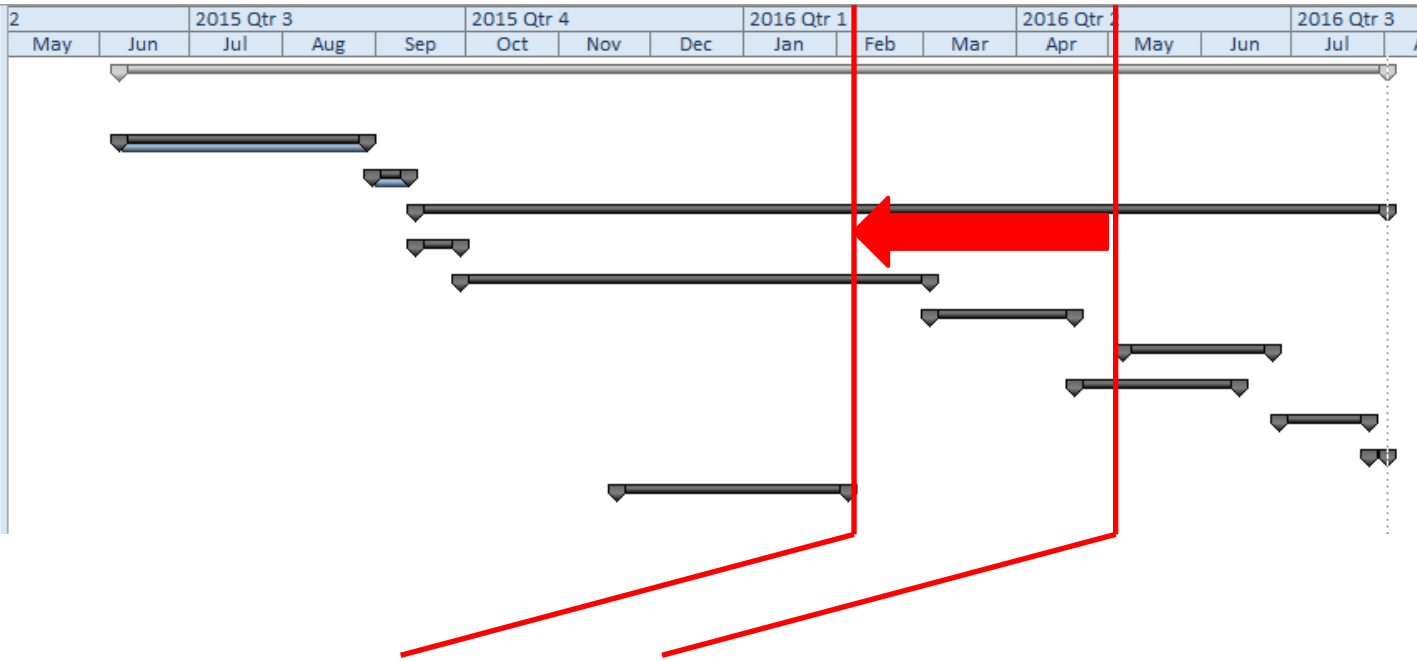
2-4-2016
Lab finished

4-19-2016
Building enclosed

8-1-2016
Construction finished
4 weeks early

Alternative Schedule

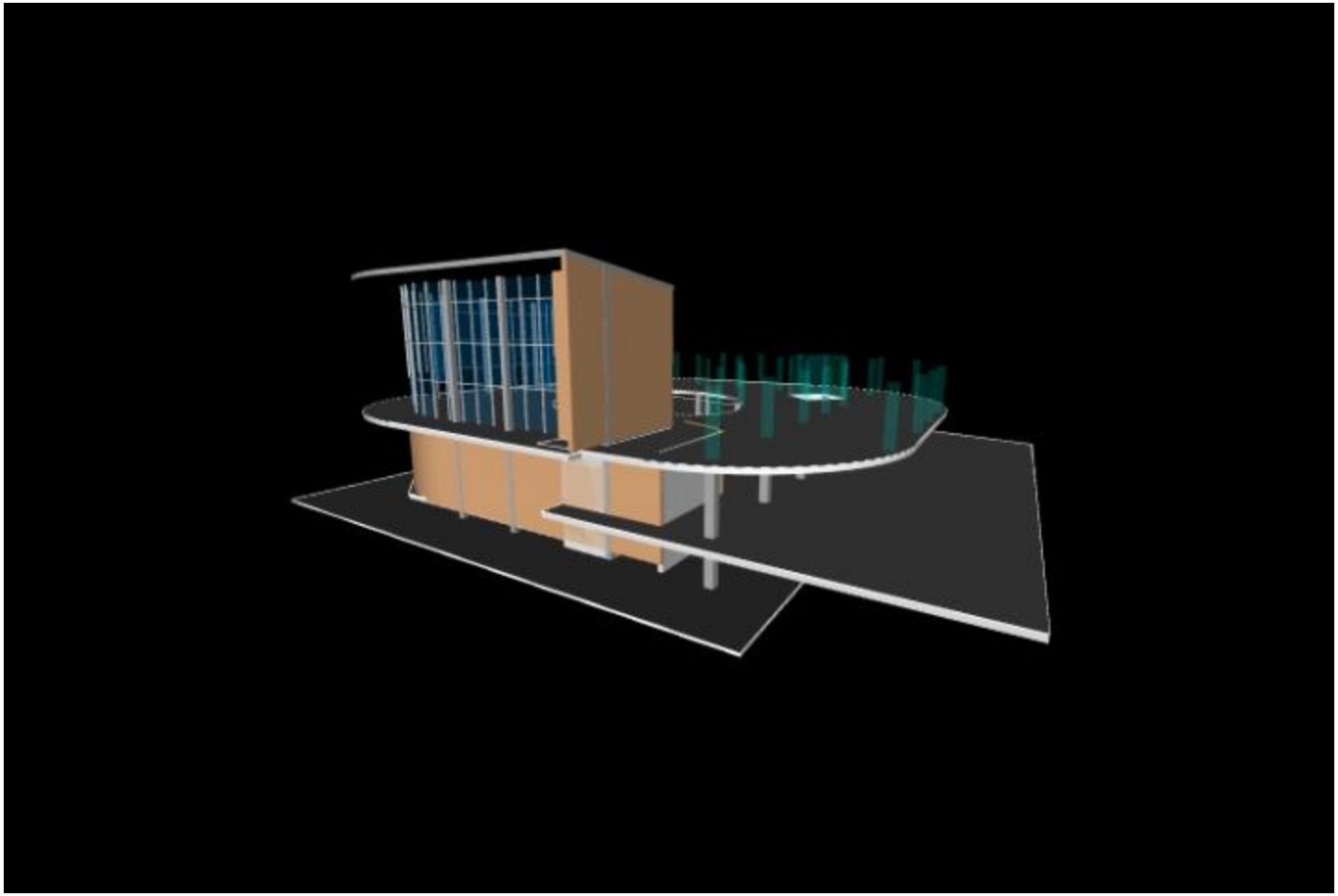
Aktivitet	Duration
Construction schedule Boomerang concrete	**301 dys**
Preconstruction	60 dys
Demolition	10 dys
Construction phase	231 dys
Site preparation	11 dys
Structure	112 dys
Shell	34 dys
Interiors part 1	36 dys
MEP/HVAC	39 dys
Interiors part 2	22 dys
Testing and handing over	4 dys
LAB	55 dys



2016-02-04
Lab finished

2016-05-02
Lab finished

Constructability 4D

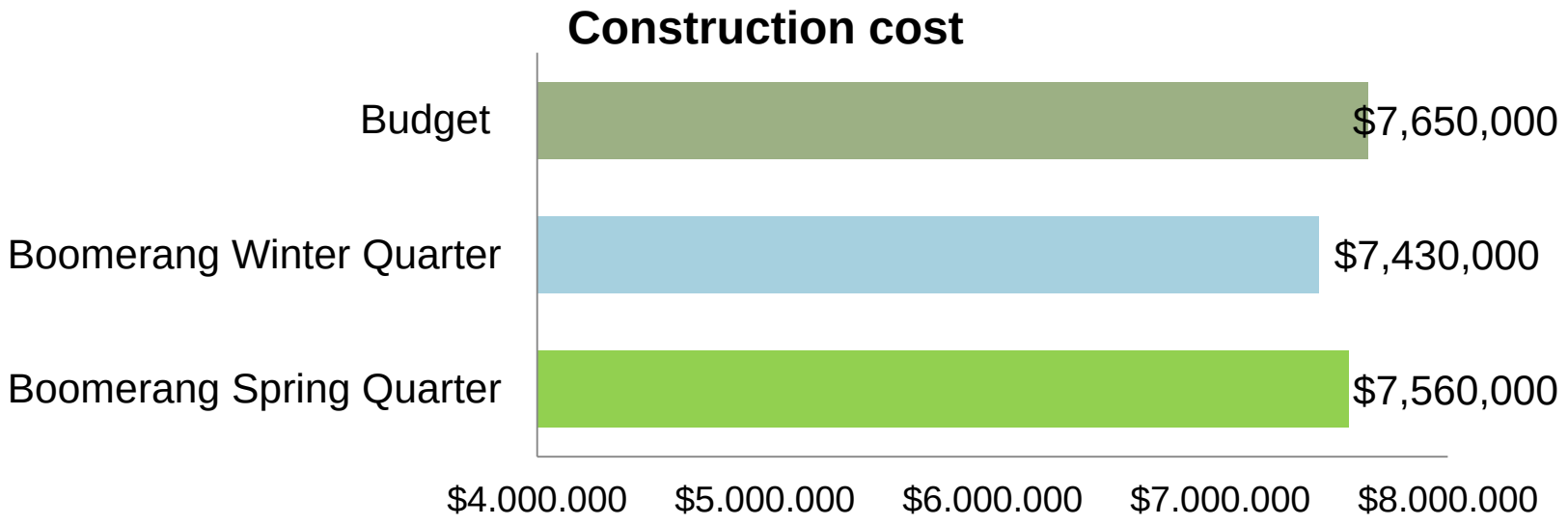


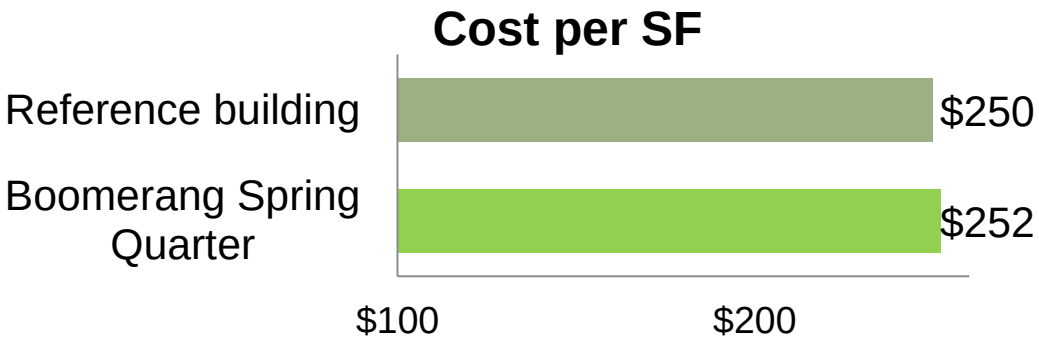
Construction innovations

- Tablets with 3D model of the building
  → *better understanding of the building*

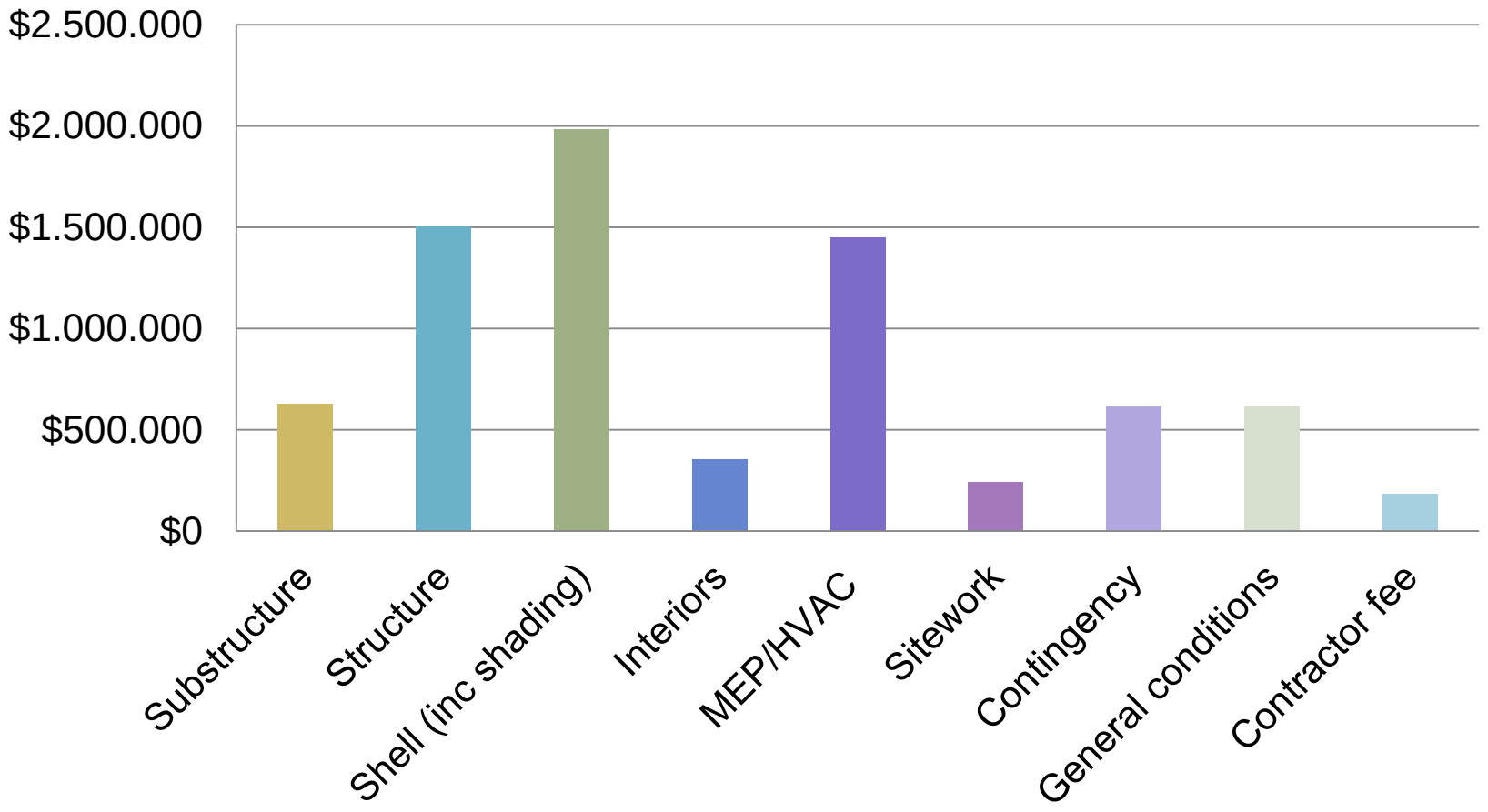
- Over night material laydown
  → *reduces construction time*

Cost Estimate

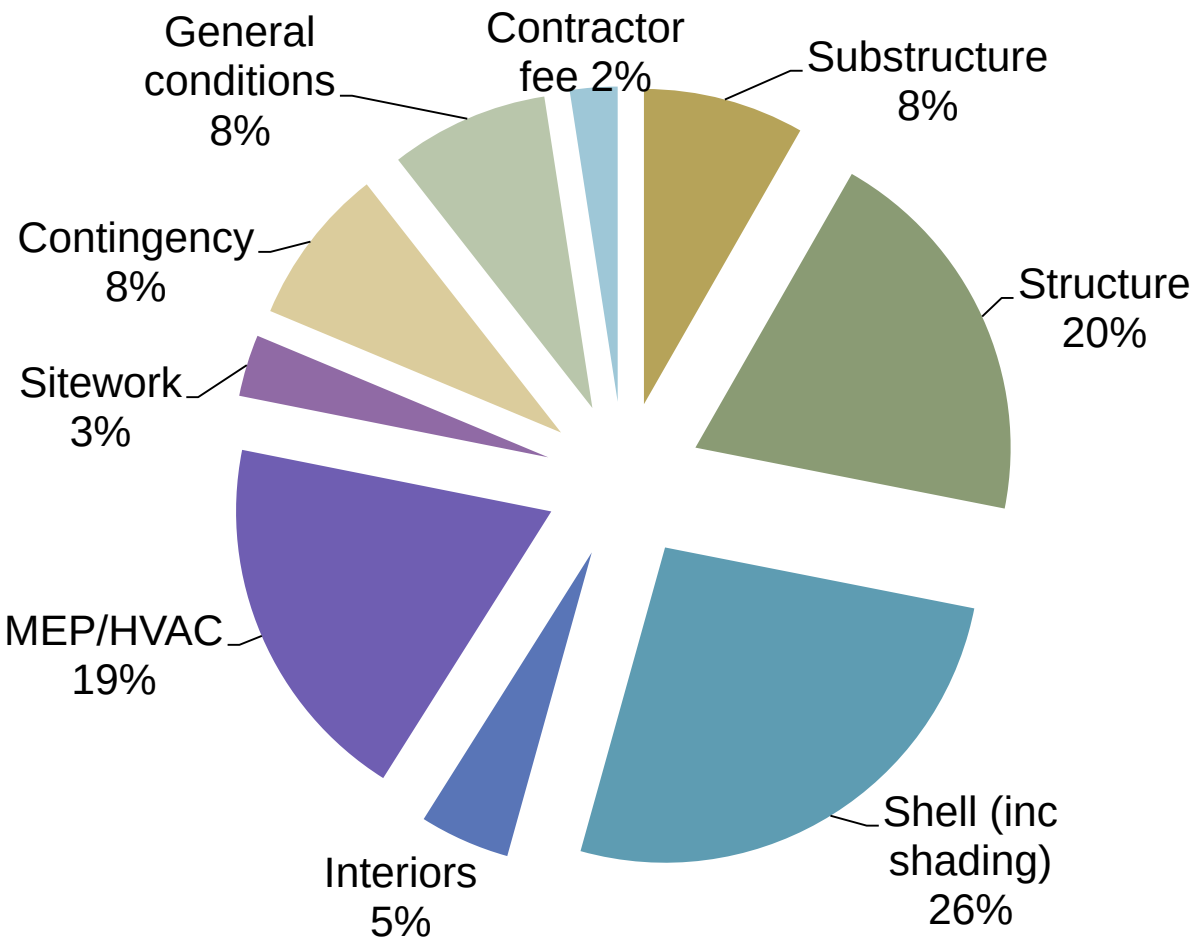




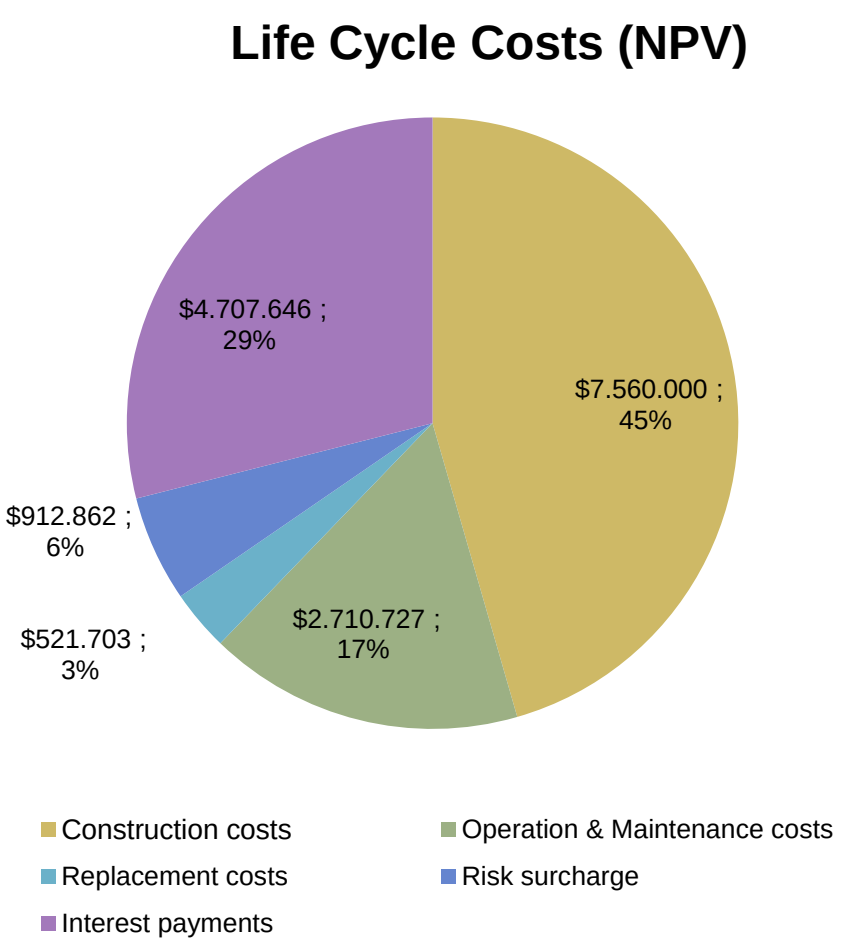
Cost Estimate

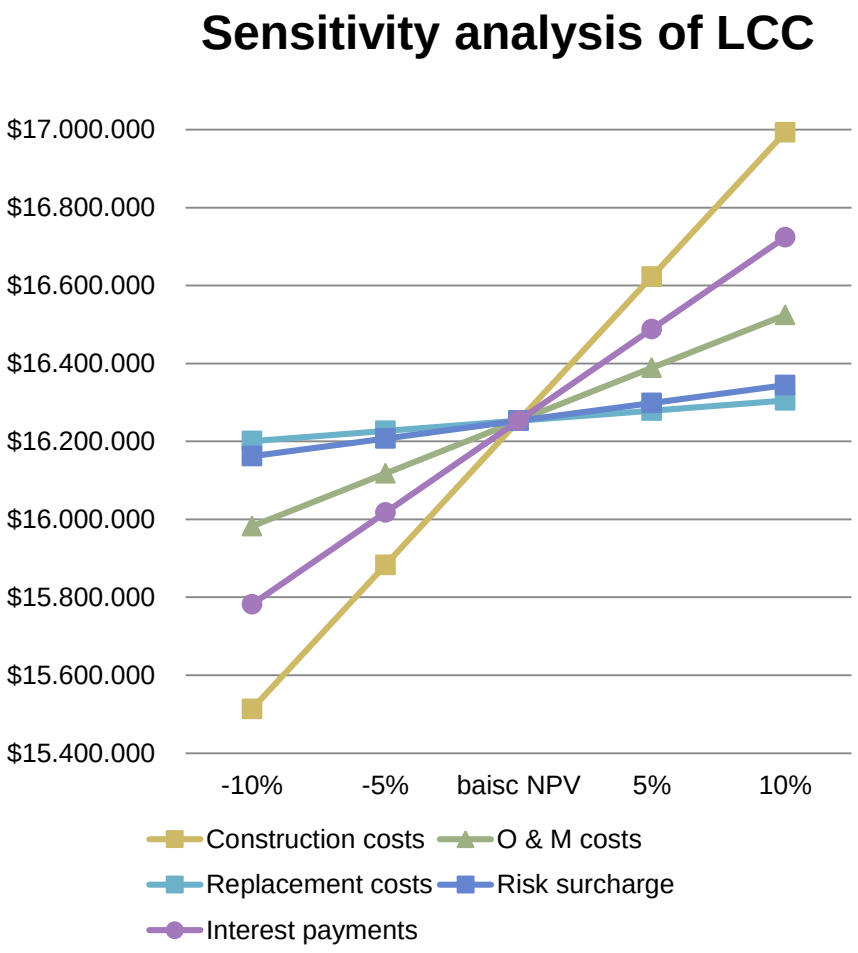


Cost Estimate

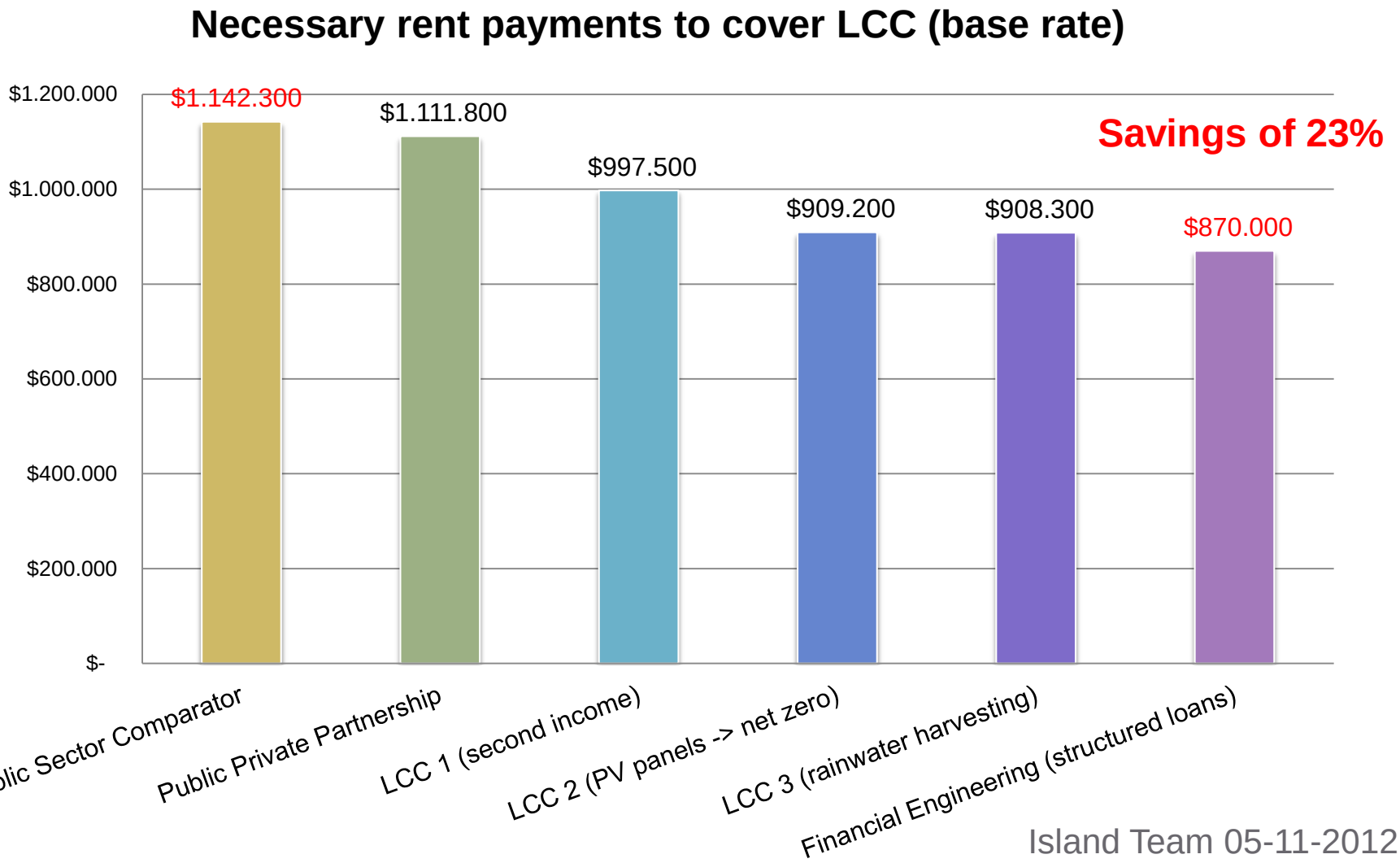


Life Cycle Costs

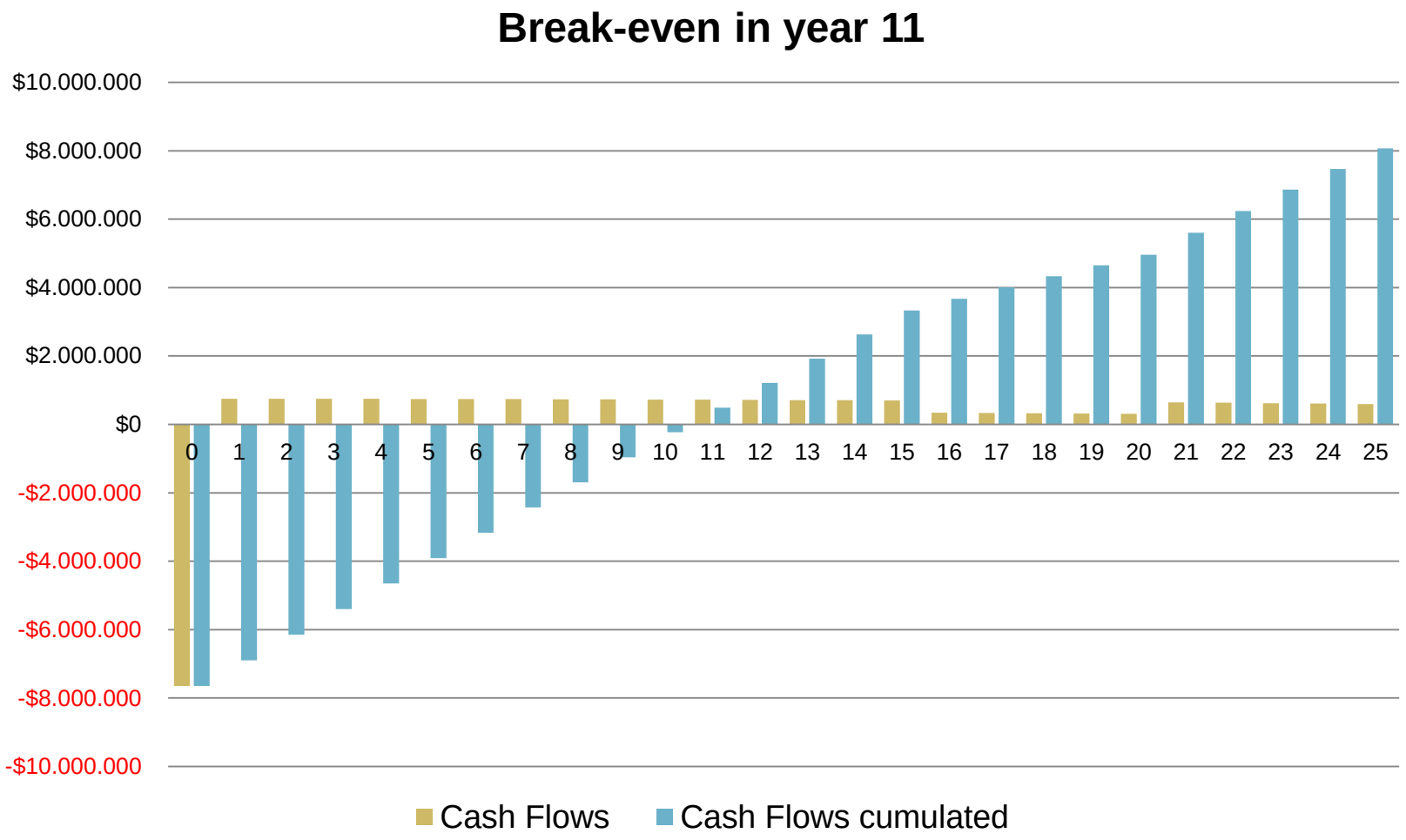




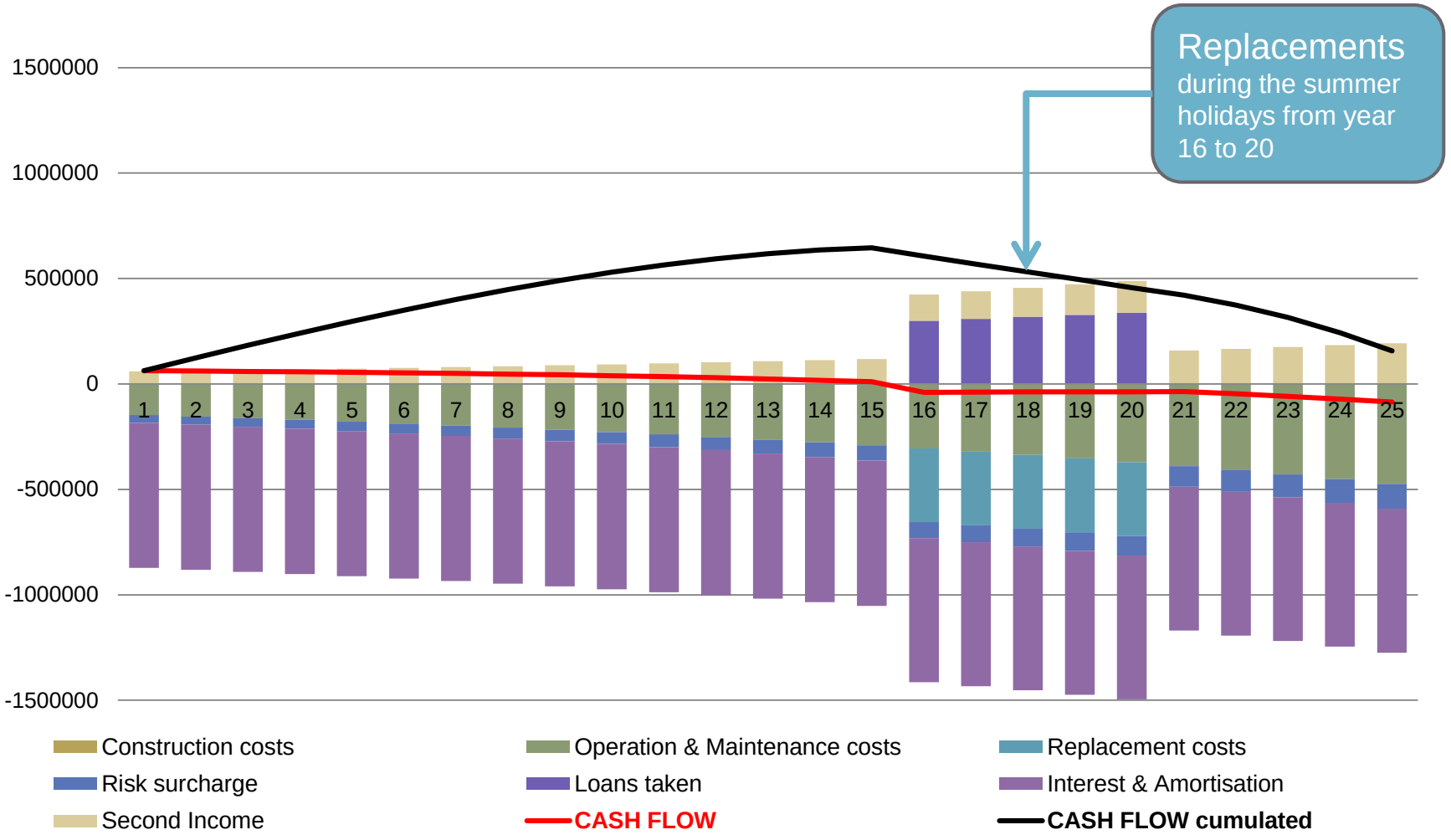
LCC Comparisons



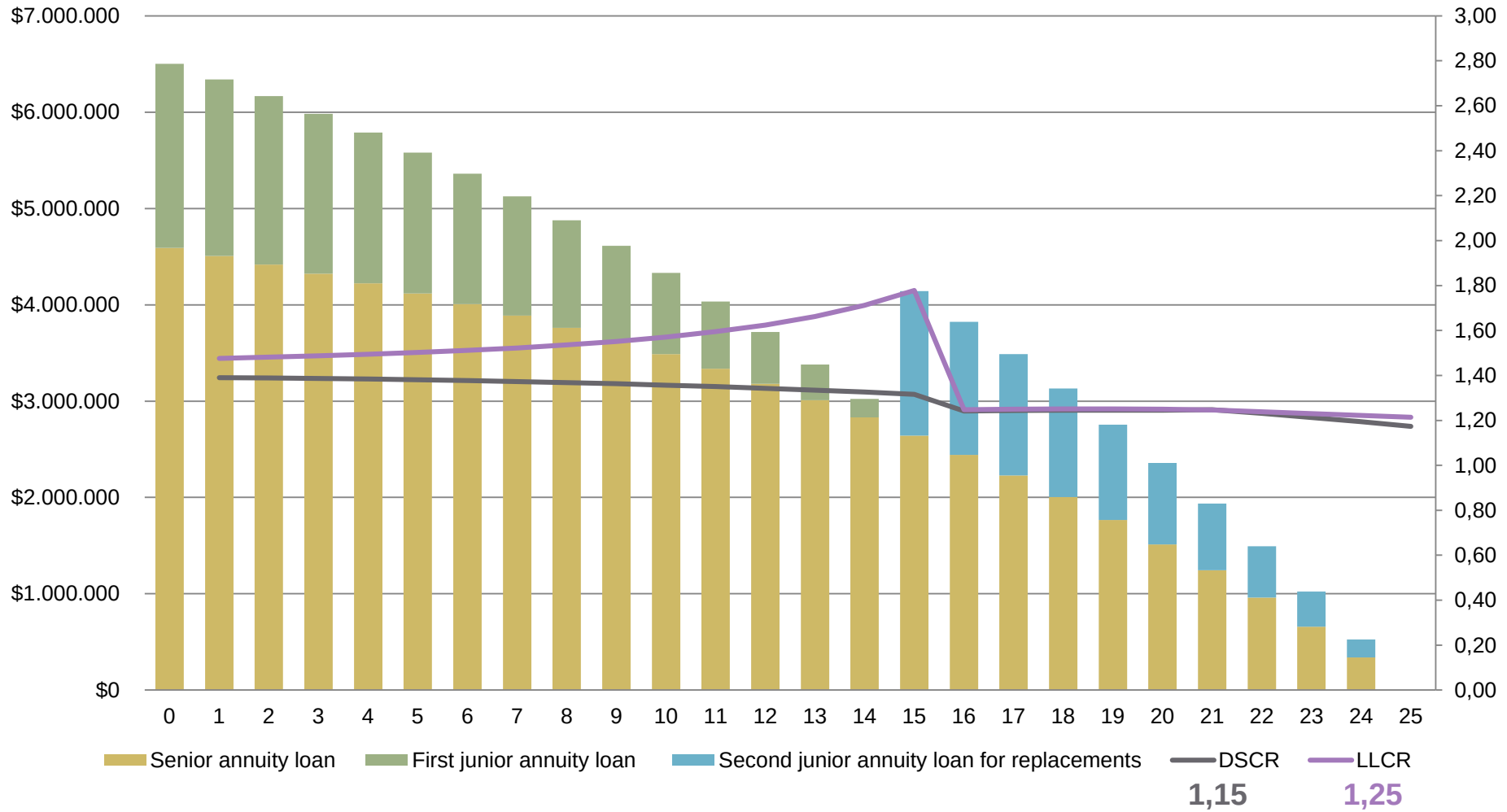
Property Cash Flow



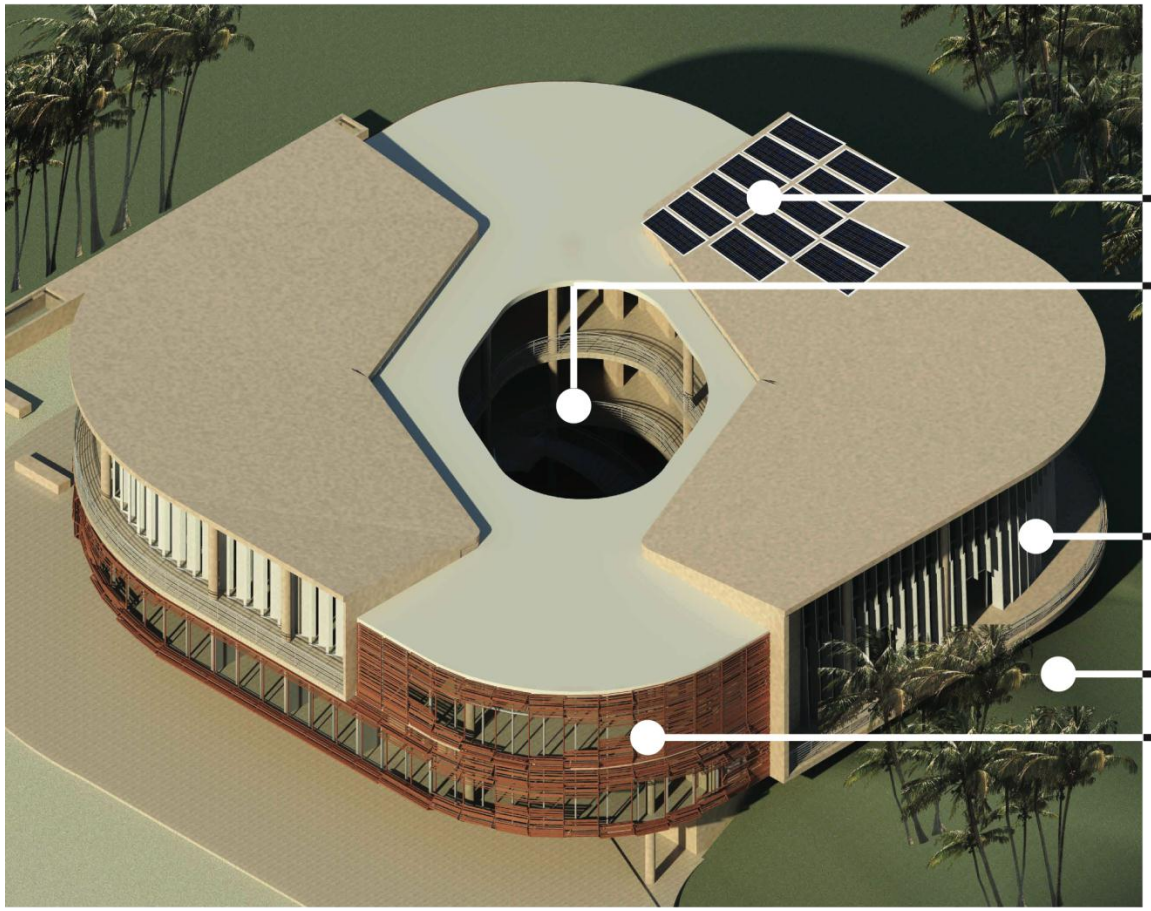
Real Cash Flows



Loan structures & financial ratios



Sustainability Approach



208 PV panels

Water Harvesting
80,000 Gal./Yr.

Balconies for social sustainability

Re-Use of Excavated Terrain

Dynamic Facade

LEED Gold

Category	Max. Points	Points given
Sustainable site	26	15
Water Efficiency	10	9
Energy and Atmosphere	35	35
Materials and Resources	14	4
Indoor Environmental Quality	15	14
	100	77

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

DGNB Silver

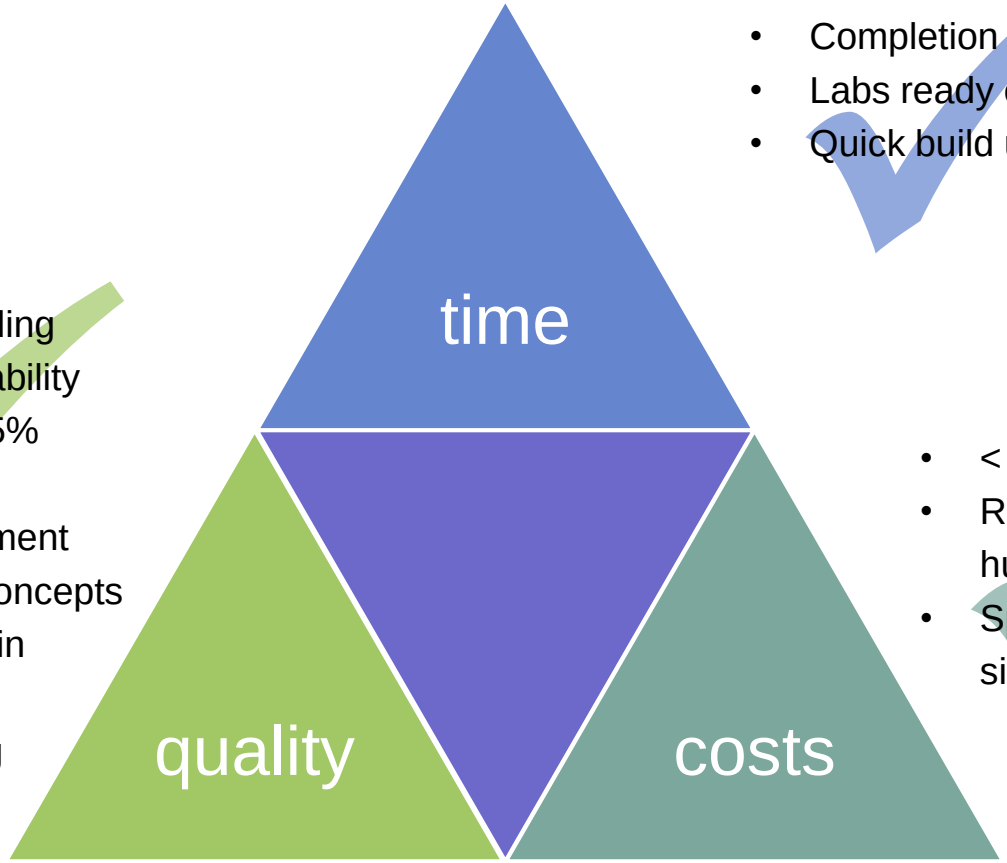
Evaluation Area	Criteria Group	Average Performance	Total Performance
Environmental Quality	Life Cycle Analysis	87,5 %	77,4 %
	Global and Local environmental Impact		
	Ressource Consumption and Waste Generation		
Economic Quality	Life Cycle Costs	70,0 %	
	Economic Performance		
Sociocultural and Functional Quality	Health, Comfort and User Friendliness	74,8 %	
	Functionality		
	Aesthetic Quality		
Technical Quality	Technical Quality of Building Design and Systems	75,0 %	
Process Quality	Quality of the Planning Process	82,4 %	
	Construction Quality		
Site Quality	Site Quality	(not counted)	

Bronze > 50 % Silver > 65 % Gold > 80 %

Target Value Design

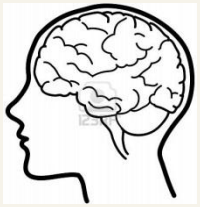
- Completion earlier
- Labs ready earlier
- Quick build up after hurricane

- Spatial requirements
- Social & educating building
- LEED + DGNB sustainability
- Energy perfomance >25% below baseline
- Integration into environment
- Integrated biomimicry concepts
- Structural performance in hurricanes
- Flexibility of the building

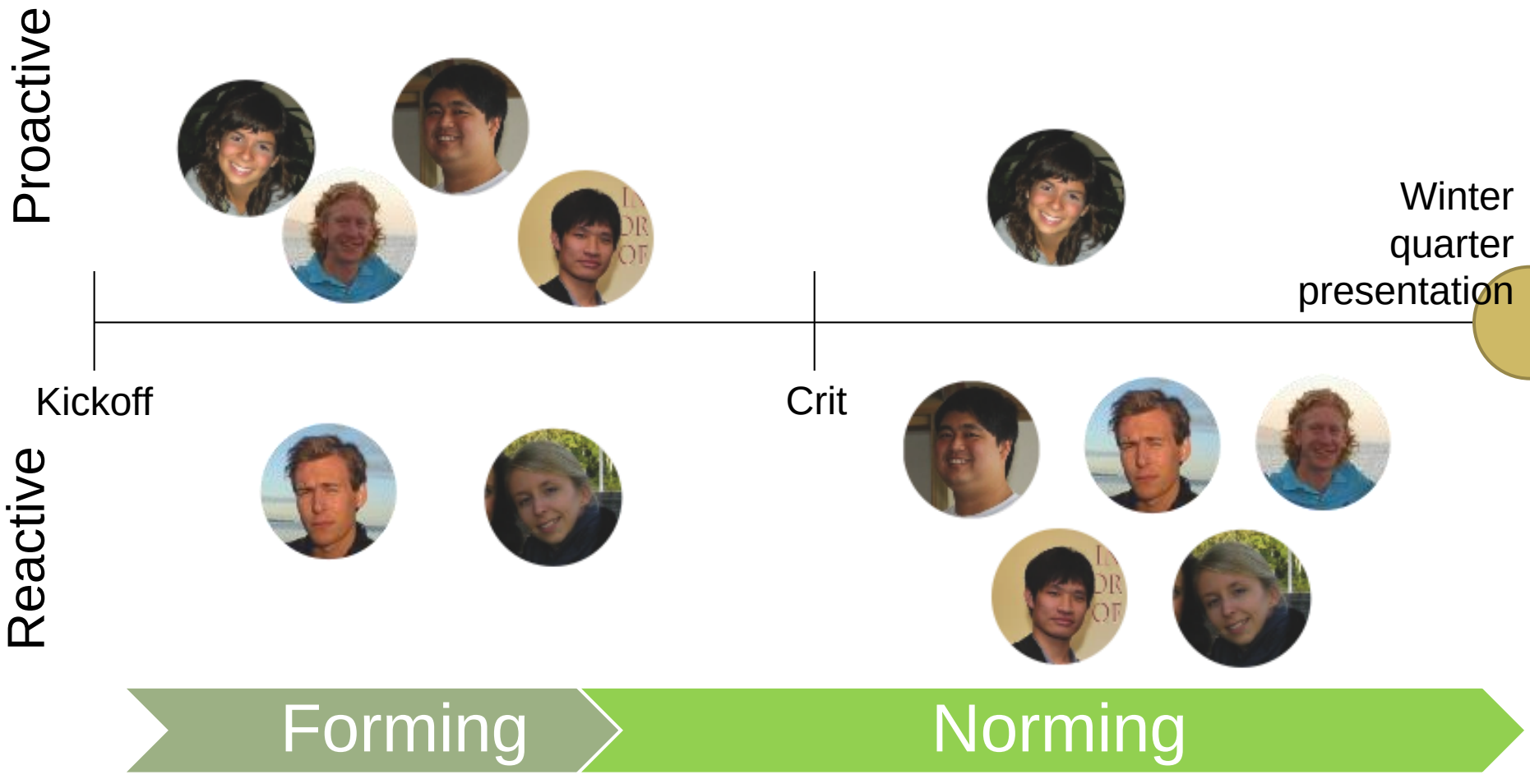


- < 880,000 $ annual rent
- Risk surcharge for hurricanes included
- Space efficiency and simplicity for o+m

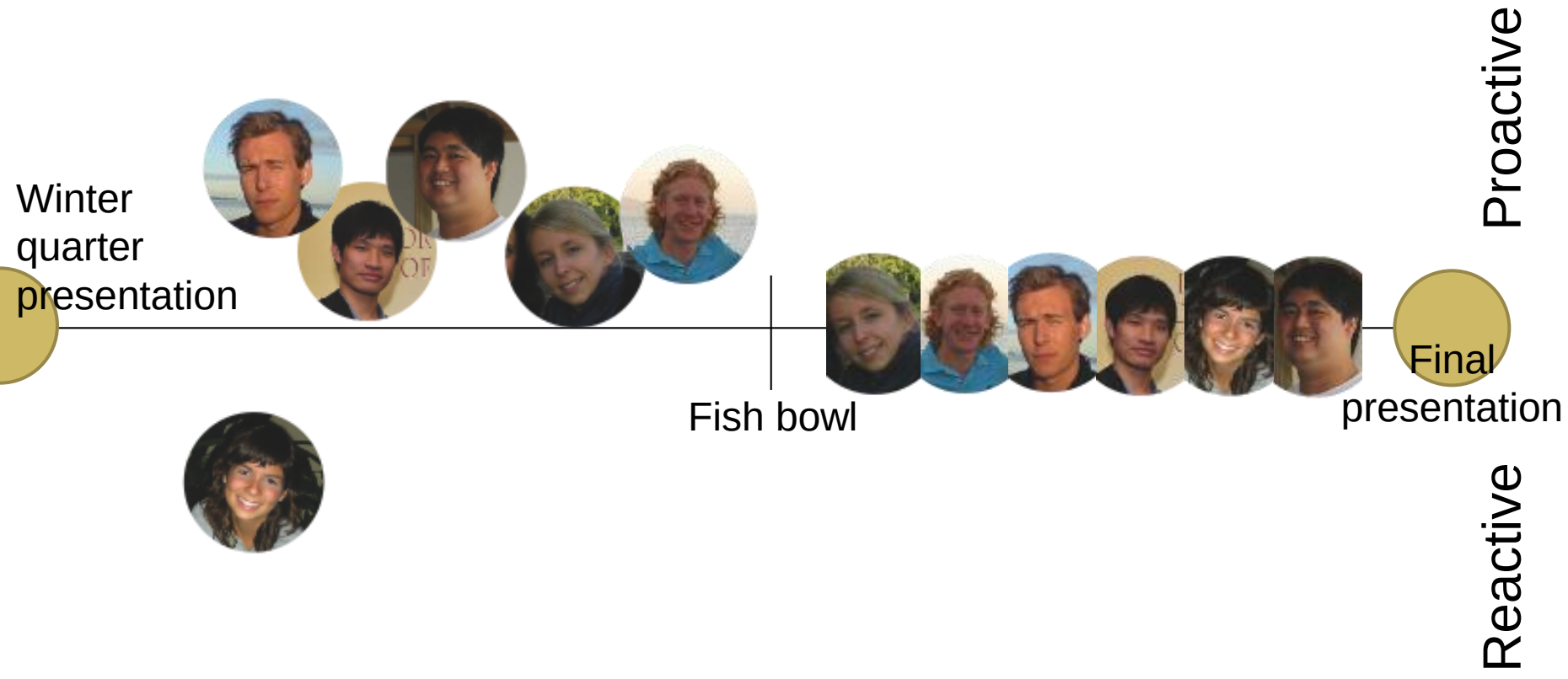
Team communication

• Informal communication • Exchange of links and videos • “In-between” communication	• Smaller chats • Sub-group meetings • Back-up to GoToMeeting	• Team meetings • Sub-group meetings	• Results • Forums in box for discussions
facebook	skype™	GoToMeeting™	box
			

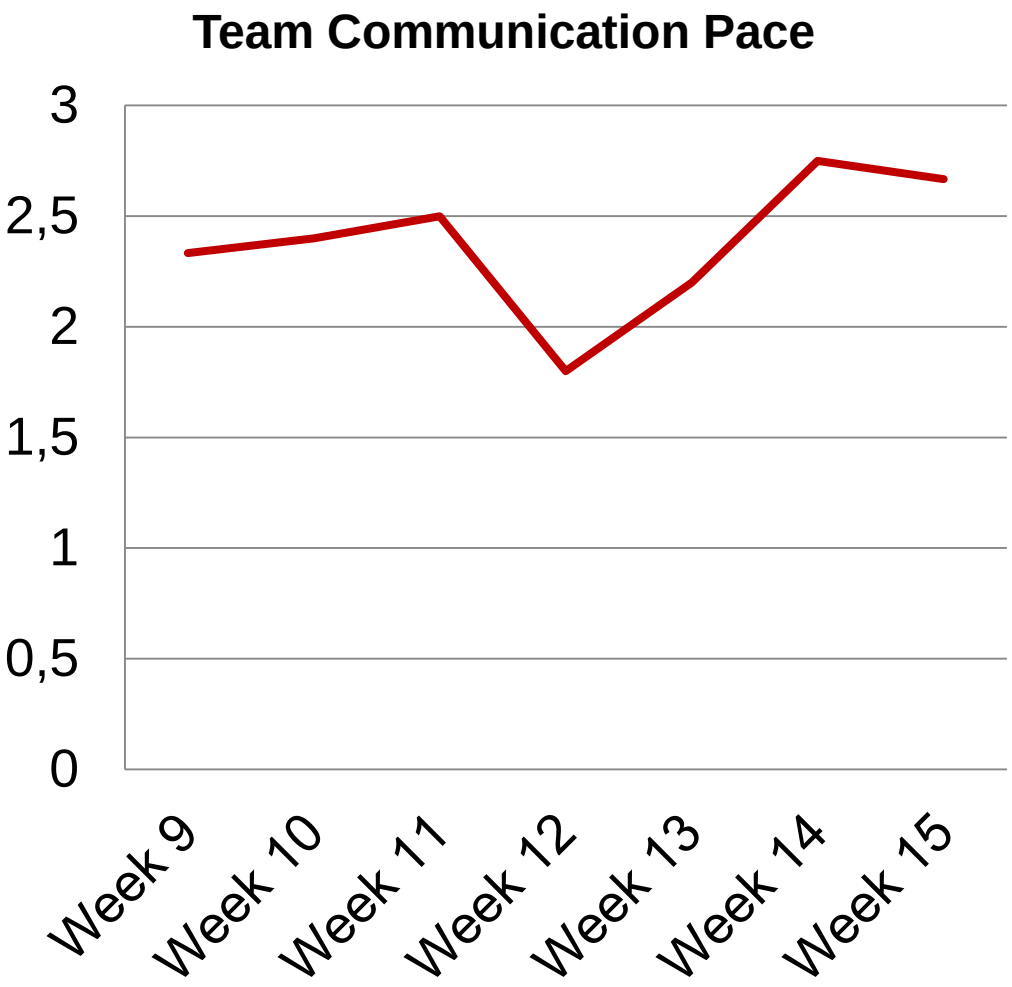
Team Development

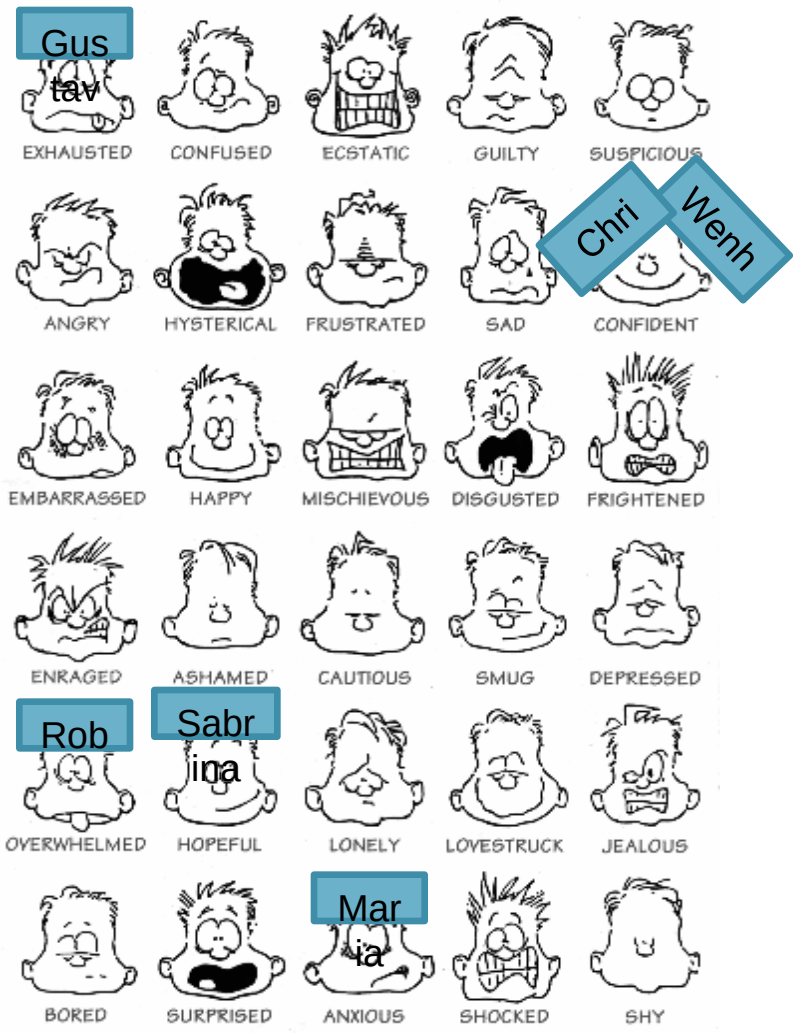


Team Development

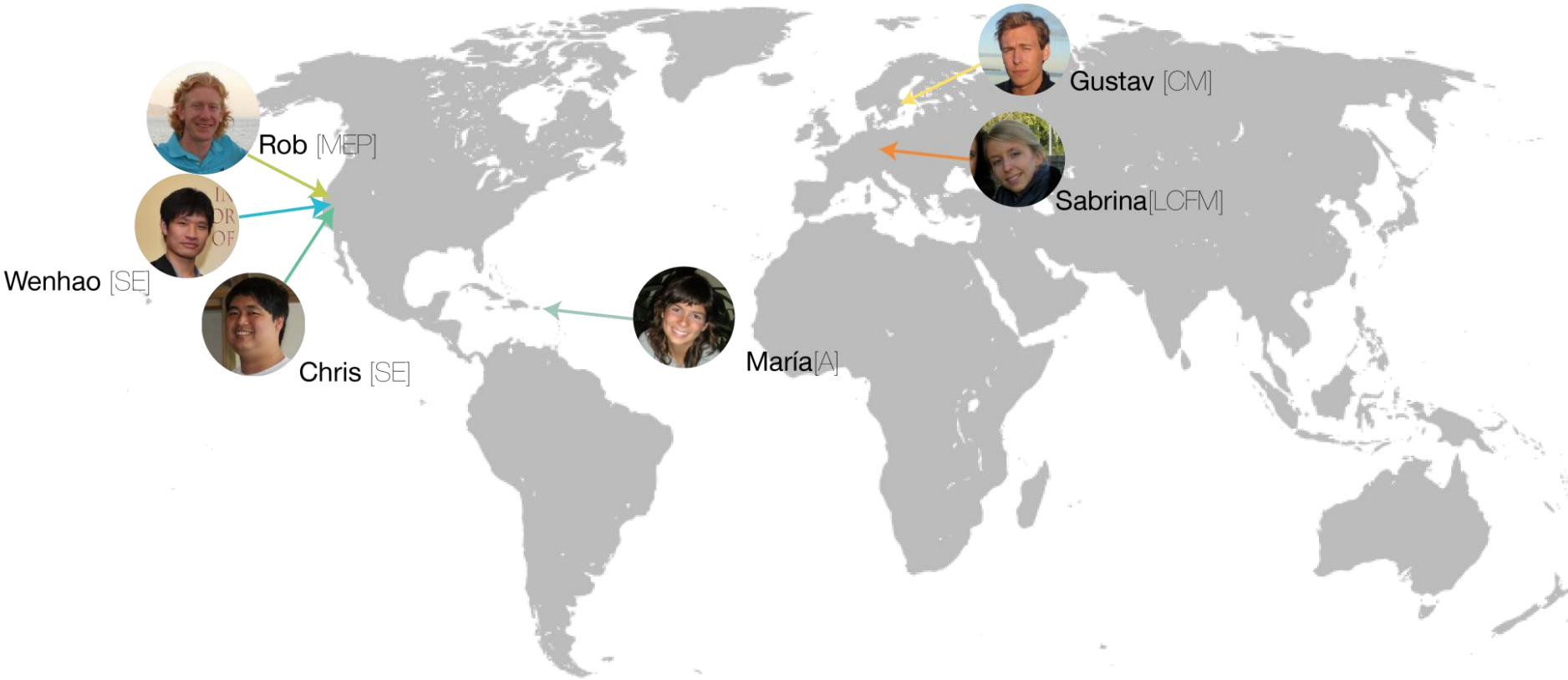


Team Process Assessment Survey





Team Culture



Team Culture

Thank you!

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