



The UW Integrated AEC Studio: Pedagogy, course structure, and insights from 2009 - 2016

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Kate Simonen (Architecture)

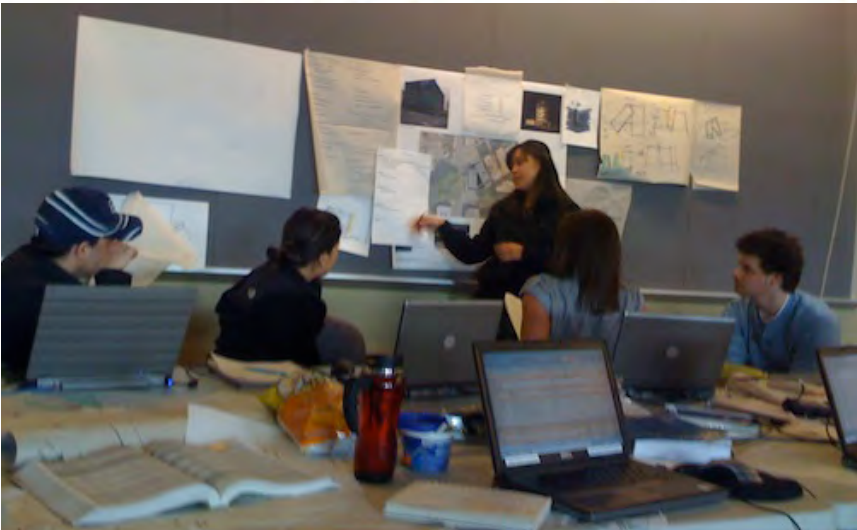
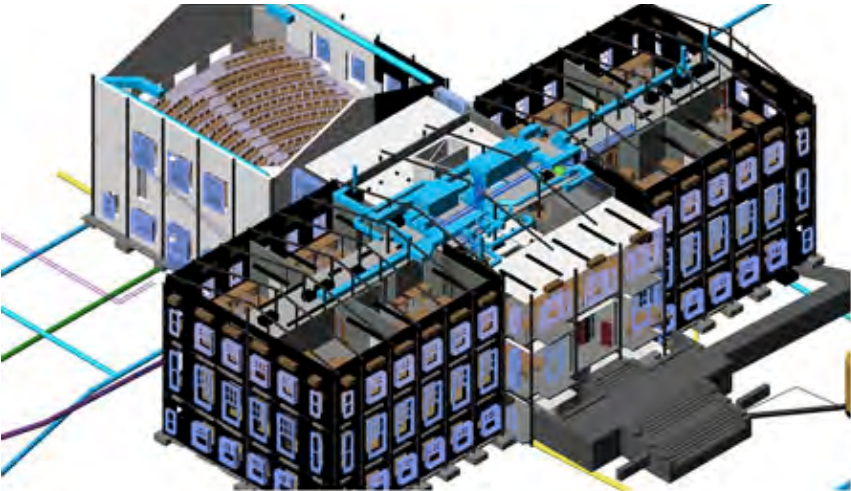
Carrie Sturts Dossick (Construction Management)

Chris Monson (BE Ph.D.)



COLLEGE OF BUILT ENVIRONMENTS

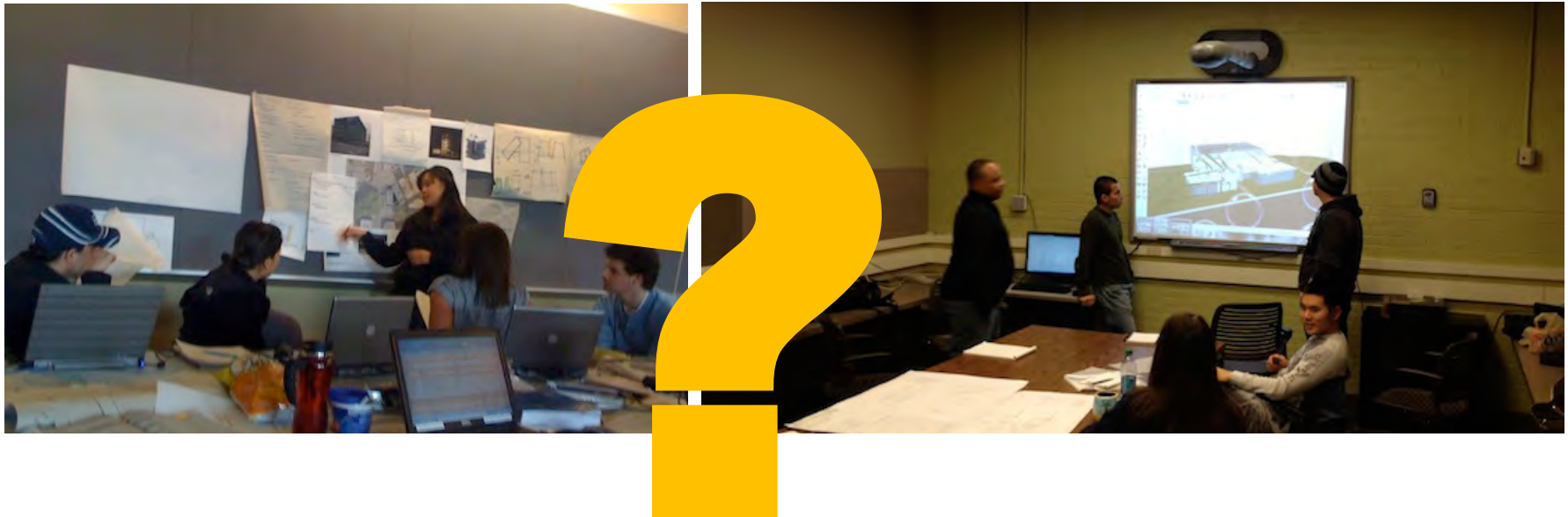
High performance buildings require collaboration



Integrated AEC Studio



Education Processes, Infrastructure, Curricula



How can AEC students be engaged across **studio/non-studio disciplines** with **different credit hours** and curriculum requirements?

UW Integrated AEC Studios

- Begun Winter Quarter 2009
- Teams of 3-10:
Architecture, CM, Civil,
Structural, Landscape Arch.,
Real Estate, Sustainability,
Facilitation
- Experiments with different
projects, studio spaces, course
schedules
- since 2014: 6 cr Arch studio +
3 cr seminars structure
- 10 week quarters



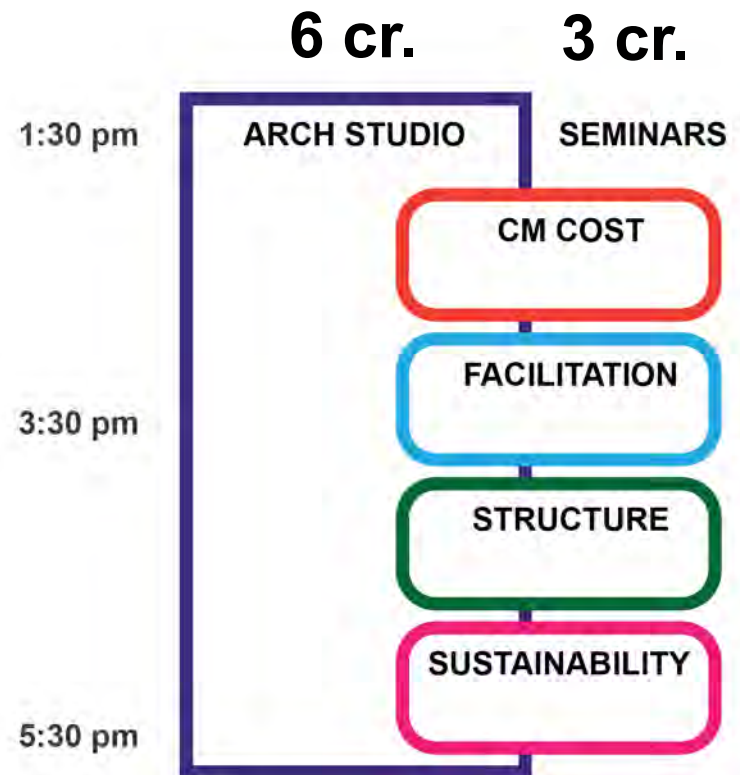
2009: Net Zero Office



2013: Modular Multi-Family

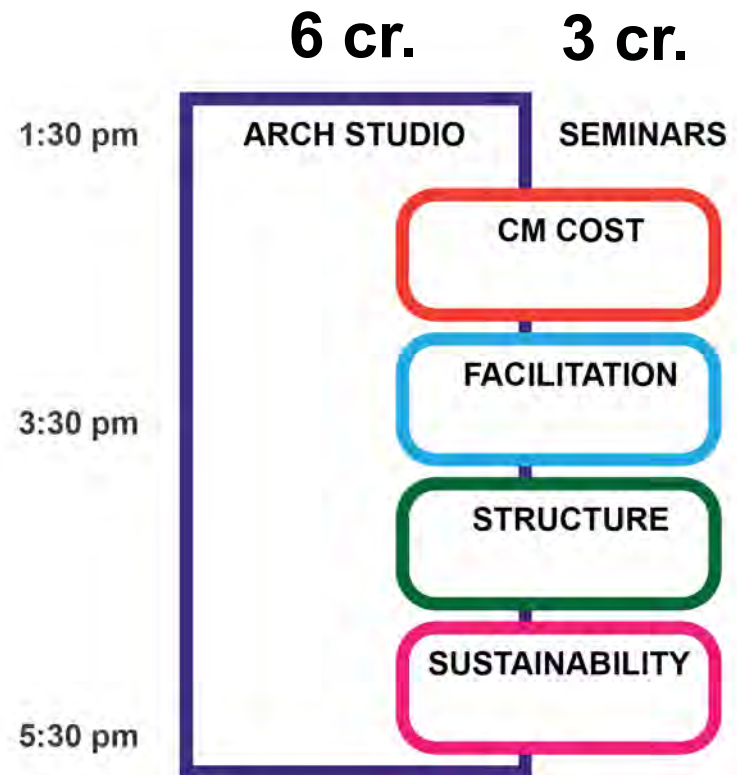
UW Integrated AEC Studios

- Arch Seniors—5th of 6 required arch studios
- Required for Arch/CM dual majors 4th year
- Four seminars—AEC content
- CM Seniors/5th year dual — right before their capstone
- Others take 3 cr. Seminars
 - Usually fulfills elective credits



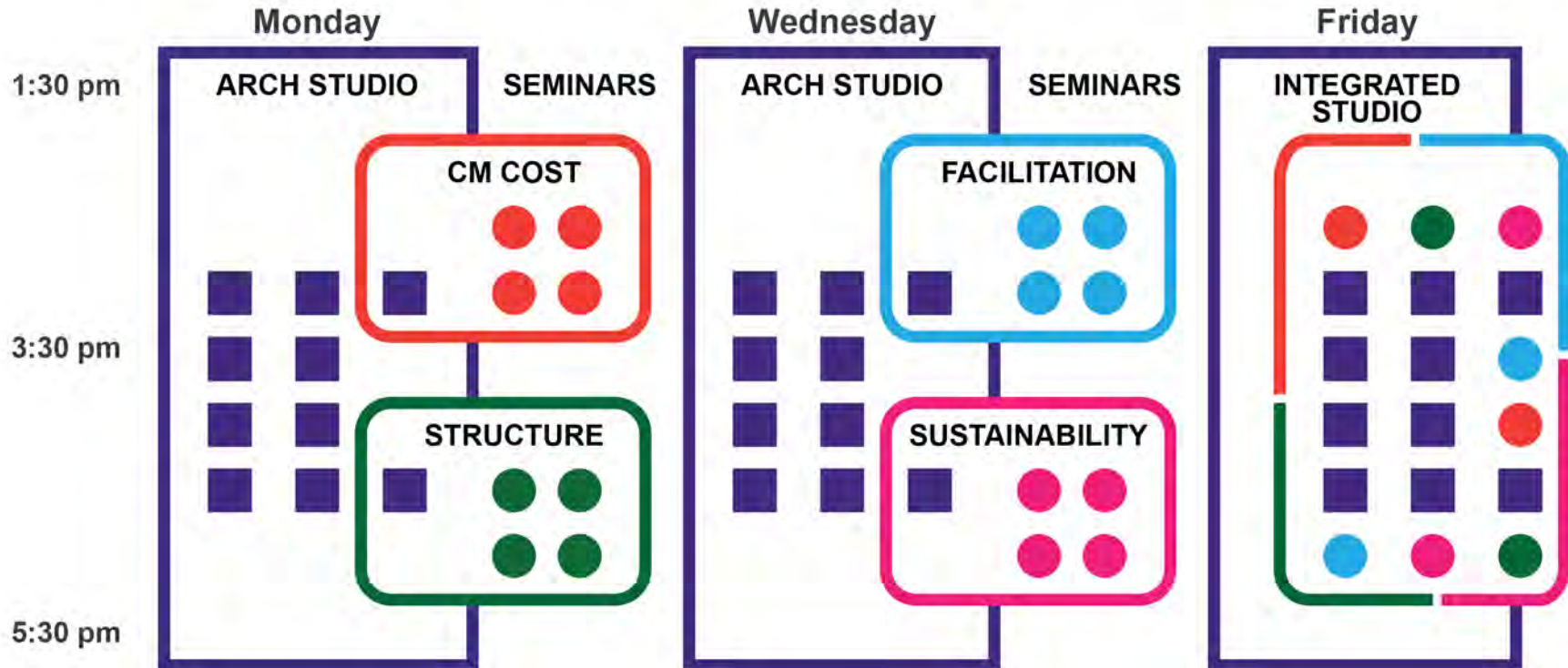
Course Design: Studios and Seminars

- Traditional arch studio
 - 1 faculty member
- 4 seminars
 - 2 faculty members
 - Teach seminars alternate days
- Seminar students have not had prior studio experience
 - Issues: research, proposition, multi-variate problem solving
 - Pin-up discussions (“out”), research for future (“in”)
 - Architecture student “process mentors” for studio habits



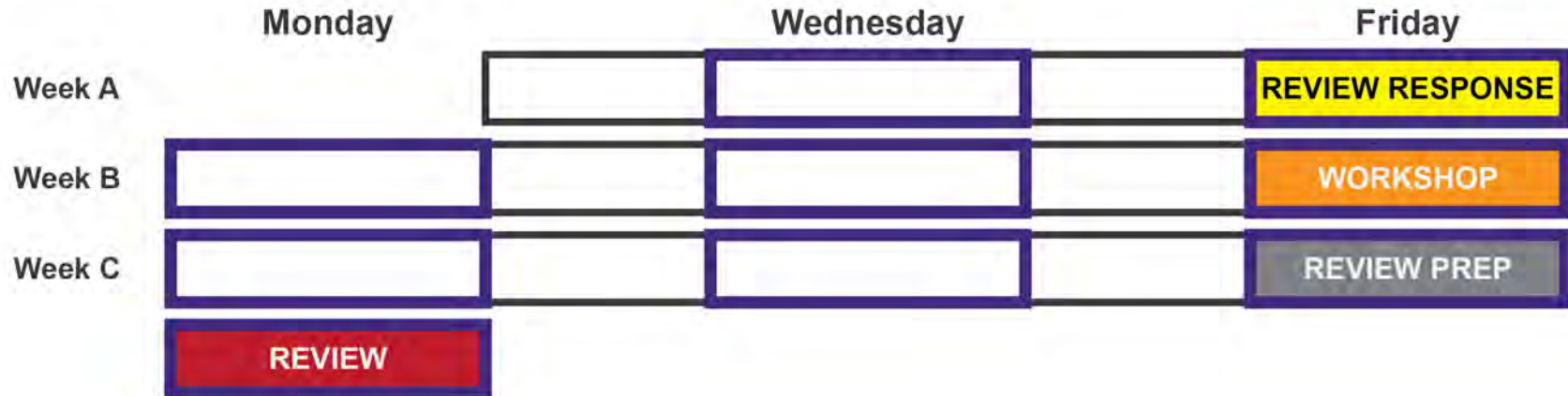
Course Design: Studios and Seminars

- Meet MWF, studio/seminars overlap, Friday team day
- Architecture student “lead” attends seminars



Course Design: “Cycles”

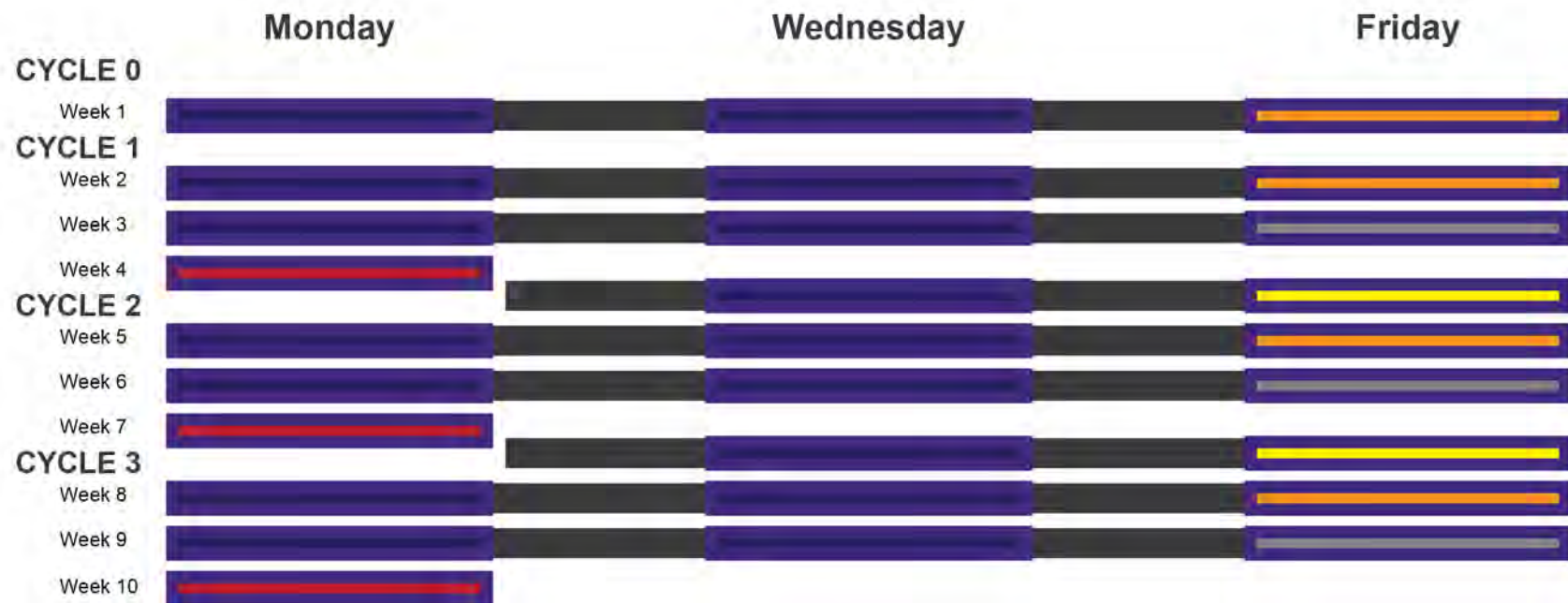
- Content “Cycle”—A) introduction [and review], B) design and integrate, team workshop, C) develop/prepare for review



- Reviews include industry experts and outside faculty
- Review responses are team reflections on information learned at reviews
- Facilitation includes team planning, peer assessment

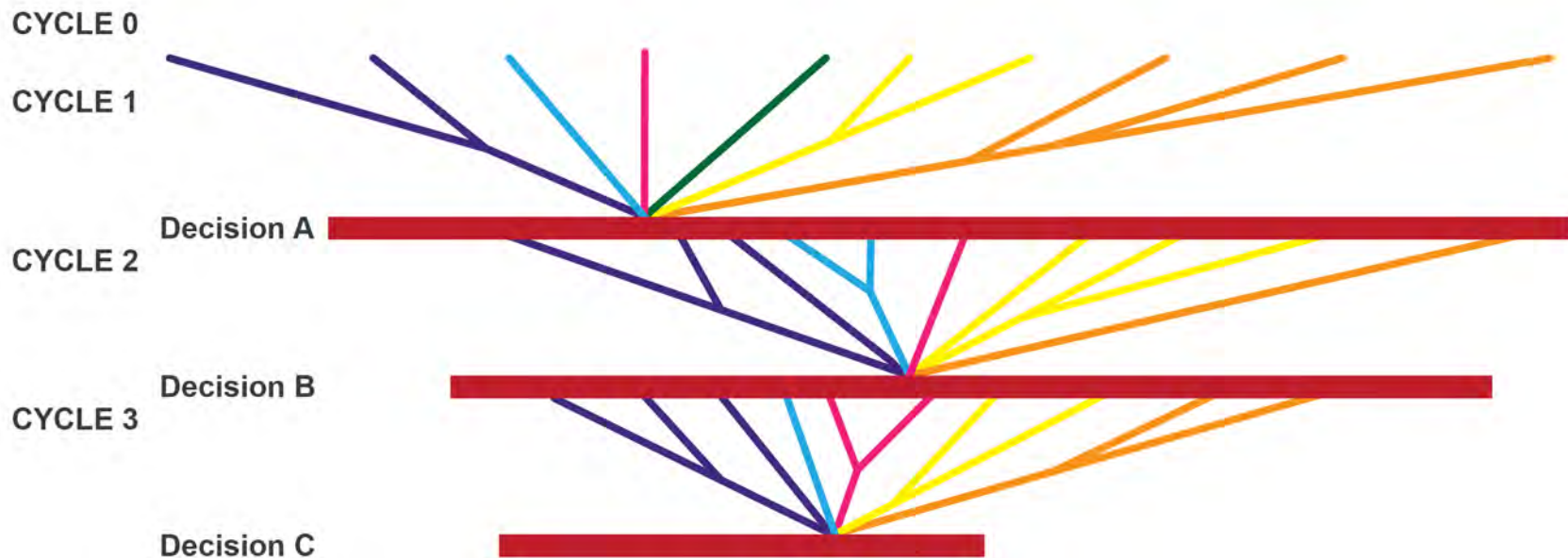
Course Design: “Cycles”

- Content Cycle 0: Intro & analysis, Cycle 1: structural system, Cycle 2: façade/envelope, Cycle 3: “deep dive” system development



Course Design: “Cycles”

- “set-based design”—developed from “set-based concurrent engineering”
Sets of possible solutions considered concurrently, narrow possibilities, converge on final interim solution. New questions posed. (Toyota; Smith, 1997).
- Parallel to LEAN process, fast-track design/construct, IPD



2016 Studio—Timber Frame Office Building

Stone 34 project:

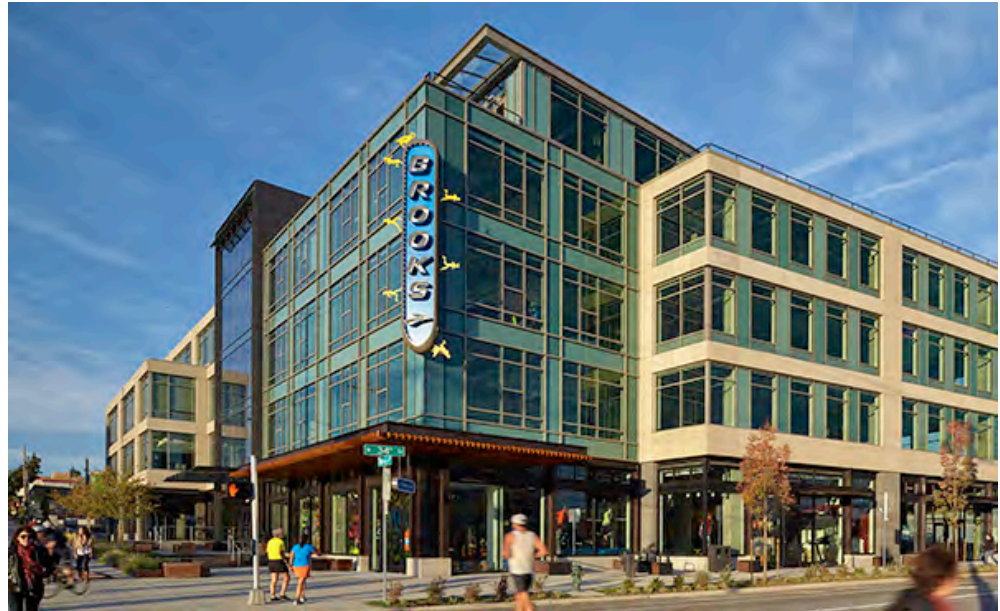
Just-built developer office building
in Fremont

Performance meeting Seattle
Deep Green Pilot program

Studio challenge: reconsider
design with timber frame structure

Metrics: cost, square footage,
sustainability, constructability

Integrated AEC team design
process



2016 Studio—Timber Frame Office Building

Work environment:

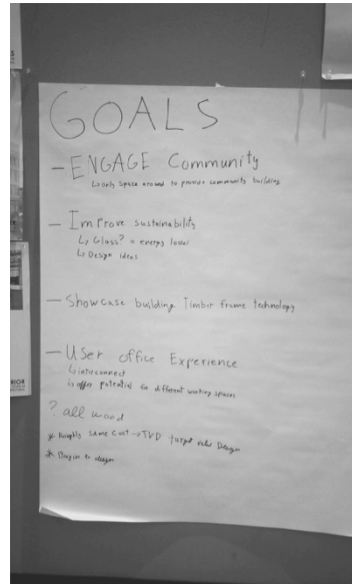
Studio space +
Two adjacent seminar rooms

Work ethic:

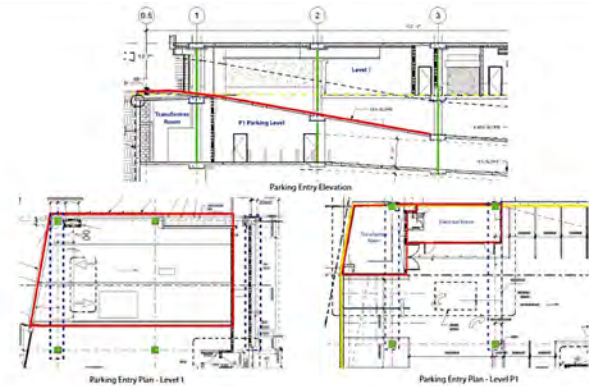
Team buy-in on project goals
Team-driven work periods

Studio instruction:

Full design team crits usual for M & W
Review project progress and discuss options
Fluid full-team work time most F sessions
All instructors stopping in as able to assist



2016 Studio—Cycle 0: Analysis



ZONE: NC3-63
Neighborhood/Overlay: Fremont Hub Urban Village
Height Restriction: 45' + 20' additional to meet LBPP
Rooftop Features: 16' allowance (if occupy > 20% of roof)

Typical building without LBPP height Departure



Building with LBPP height Departure



Create a vibrant pedestrian connection and open up views down Stone Way.

Existing Zoning Envelope



Push the building back to provide significant neighborhood space at grade



In exchange for neighborhood space at grade: Allow additional building height and narrower floorplates, up to 60 ft in height

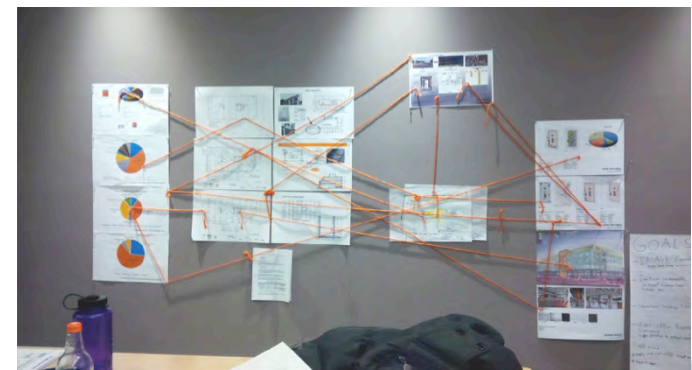


Provide taller floor to floor heights to increase daylight into the building

Week 1 of 10:
Each discipline analyzed documents and gathered information on the Stone 34 project

In a Friday workshop, students pinned up work and shared findings across disciplines

Teams looked for connections between issues identified

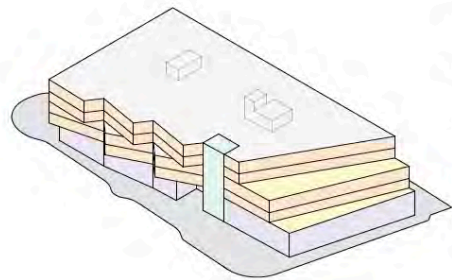
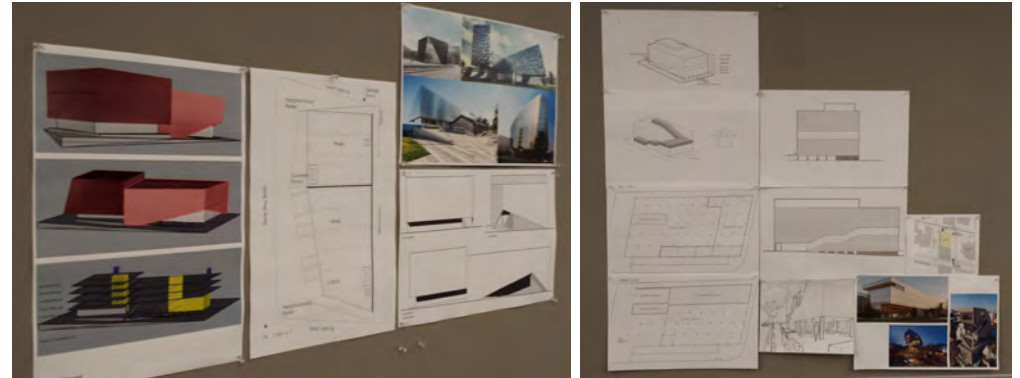


2016 Studio—Cycle 1: Structural System

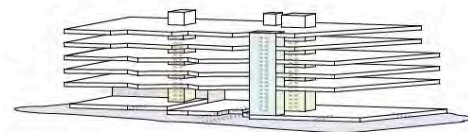
Weeks 2, 3, and 4 of 10:
Teams started with 2-3 massing schemes for preliminary framing analysis

Review at end of cycle 1 was meant to help students use the structural issues to select the best scheme

Decision not uniformly logical

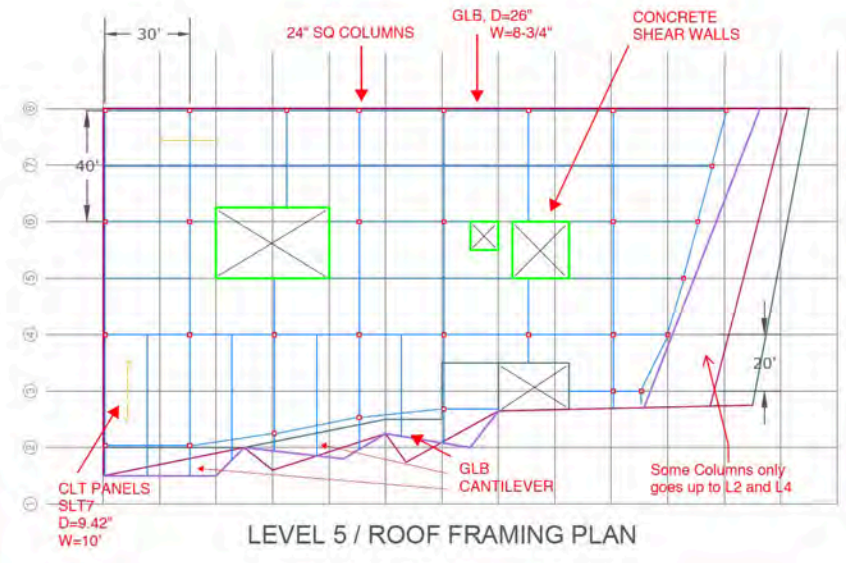


- Office**
Including west facade providing opportunities for Lata (link and downtown view) and south facade (terrace) to view for outdoor terrace space.
- Outdoor Office Terrace**
Adding outdoor terrace for outdoor terrace spaces on office levels to provide additional natural light and creating space for office employees to step away from their work and enjoy the view.
- Retail**
Ground level retail space away from the street giving space back to public activity. It additionally follows the slope of the site (lower or double height retail space with a mezzanine level on the southern building end).
- Feature Stair**
A feature stair located along the west facade at the entrance provides connection between the building's floor and additional natural light to the office spaces.
- Sidewalk Activation**
At the retail level above from the street, space is given back to the community for public use.

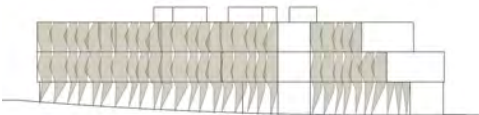
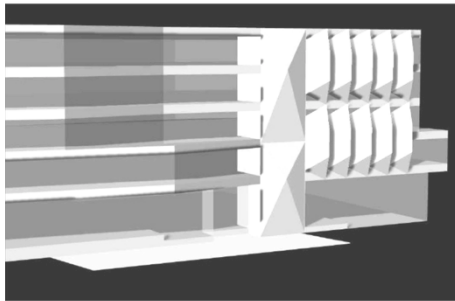


Scheme 1 Circulation

- Egress Stairs
- Elevator
- Sidewalk
- Feature Stair
- Parking Garage Entrance



2016 Studio—Cycle 2: Façade and Envelope

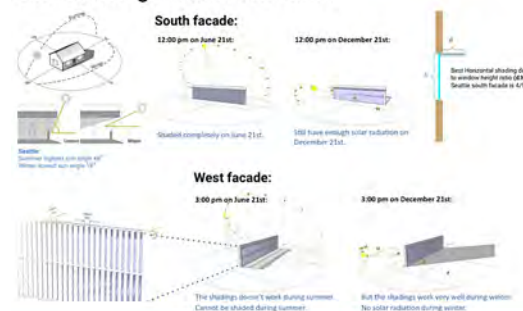


Weeks 4, 5, and 6 of 10:

Design exploration was assisted by information gathering for materials and assemblies

Sustainability factors & strategies were evaluated

Sun Shading/ Solar Heat Gain

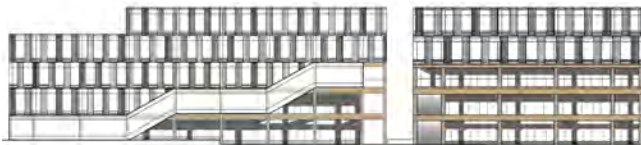


Manufacturers

- PROJECT LOCATION:** 3400 Stone Way North, Seattle, Washington 98103
- GLAZING MANUFACTURER:** VPI Quality Windows, 3420 East Ferry, Spokane, Washington 99202, Distance to Project Location - 286.6 miles
- OPERABLE WINDOW MANUFACTURER:** Wausau Window and Wall Systems, 7800 International Drive, Wausau, WI 54401, Distance to Project Location - 1843.1 miles
- ALUMINUM PANEL MANUFACTURER:** AEP Span, 2141 Milwaukee Way, Tacoma, WA 98421, Distance to Project Location - 34.6 miles
- GLULAM MANUFACTURER:** Mathews Lumber, 15800 Woodinville Richmond Road NE, Woodinville, Washington 98072, Distance to Project Location - 17.6 miles
- CLT MANUFACTURER:** DR Johnson Lumber Co., 1970 Pioneer Road, P.O. Box 66, Rock, Oregon 97148, Distance to Project Location - 375 miles

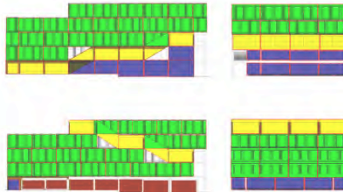


2016 Studio—Cycle 2: Façade and Envelope

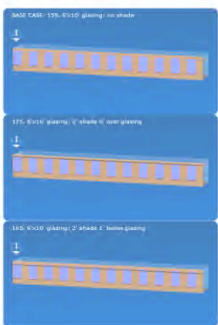


Estimation

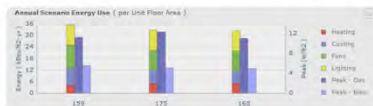
- Stone 34 Envelope
 - o Total SF: 54,124 SF
 - o Total Cost: \$ 3,277,696
 - o Cost/SF: \$ 60.56
- New Design Envelope
 - o Total SF: 49,050 SF
 - o Total Cost: \$ 3,129,708
 - o Cost/SF: \$ 63.81



HORIZONTAL SHADING OPTIONS



Model (sf/floor)	Heating (sf/floor)	Cooling (sf/floor)	Fans (sf/floor)	Lighting (sf/floor)	Total (sf/floor)
159.	3.97	8.87	12.14	10.7	35.68
175.	4.73	6.98	10.41	10.7	32.82
165.	4.94	6.67	10.16	10.7	32.47



- Horizontal 2' deep shades provide energy benefits to South-facing wall
- Shading below top of glazing produces maximum efficiency



Exterior Cost Comparisons



Final design options were analyzed for energy, daylighting, and cost

2016 Studio—Cycle 3: System Development

Weeks 8 & 9:

Partnerships

within teams to

explore in-depth

some aspect or

feature in the

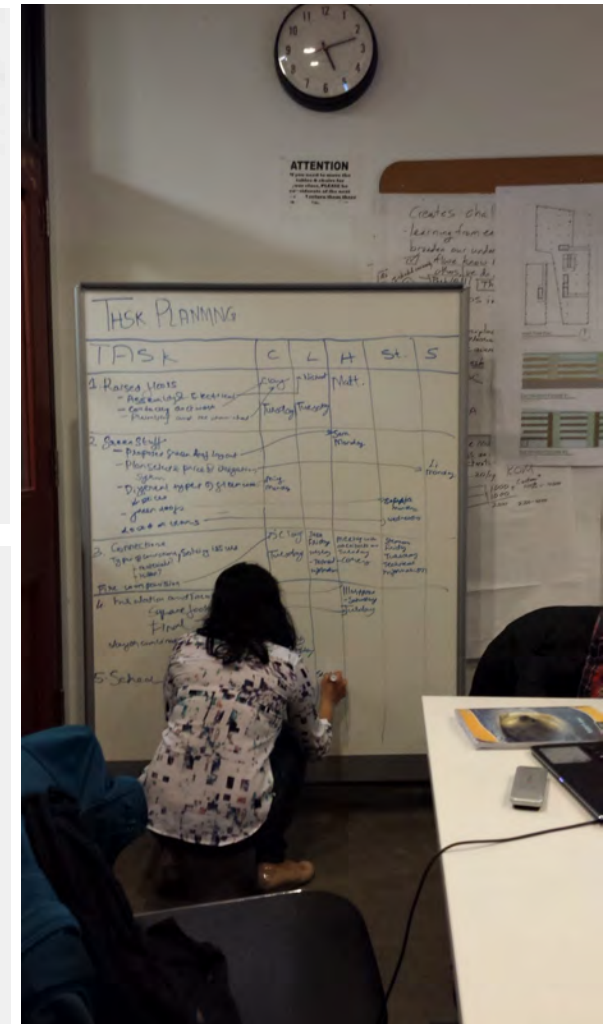
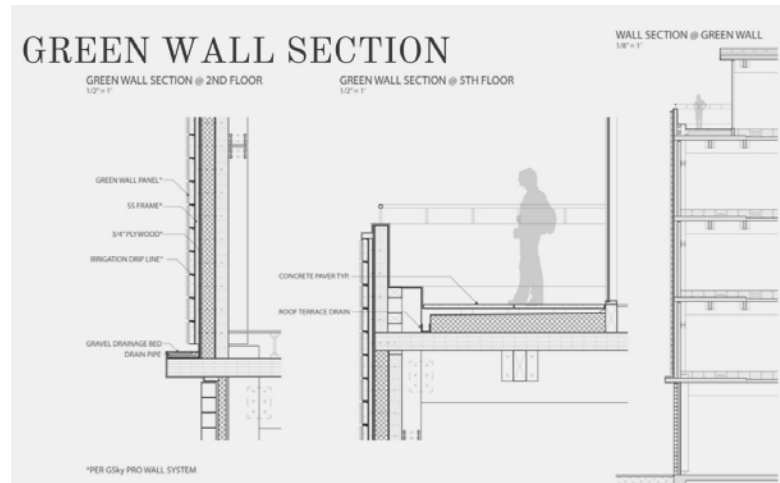
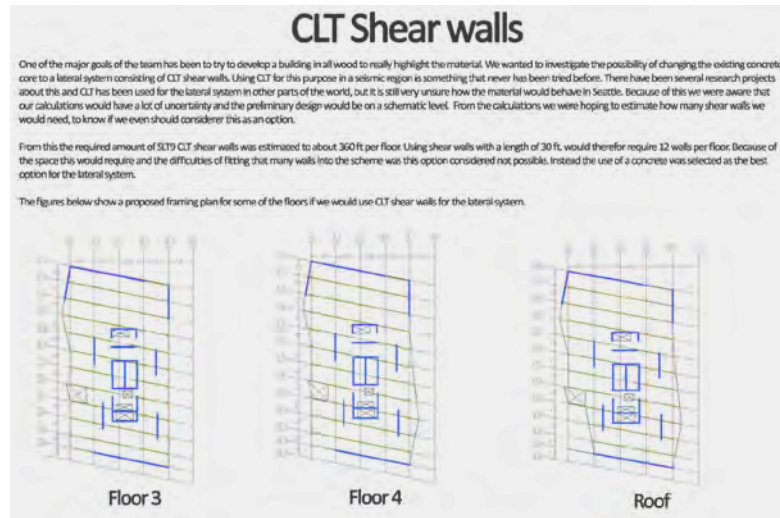
conceptual design

Each “deep dive”

feature should ideally

be understood from

multiple perspectives



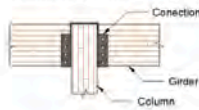
2016 Studio—Cycle 3: System Development

STRUCTURAL - DEEP DIVE CONNECTIONS

Girder to Column



Beam to Girder



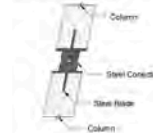
Beam to Wall



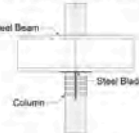
Column to Column



Sloped Column to Sloped Column



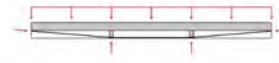
Steel Beam to Wood Columns



POST TENSIONED WOOD BEAMS

Design

- Two point loads on the bottom
- Angled axial compressive force
- Composite member
- Steel strands to eliminate deflection due to applied dead loads



Advantages:

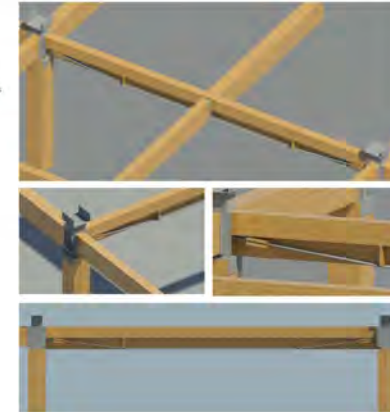
- Decreased beam depth
- Improved structural performance, especially seismic
- Lower cost than traditional beams
 - Without PT Beams: \$3.9M structure
 - With PT Beams: \$3.9M structure
- Innovative technology

Disadvantages:

- High risk due to limited use in the US
- Increased construction time
- Contractor may charge premium

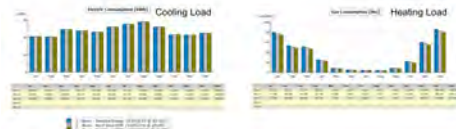
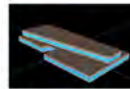
Structural Members with PT:

- Columns - 18" square
- Post-Tensioned Girders - 10.75" x 24"
- Secondary Beams - 8.75" x 22"
- Tertiary Beams - 8.75" x 21"



Thermal Performance of Green Roof

- Two story model in eQuest
- Heat containing > heat reduction



Hydrological Performance of Green Roof

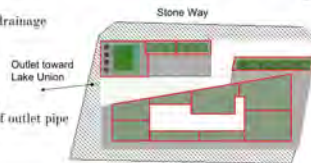
Model peak flow in EPA-SWMM

Green roof applied:

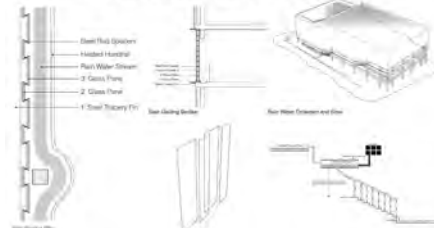
- divided into 12 units for drainage
- 4% Peak flow reduction

Gravels pavement applied:

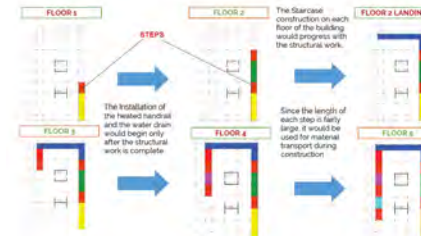
- 11% peak flow reduction
- Potential error: the size of outlet pipe



OPEN AIR STAIR: STAIR RAIN RIVER & HEATED HANDRAIL SYSTEM

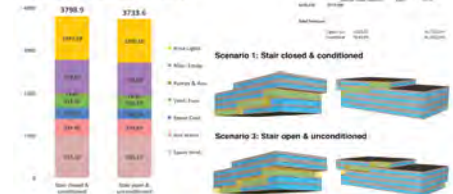


STAIRCASE CONSTRUCTION SEQUENCE



OPEN AIR STAIR: PERFORMANCE & COST

Annual Energy Consumption (MSTU)



2016 Studio—Final Review



Integrated AEC Studio

2016 Studio—Team A



ASCEND 3400 Stone Way N



Team A

Team Members

ARCHITECTS



SHANNEN
MELANIE
GEORGE
RILEY

LOGISTICS



SIDDHARTH
CHRISTINA NHI

STRUCTURAL ENGINEERS



JEAN-LUC
MIRA

COST ESTIMATORS



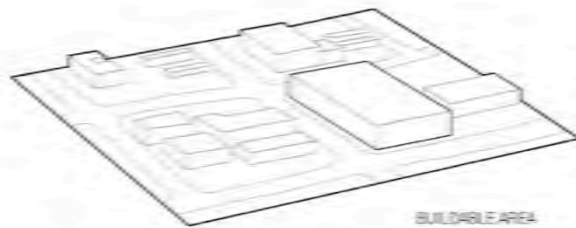
ANTOINE
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SUSTAINABILITY ADVISORS



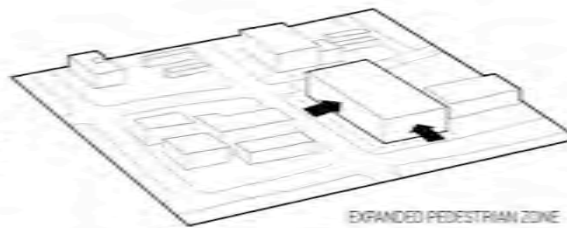
PEYTON
XIUQING

2016 Studio—Team A



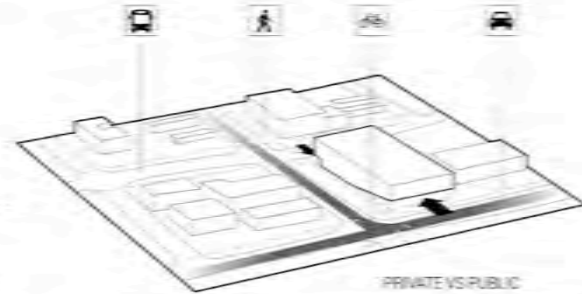
BUILDABLE AREA

The project is given the maximum height, density code restrictions and demands.



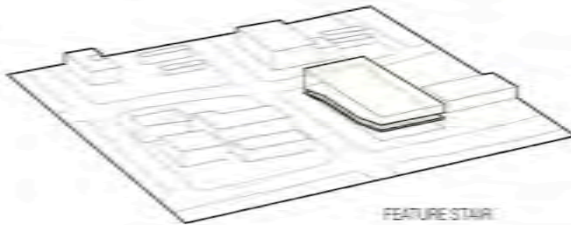
EXPANDED PEDESTRIAN ZONE

The project envelope is pushed back to give some site back to the public for outdoor interaction.



PRIVATE VS PUBLIC

Separation of the public and private spaces is defined by the major thoroughfares around all the building. The building is also positioned on the public space to avoid the worst location.



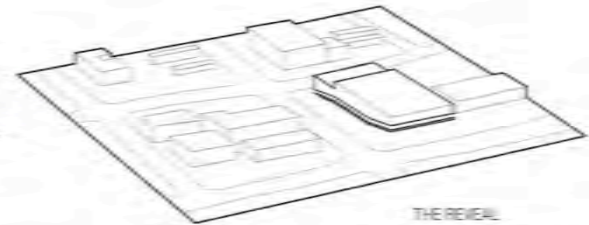
FEATURE STAIR

The grand stair provides access. The stair invites people to come to walk up the stairs then taking the elevator while creating a visual connection with the public.



COLLABORATION SPACES

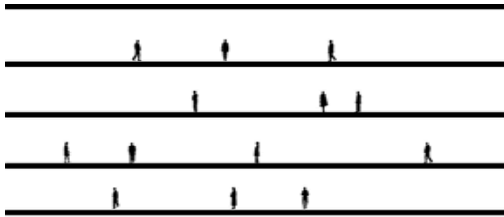
The stair transforms into collaboration spaces in the middle part of the entry to encourage communication among office employees.



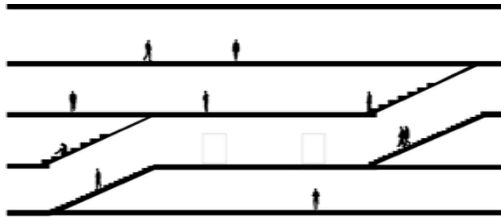
THE REVEAL

A multi-story office building with a central courtyard and a grand stair.

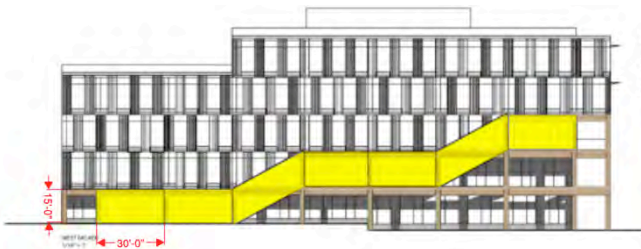
2016 Studio—Team A



TYPICAL MULTI-STORY ORGANIZATION
In a typical midrise office, floors operate in isolation. Even when occupants work for the same organization, their interaction is minimal.

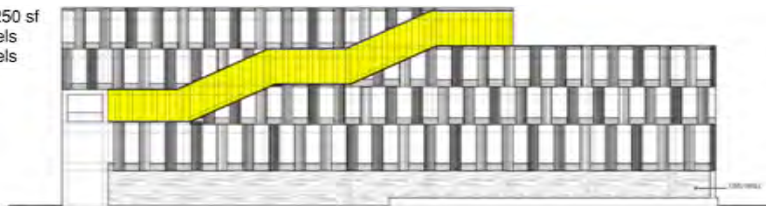


CONNECTED ORGANIZATION
The stair boasts a circulation space that links all the collaboration and interaction between occupants of



Total Area: 3150 sf
2x11: 42 Panels
3x11: 42 Panels

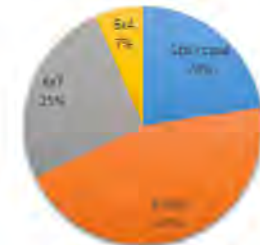
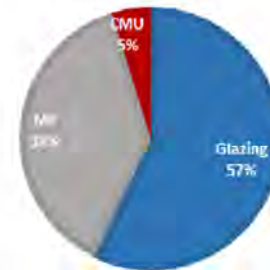
Total Area: 2250 sf
2x11: 30 Panels
3x11: 30 Panels



New 'Big Stairs' Design

	SF/ct	U.P.	Cost	
Glazing	Al Framed Storefront, Dark Mullion (STAIRCASE)	5,400 \$ 75	\$ 405,000	
	Al Framed Storefront, Dark Mullion (Retail)	10,800 \$ 75	\$ 810,000	
	6x7 Punch Windows (Upper), S&I	8,316 \$ 55	\$ 457,380	
	6x4 Pop out Windows (Upper), S&I	198 \$ 600	\$ 118,800	
Glazing	24,516		\$ 1,791,180	
Metal Paneling	Metal Panel Framing	16,632 \$ 31.50	\$ 523,908	
	Aluminum Paneling 4x15, Vertical	11,880 \$ 40.00	\$ 475,200	
	Aluminum Paneling 4x6, Horizontal	4,752 \$ 40.00	\$ 190,080	
Metal Paneling	16,632		\$ 1,189,188	
Masonry	CMU Panels @ Retail S&I + Water Repellents	3,150 \$ 47.60	\$ 149,940	
	Masonry	3,150		\$ 149,940
Total Exterior Envelope		49,050	\$ 63.82	\$ 3,130,308

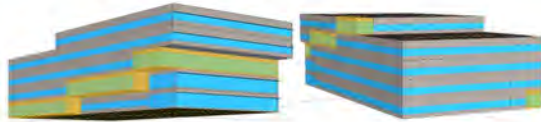
ENVELOPE BREAKDOWN



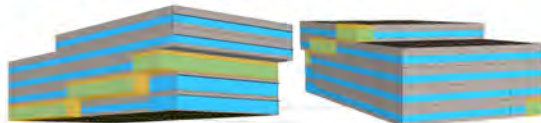
2016 Studio—Team A

Energy & Performance Analysis

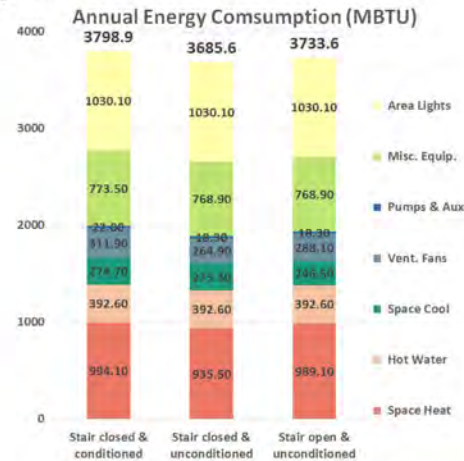
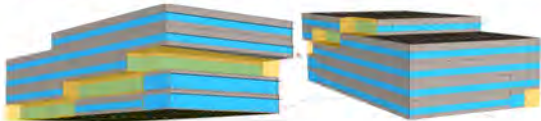
Scenario 1: Stair closed & conditioned



Scenario 2: Stair closed & unconditioned



Scenario 3: Stair open & unconditioned



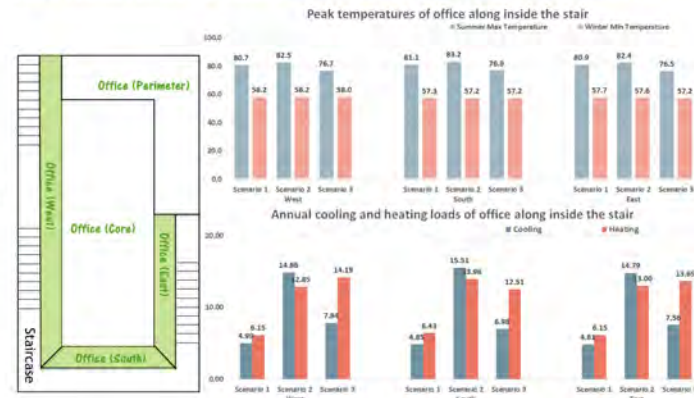
Comparing with scenario 1, scenario 2 consumes less energy for cooling and heating as the total conditioned space is reduced.

Comparing with scenario 2, some of the core office zones are turned to be perimeter zones after the stair became an open air space in the scenario 3. So in the scenario 3 the building consumes less energy for cooling, but more energy for heating. When comparing the total energy consumption, scenario 2 consumes the lowest.

Peak temperatures & total loads of office along inside the staircase

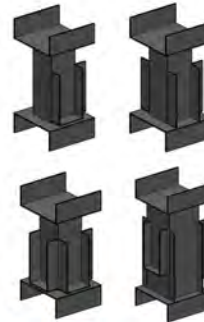
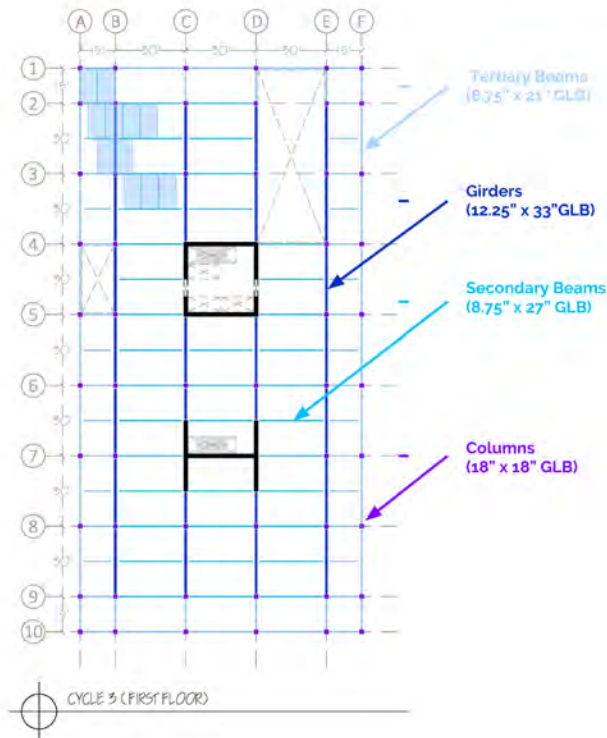
When the staircase is open, the maximum temperatures during summer are reduced by 7.0% in the West, by 7.6% in the South, and by 7.2% in the East compared to the scenario 2. This reduction is probably attributed to the effectiveness of natural ventilation as those three areas are turned into perimeter zones. Natural Ventilation helps a lot in moving away the cooling loads from the office space. While, during winter, the minimum temperatures are not decreased too much. And this can be explained with the high internal heat gain in the office space offsets part of the heating load.

Considering both the energy consumption and the comfort condition, scenario 3 is the best design scenario.



2016 Studio—Team A

Framing, Columns, and Connections



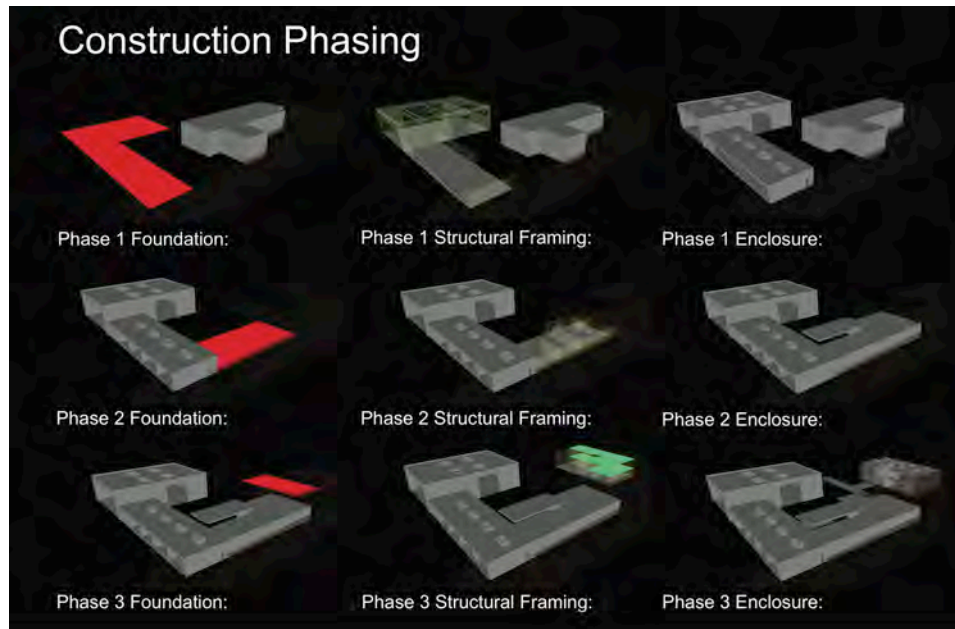
Structural Connections Cost Analysis

Description	Quantity	Cost	Total
Cycle 2 Structure			
Special Fabricated Fasteners	60	\$ 500.00	\$ 30,000.00
Girder Fasteners	200	\$ 385.00	\$ 77,000.00
One Level Cost			\$ 107,000.00
Total Cost			\$ 535,000.00
PT Beam Structure			
Special Fabricated Fasteners	54	\$ 500.00	\$ 27,000.00
One Level Cost			\$ 27,000.00
Total Cost			\$ 135,000.00

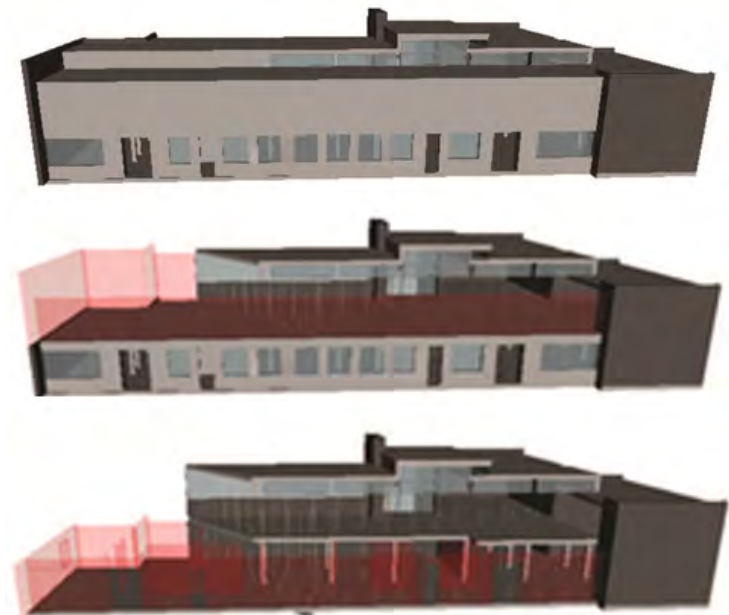
Post Tension Beam Cost Analysis

Description	Quantity	Length	Cost	Total
Beams				
8.75" x 21" x 30'	93	30	\$ 35.78	\$ 99,826.20
8.75" x 21" x 15'	210	15	\$ 35.78	\$ 112,707.00
12.25" x 24"	189	30	\$ 45.00	\$ 255,150.00
PT Beams				
(2) 2.5" x 12"	224	30	\$ 8.84	\$ 59,404.80
10.75" x 12"	112	30	\$ 29.82	\$ 100,195.20
PT Cable	70	110.25	\$ 2.50	\$ 19,293.75
Columns				
18" x 18"	252	10	\$ 74.75	\$ 188,370.00
CLT Slab				
5-Ply	5	28800	\$ 15.00	\$ 2,160,000.00
Concrete Topper				
2" Topper	5	178.13	\$ 675.00	\$ 601,200.00
Total Building Cost				\$ 3,596,146.95

Insights: Cooperation vs Collaboration



Team B Cooperative 4D Model



Team A Collaborative 4D Model

Insights: Spaces Reinforce Norms

- Teams differed significantly
- Collaboration norms established early
- Co-ownership in design
- Strong relationship between space usage and interaction

“It is not only a matter of appropriate hardware and software, but also one of appropriate digital studio layout to facilitate collaborative team work.”

- Bob Holland

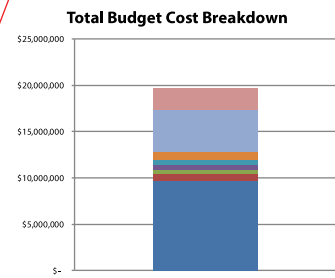


Integrated AEC Studio

Examples: Communicating Analysis

Final Review Cost Analysis

SUPERSTRUCTURE	Total \$	\$/SF
1-Bedroom	\$ 5,635,649	\$ 151
Studio	\$ 3,442,912	\$ 143
Penthouse	\$ 330,441	\$ 105
Amenity	\$ 313,584	
Roofing	\$ 752,987	
Conveying	\$ 397,575	
Exterior Finishes	\$ 619,355	
Landscaping	\$ 432,740	
Logistics	\$ 912,400	
Subtotal	\$ 12,837,643	
SUBSTRUCTURE	Total \$	\$/SF
Podium	\$ 4,542,838	\$ 210
Subtotal	\$ 4,542,838	
Total	\$ 17,380,481	
Overhead	\$ 2,350,680	
Approx Total	\$ 19,731,161	



Total Units	135
Total Modules	216
Residential Area	64572
Commercial Area	6100
Amenity Area	1771
Total Assignable	66704
Usable Area	107389
Assignable:Usable	62%
Modular Budget	\$ 9,722,586
Substructure Budget	\$ 4,542,838
Total Budget	\$ 14,265,424
Transportation Cost	\$ 556,000
Total \$/ Usable SF	\$ 151
Modular Budget:Total Bud	68%
Total Annual Rent	\$ 2,416,982
Years to Return	8

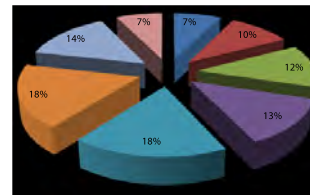
Figure 1. Total Cost Breakdown with Total Budget Bar Chart

Figure 2. Final Low Rise Data Table

1-Bedroom Cost Breakdown	Quantity	Unit	\$/ SF	Total	Assumptions	Percentage
1 Bedroom	526	SF	\$ 151	\$ 79,375	Unit is made up of two modules.	100%
Structural	1	LS	\$ 11	\$ 5,950	See Breakdown Below	7%
Finishes	1	LS	\$ 15	\$ 7,910	See Breakdown Below	10%
Mechanical-HVAC	463.5	SF	\$ 21	\$ 9,683	See Breakdown Below	12%
Electrical	463.5	SF	\$ 20	\$ 10,491	See Breakdown Below	13%
Plumbing	1	LS	\$ 27	\$ 14,046	See Breakdown Below	18%
Exterior Enclosure	1	LS	\$ 27	\$ 14,179	See Breakdown Below	18%
Bathroom	1	EA	\$ 21	\$ 11,305	See Breakdown Below	14%
Kitchen	1	EA	\$ 11	\$ 5,812	\$/SF is based on Kitchen total dependent on the SF of the entire 526 SF	7%

Figure 3. 1-Bedroom Cost Breakdown Table with Pie Chart

1-Bedroom Cost Breakdown



	SR85	SR125
CHARRETTE	\$ 21	\$ 21
CYCLE1	\$ 17	\$ 25
CYCLE2	\$ 17	
CYCLE3	\$ 24	
FINAL REVIEW	\$ 20	

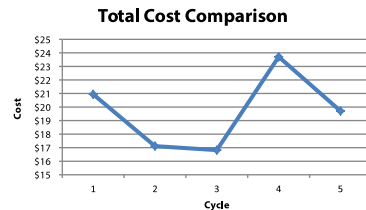


Figure 4. Total Cost Comparison Table with Line Graph

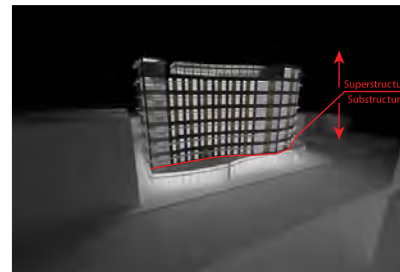


Figure 5. Superstructure and Substructure

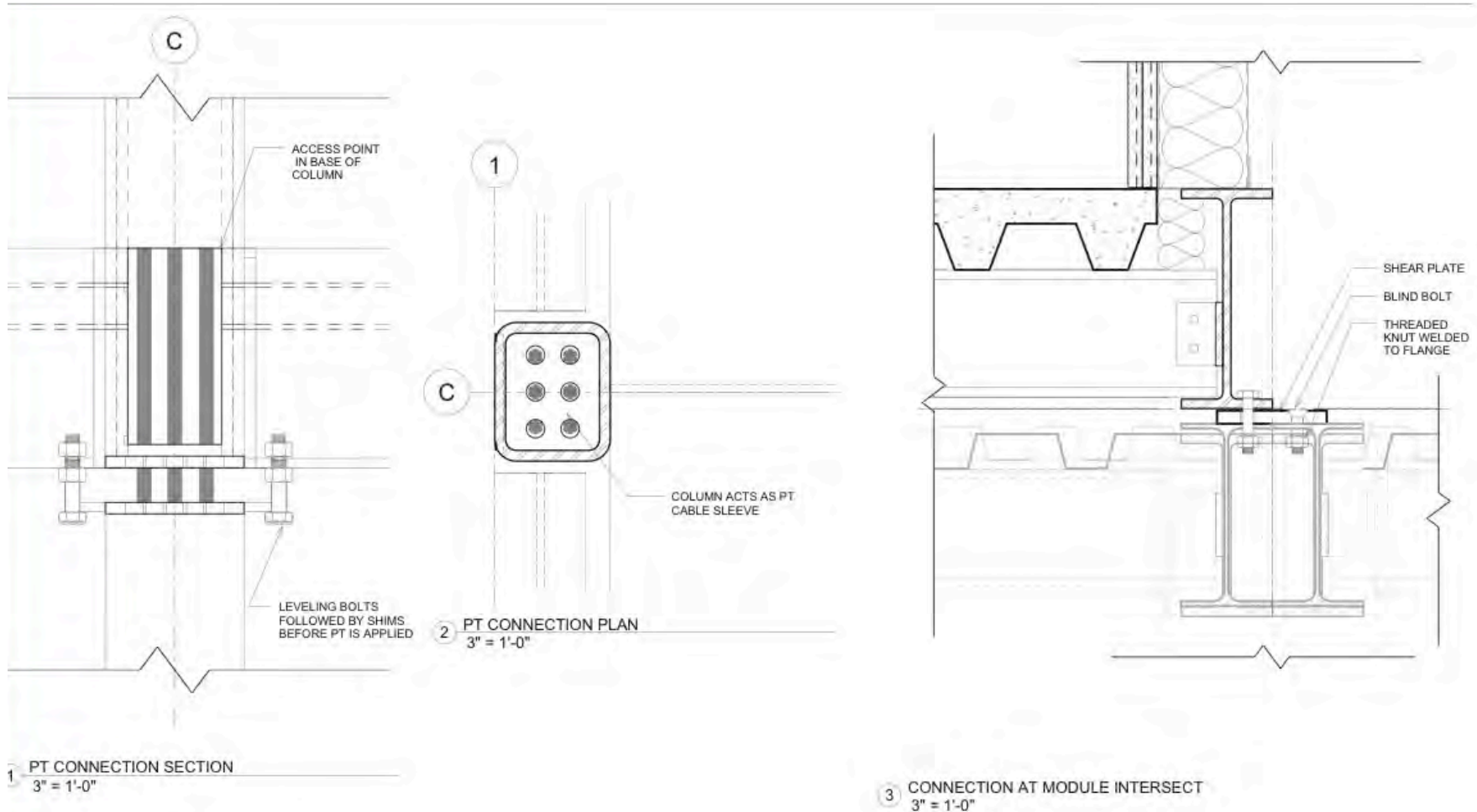
Narrative:

Final Review Cost Analysis has taken all of the research done thus far and modified costs to match all assumptions, and re-designs. Assumptions include: 10% reduction for all factory/modular offsite work (Figure 5), deduction of Walkable Skylight, corrections to structural costs to match agreed upon materials, corrections to exterior enclosure to match agreed upon materials (Figure 3), and corrections to Transportation to account for shape of modules and transportation of two modules for 1-Bedroom, Penthouses, and two Amenity Spaces (Figure 2). The changes mentioned above not only made our estimates more accurate, but reduced our costs significantly from \$23.7 million to a total of \$19.7 million with inclusion of Overhead (Figure 1).

Figure 2 also depicts that our total Assignable and Usable Areas have decreased due to more accurate design take-offs. Even though these areas have been lost we have gained costs in Landscaping costs (Figure 1) which include Green Roofs, Bio-Swales, Trees, and interior Atrium Green Mounts. What we have sacrificed in cost and usable and assignable area we have made up in designing a friendlier community space which exhibits a sense of welcome inside and out.

We have also gone back and took a look at our past cost estimates and came to find out that we have been on quite the adventure. As Figure 4 shows, we have abandoned the High Rise - SR 125 option and continued on with the Low Rise - SR 85. The biggest change in cost occurred between Cycle 2 and Cycle 3 when our modular structural system, exterior enclosure system, and transportation took on high \$/SF and miscalculations. Through this Cycle we have learned that there is always room for data, design, and assumptions to change and improve. At this stage in our studio project development we have achieved a reasonable cost for modular Low Rise construction, at \$151/SF of total cost, with an amazingly low return rate of 8 years (Figure 2). The data presented here represents our best and final numbers for the project at hand, as well as our understanding of the entire project itself. This project has given us an interesting perspective of all components and key players that are involved in the Design-Build process. The amount we have learned as a team is exponential, and will be extremely useful in all of the different fields that we will be pursuing individually.

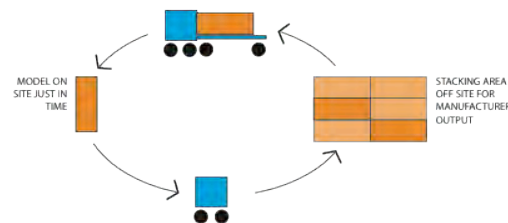
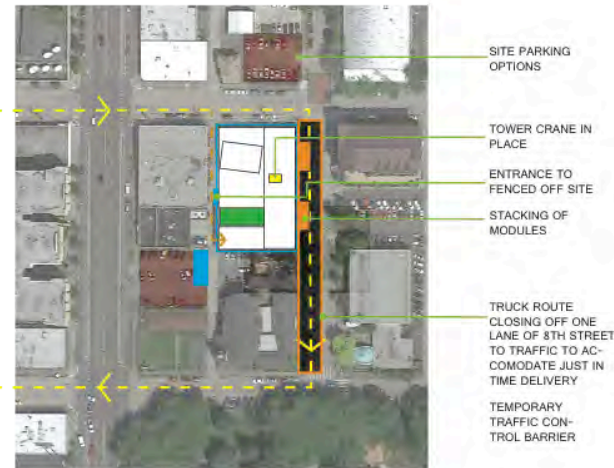
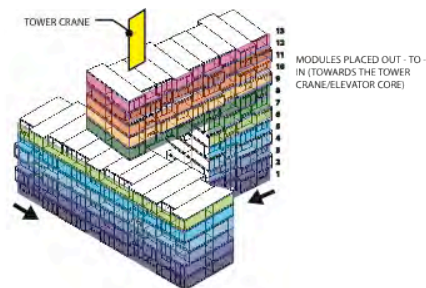
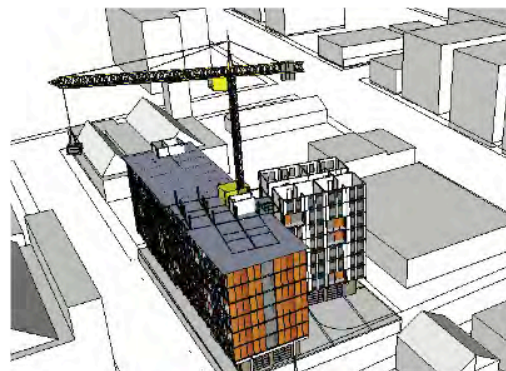
Examples: Communicating Details



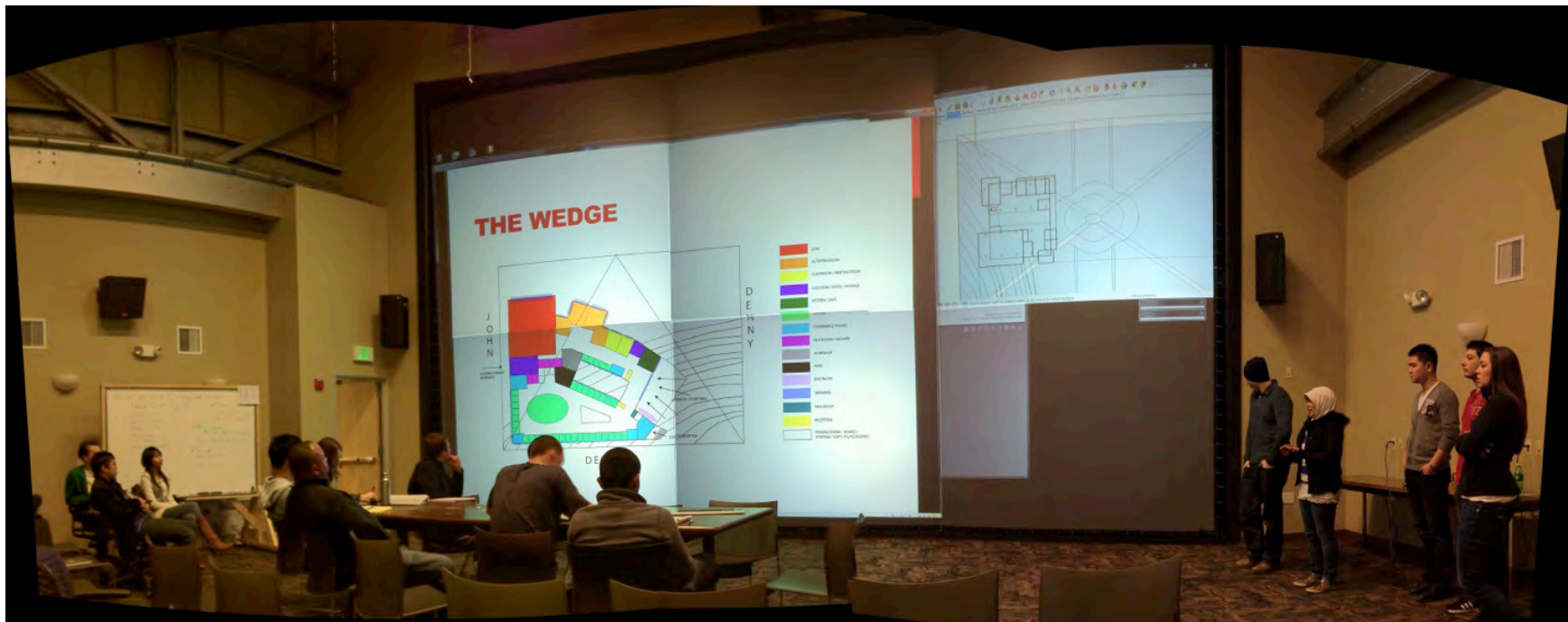
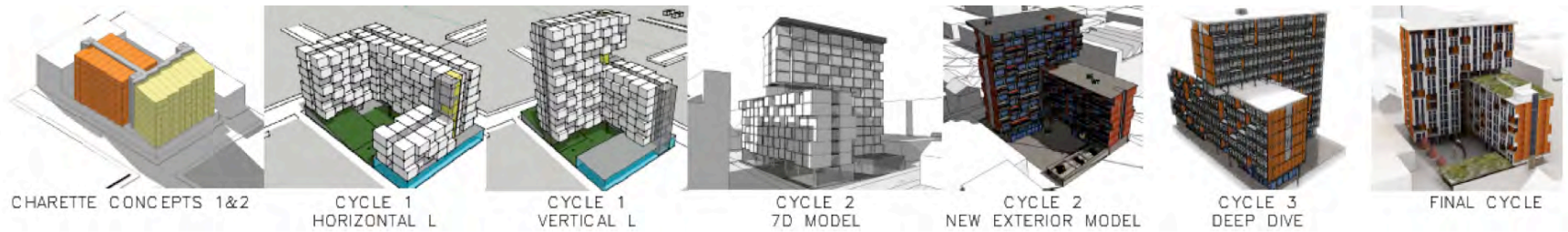
Examples: Communicating Constructability



STEP FIVE: MODULES LEVEL ONE



Presenting to Industry and Instructors



Integrated AEC Studio

W
COLLEGE OF BUILT ENVIRONMENTS



The UW Integrated AEC Studio: Pedagogy, course structure, and insights from 2009 - 2016

Ann Marie Borys (Architecture)

Kate Simonen (Architecture)

Carrie Sturts Dossick (Construction Management)

Chris Monson (BE Ph.D.)



COLLEGE OF BUILT ENVIRONMENTS

Complexity → Interdisciplinary Learning

More than one discipline

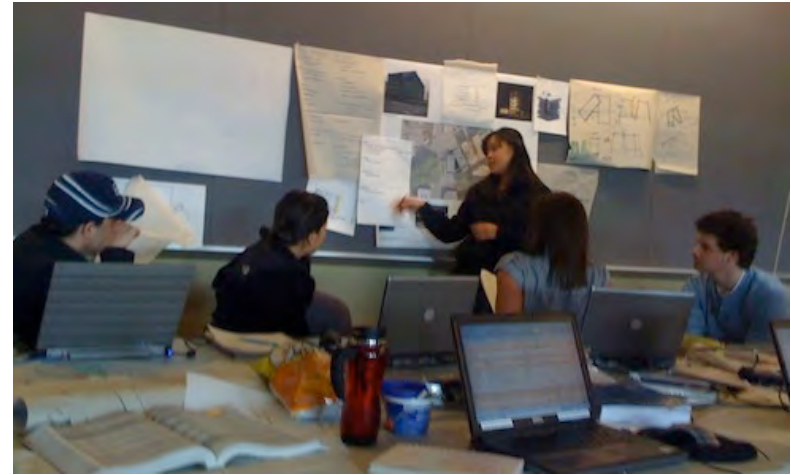
Methodology

Language

(Schaffer et al. 2008; Orr, 2006)

Interdisciplinary studio (lab)
design courses

(McCuen & Fithian 2010; Dossick & Pena 2010;
Holland et al. 2010; Dib & Koch 2010;
Gardzelewski et al. 2010; Salazar et al. 2010)



Interdisciplinary Work

“design as a **social** process”

(Bucciarelli 1994)

develop **shared mental models** collaboratively

(Orr 2006)

A move away from **cooperative approaches**

- division of work into independent parts (Smith et al. 2005)

Collaborative interdisciplinary learning

- unstructured processes
- negotiate goals,
- define problems,
- develop procedures, and
- produce socially constructed knowledge

(Goldsmith & Johnson 1990, Dorsey et al. 1999)