INTERNSHIP RESEARCH PROGRAM

Modular Construction Brief

2022

MVE + PARTNERS

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- Zaha Hadid Modular Housing Complex For Honduras

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- Project Site
- MVE Proposal
- Project Program
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- Schedule

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

Types Of Materials (Lightweight)

Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)

2D Panels - Flexible Design and Simple Logistics

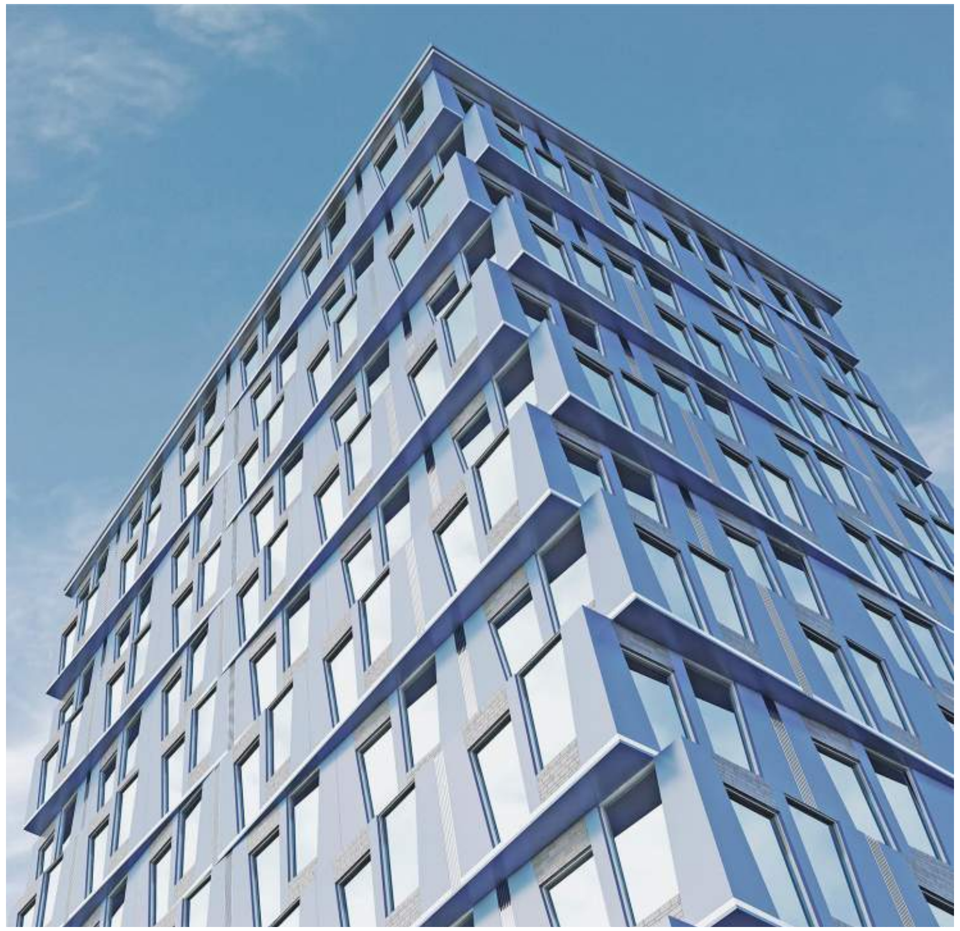
Have you ever put together an IKEA bookshelf or other prefab furniture? Then you're familiar with 2D panelized modular construction. The only difference is that construction projects use many more panels and the panels are generally much larger and more varied. They can be unfinished, finished or even contain conduits for air-conditioning, ventilation and plumbing.

3D Modules - Increased Productivity and Efficiency

A 3D module can be anything from part of a room or a whole room to part of a building or even a whole building. It can also be unfinished, pre-finished or fully finished and ready to hook up to utilities.

Hybrid Modular Construction - The Best of Both Worlds

Depending in the project, the best option can be the hybrid model. This approach combines the flexibility and shipping advantages of the 2D panels with the productivity benefits of 3D modules. One common hybrid solution is to use 3D modules for kitchens and bathrooms and 2D panels for the rest of the building. This means that the intricate work for the kitchen and bathrooms can be done in the factory without limiting the size of the finished building.



https://selogroup.co/precrafted-construction-its-a-process-not-a-product/

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

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Wood

Wood stands out for its very high static quality. In reference to its deadweight, wood carries 14 times as much as steel; its pressure resistance equals that of reinforced concrete. Multi-story wooden buildings and wide-area load-bearing structures are optimal areas of use. The reason for the high stability is the microstructure of wood, which ensures high load-resistance with simultaneously low deadweight. In spite of its low weight, wood offers high tensile and pressure resistance and it is resilient to weathering when it is used correctly.

Steel

Steel is a very strong material which explains why it is used in most building construction industries because it has strength to weight ratio which is very high. It is also famous for its ability to withstand temperatures at very high degrees. However, the material may become weaker bit if exposed to extremely high temperatures which may compromise its functionality. You can either weld or bolt the shapes together and they will stick perfectly.

Concrete or Cement

Concrete is extremely resistant to the physico-chemical attack emanating from the environment: frost, rain atmospheric pollution, etc. It is particularly well-suited for structures exposed to demanding and extreme conditions. Porosity and density. These properties are responsible for the first two.

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Step 1 - Design

Modular design needs to consider not only the final product but also the requirements of factory assembly and transportation. What really sets the design process apart in precrafted buildings is its reliance on vast libraries of modules from past projects. As designers create new plans, they draw on these modules, which they alter as necessary. This speeds up the design process and ensures that few, if any, changes will be needed down the line.

Step 2 - Factory Manufacturing

Next comes the manufacturing process. Repeatable tasks are automated and difficult tasks are done with precise machine-assisted tools that allow relatively few low-skilled workers do the work of many high-skilled craftsmen. Since weather is not a concern, there is little downtime. All of this leads to faster build times and lower costs than traditional construction.

Step 3 - Foundation Work & Transportation

While workers in the factory are constructing the building, other workers can simultaneously complete the foundation. This saves months of valuable time.
Since pre-fabricated building have to be transported to the site, they are made of lighter, stronger materials than traditional construction.

Step 4 - On-Site Assembly

With the foundation laid, the building is transported tot he site. The building or elements of the building can be transported in one piece, secured tot he foundation, and hooked up to plumbing and electricity services.

https://selogroup.co/precrafted-construction-its-a-process-not-a-product/

Phase 1: Research for Building Use - Residential & Hospitality

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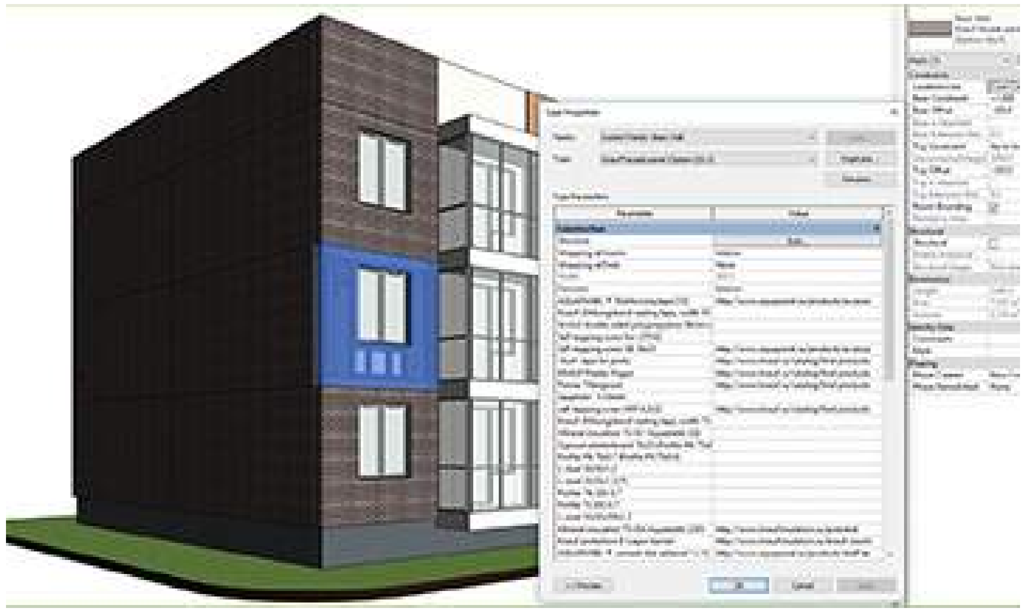
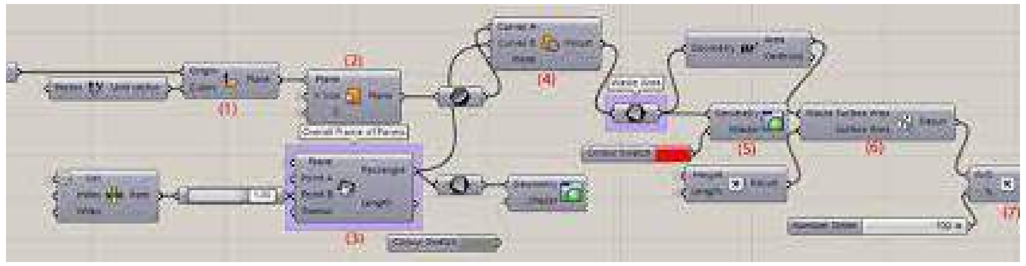
Coordinate!

Scripting .... **BIM**

1 | Automation
2| Iterate. Really Fast

1| Coordinate Systems
2| Clash Detection





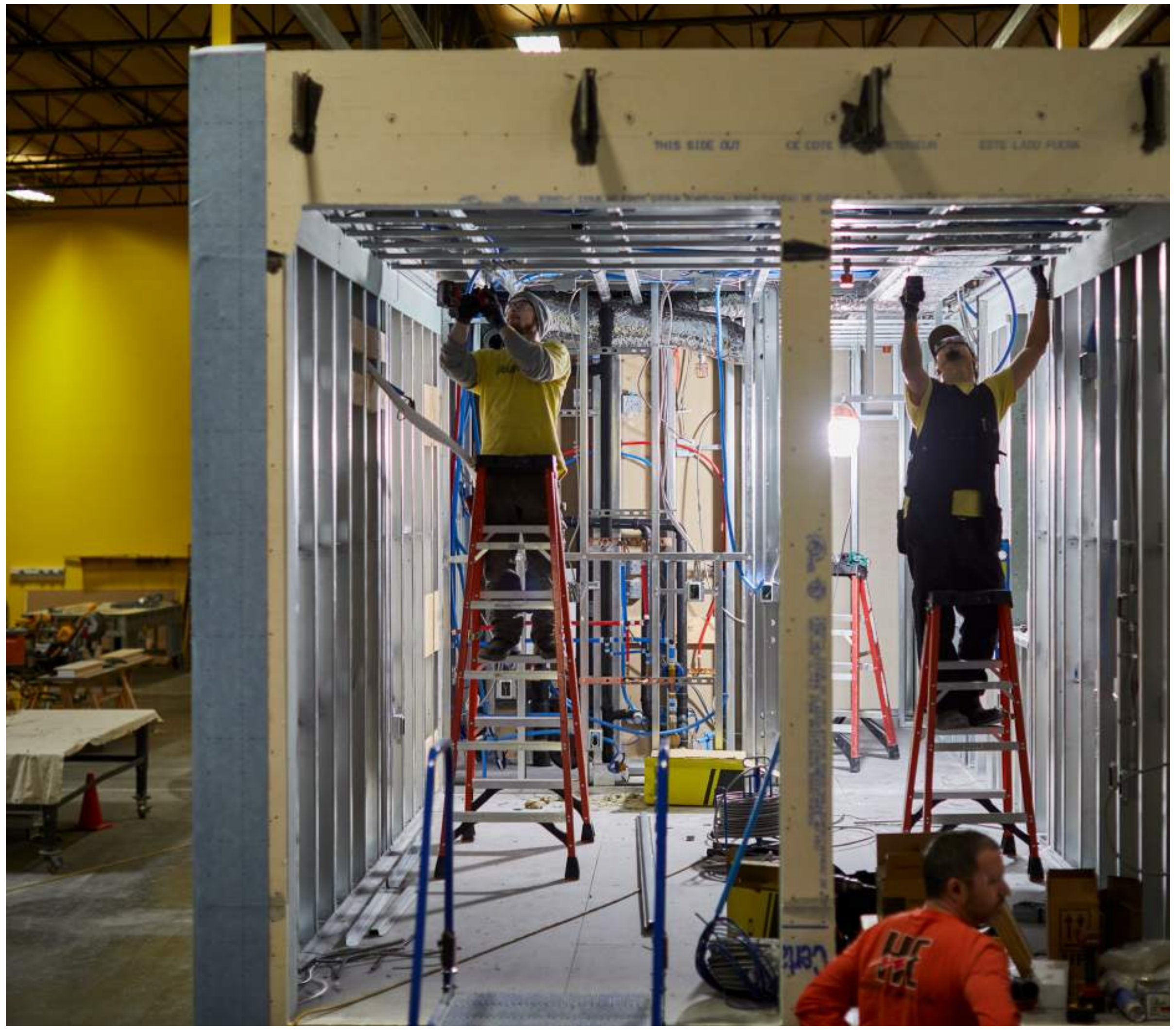
“Blockable” Vertically Integrated Modular Development

Mga Architects Modular Housing Prototype

Gensler & Arup Citizenm Modular Hotel, Seattle

Precht Studio Concept For Modular Housing With Their Own Vertical Farm

Zaha Hadid Modular Housing Complex For Honduras



Blockable Prototypes

Buildings are standardized and repeatable, thereby reducing assembly time

Vertically Integrated Modular Development

https://blokable.com/vim/

https://vimeo.com/670248425

Phase 2: Precedents

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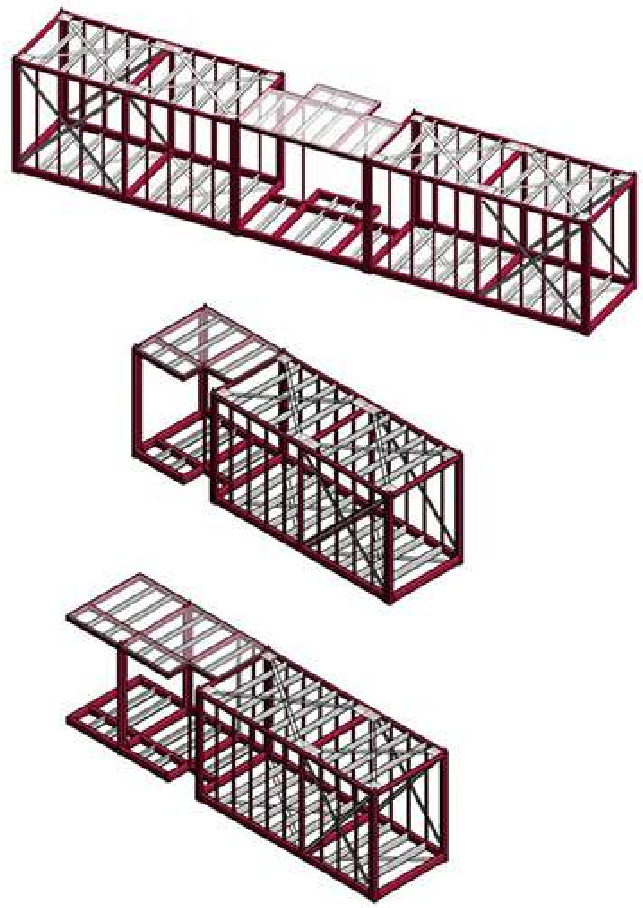
Module

Components Of Module

Elevation

https://mg-architecture.ca/work/honeycomb-housing-prototype-product/



Structurally Detailed Module With Connection

Placing Modules On Site

Exterior View

Interior View

https://www.arup.com/projects/citizenm-seattle-south-lake-union

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Exterior View

Interior View

Step by Step Process

https://www.dezeen.com/2019/02/22/precht-farmhouse-modular-vertical-farms/

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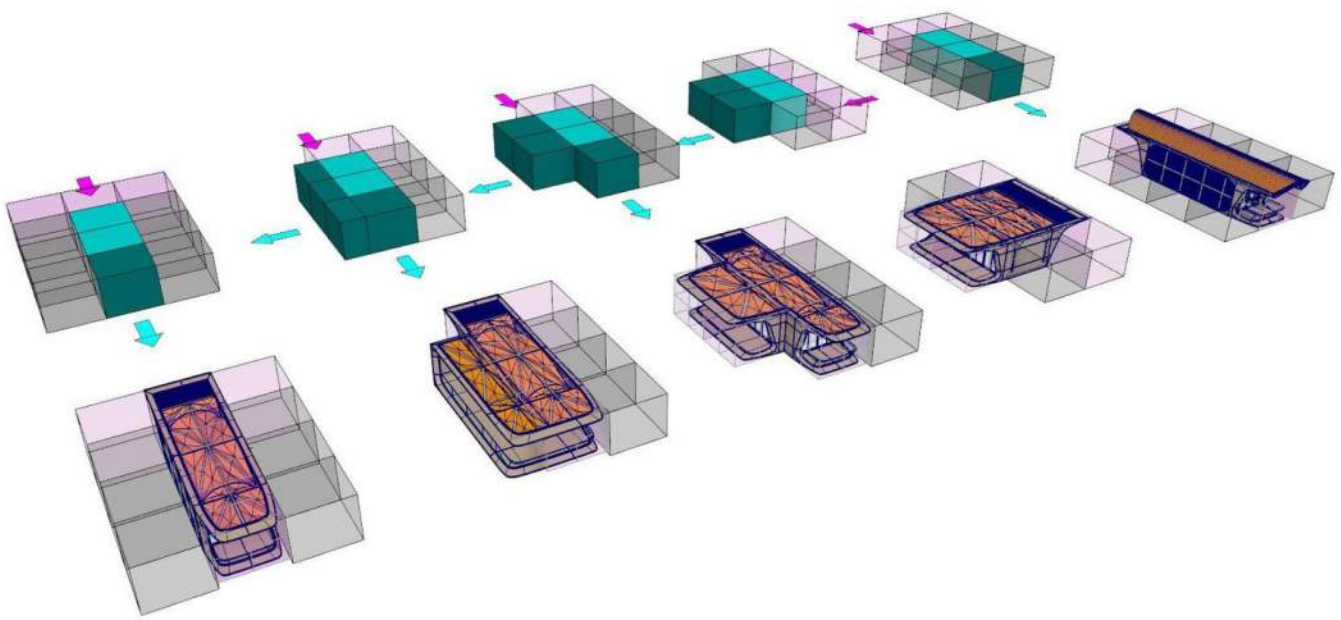


Playing With The Facade Rule Sets

Understanding Composition With Different Parameters

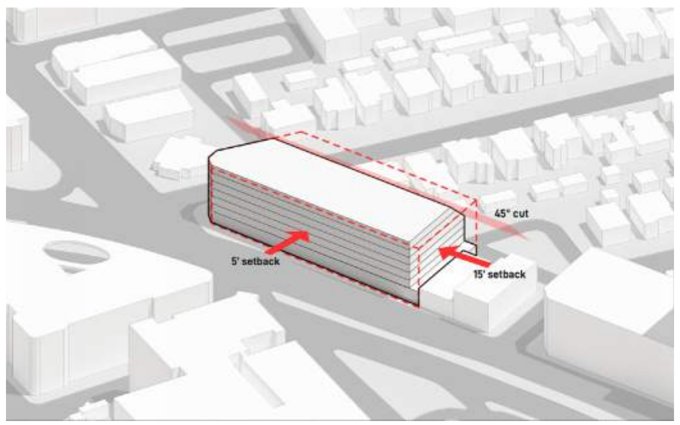
https://worldarchitecture.org/article-links/efvgg/zaha-hadid-architects-designs-residences-made-of-modular-system-with-sustainable-timber-in-honduras.html https://youtu.be/xeZCUHKRpB8


THE SITE
LA CIENEGA BLVD
S SAN VICENTE BLVD

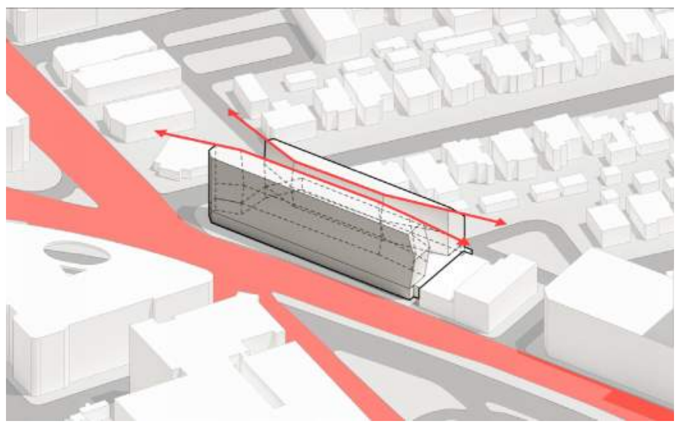
Phase 3: Project Implementation

- Project Site
- **MVE Proposal**
- Project Program
- Possible Unit Types
- Efficiency spreadsheet
- Schedule

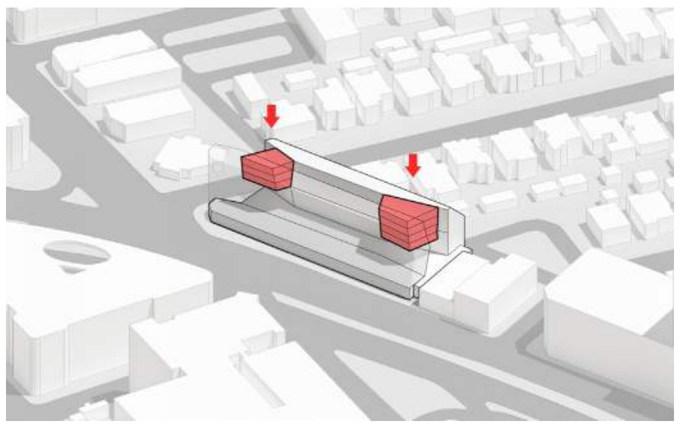
01 | Building Block



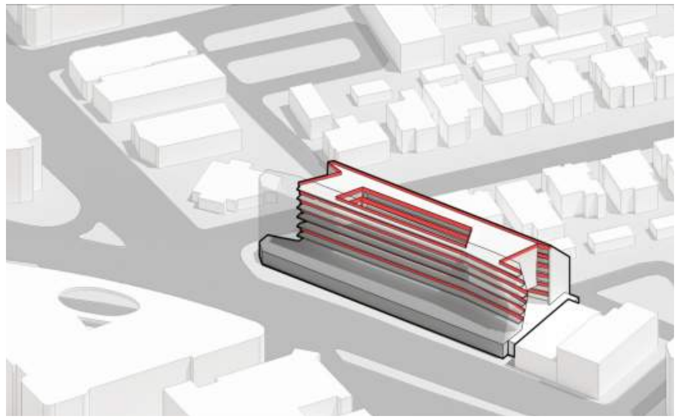
02 | Set-Backs



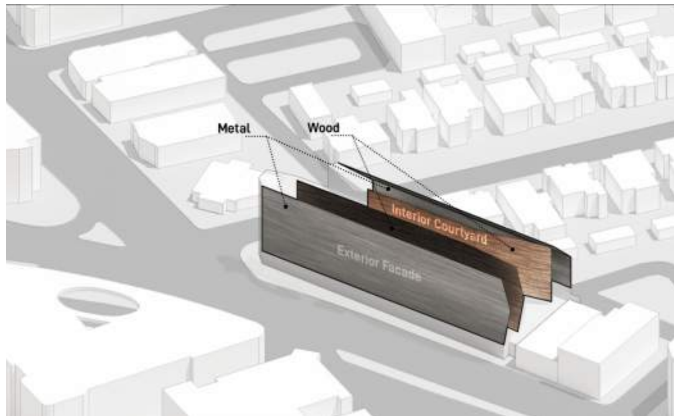
03 | Slices



04 | Jewel Pieces



05 | Guardrails



06 | Materiality

07 | Courtyard & Roof

08 | Final Massing

Project Site

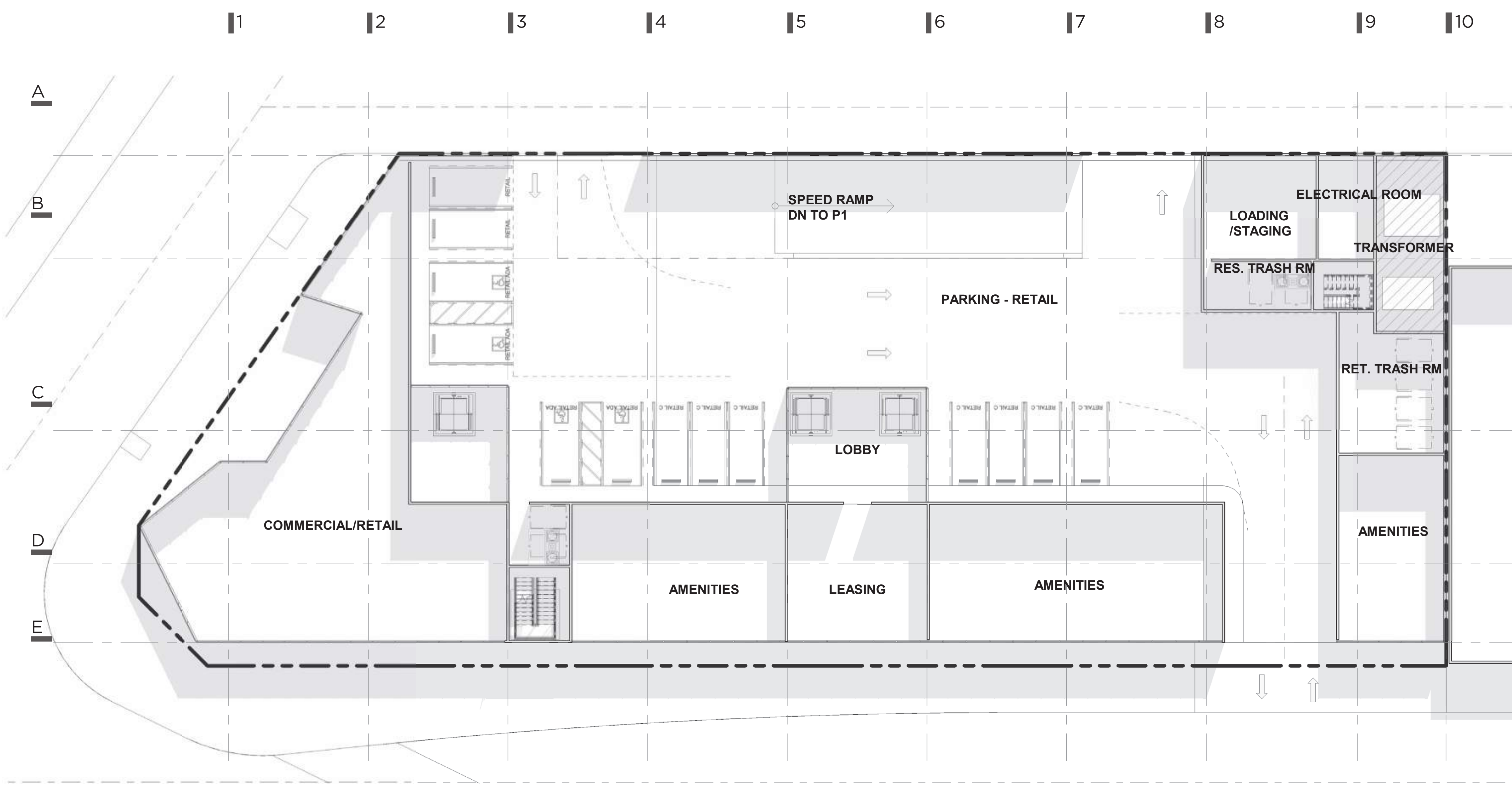
MVE Proposal

Project Program

Possible Unit Types

Efficiency spreadsheet

Schedule



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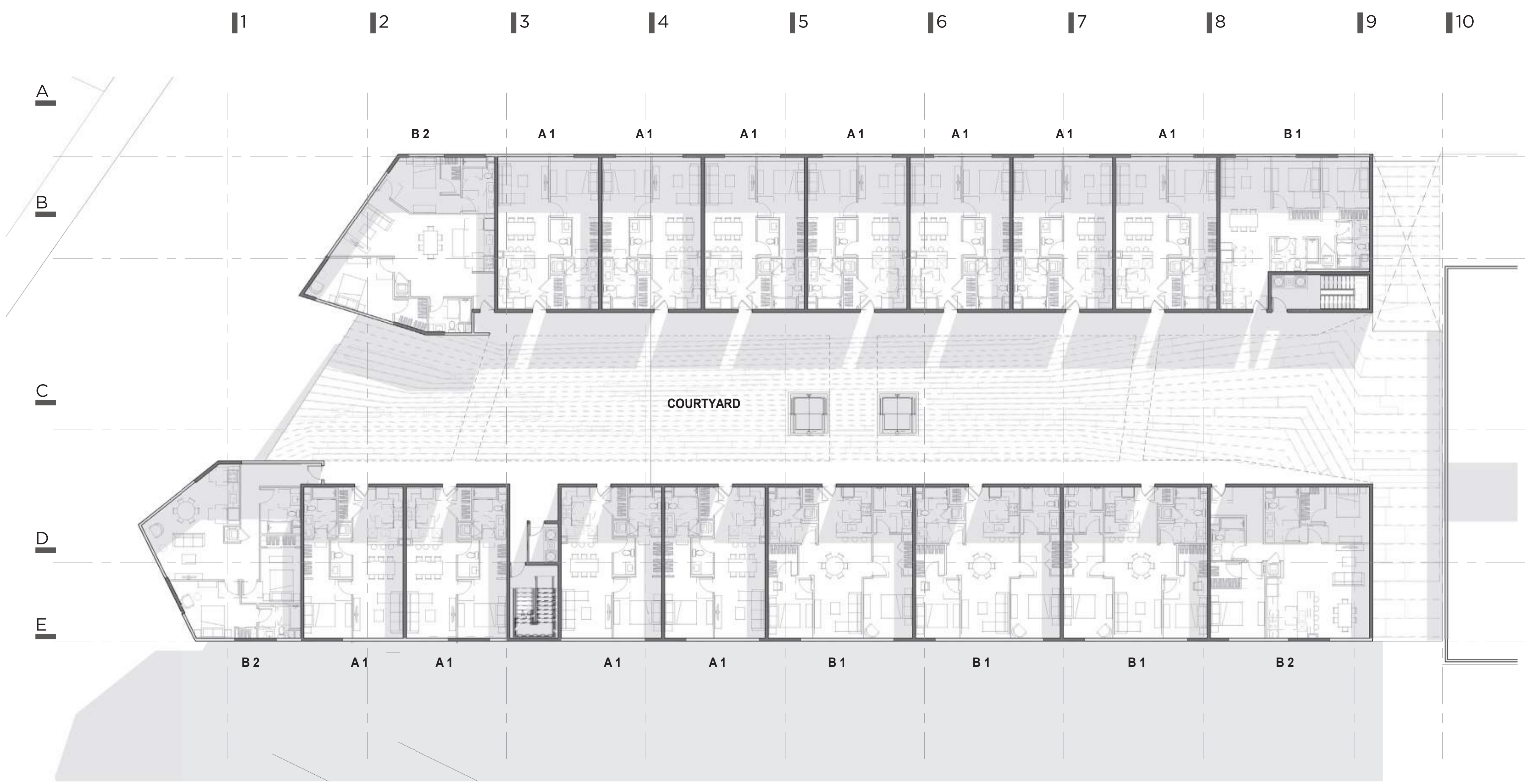

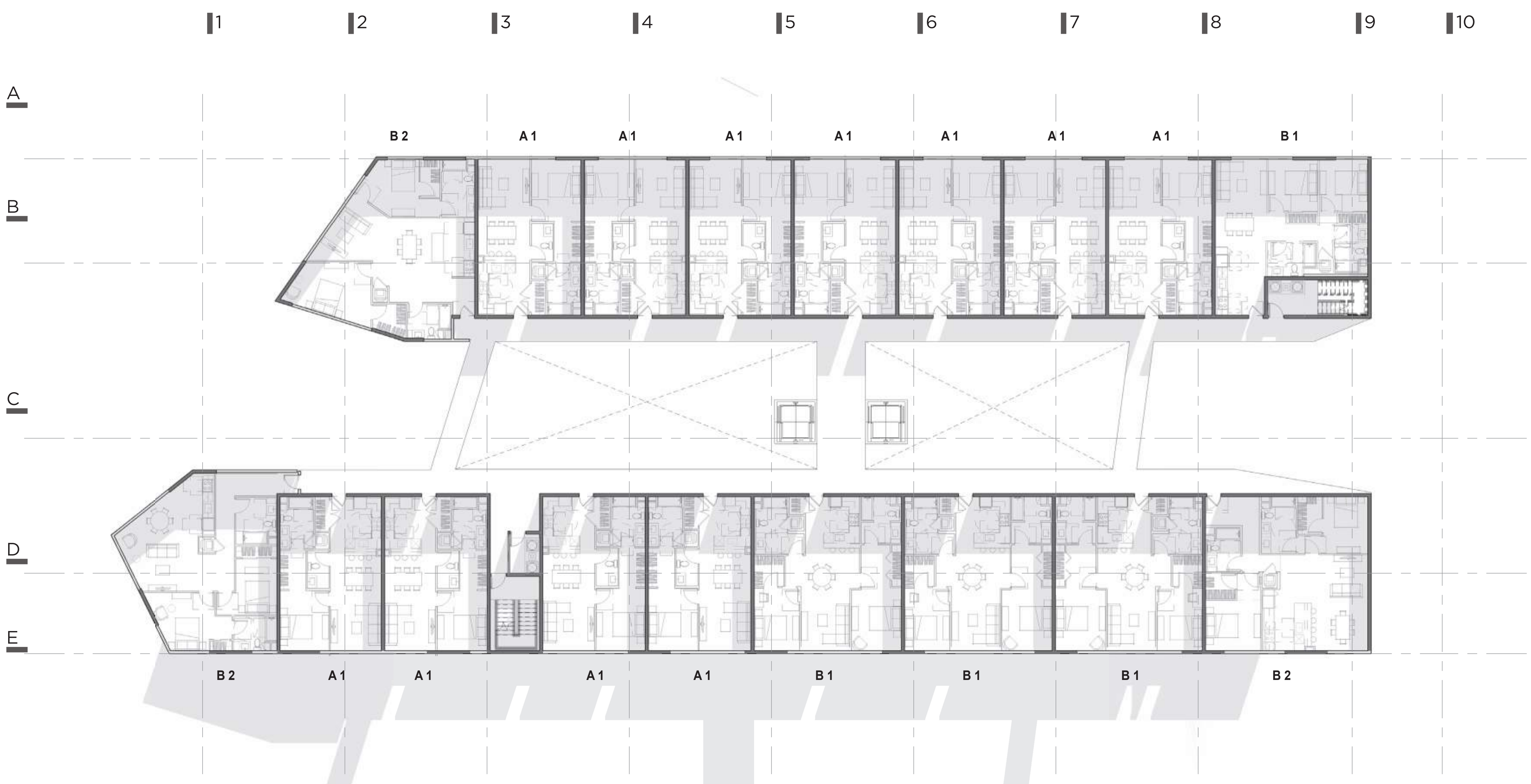
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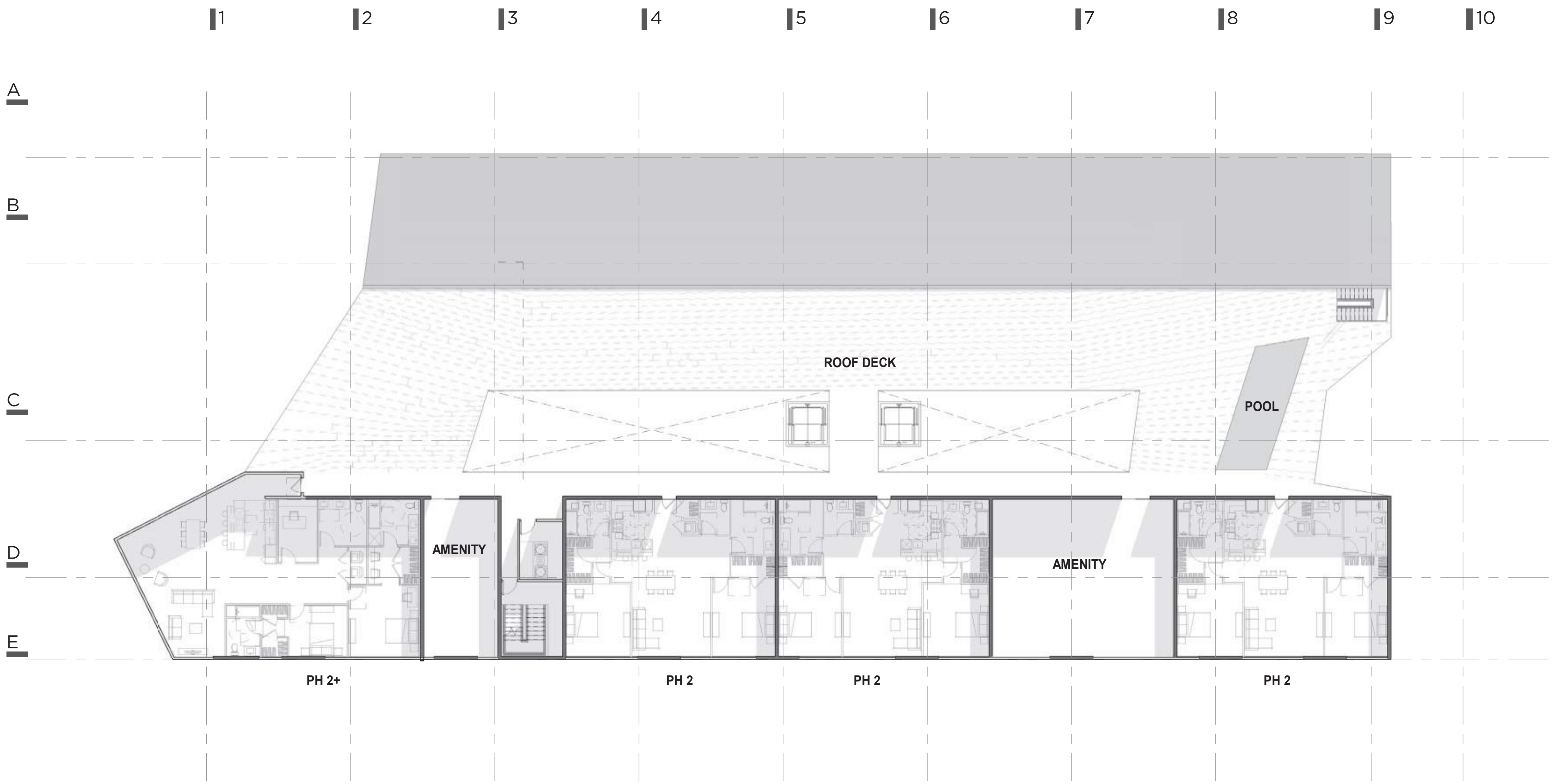
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ROOF DECK
POOL
AMENITY
AMENITY
PH 2+
PH 2
PH 2
PH 2


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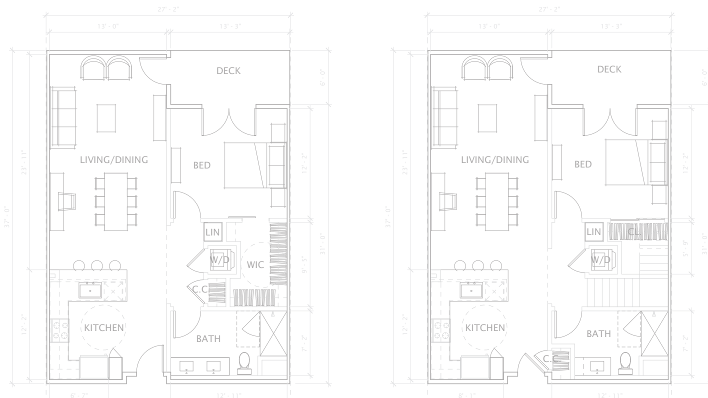
1

MVE

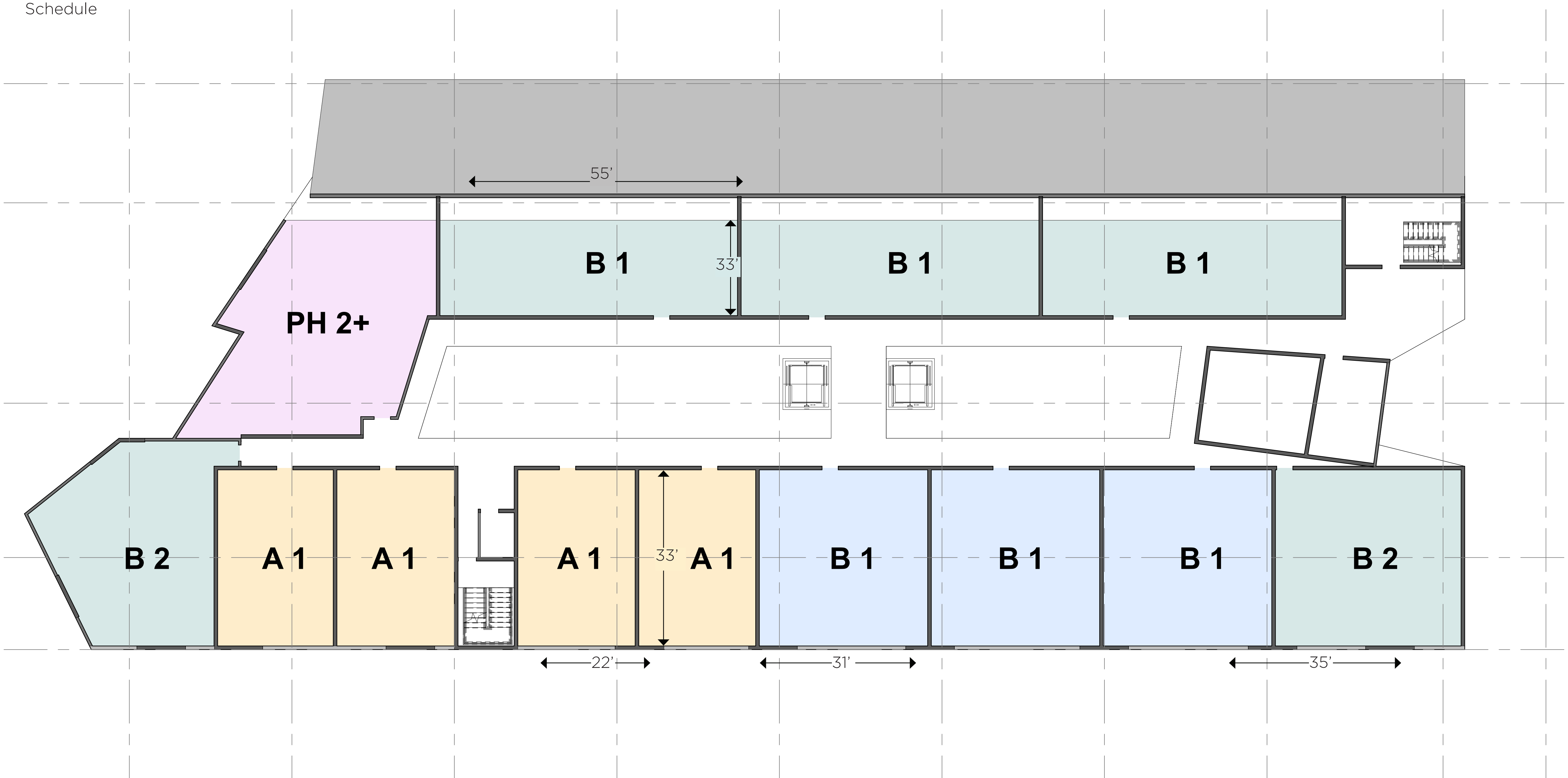


RESIDENTIAL
100 DU
-
933SF AVERAGE UNIT SIZE

AMENITIES
6,500 SF

PARKING RATIO
2.2 SP/DU

**** Take this as a starting point and discuss during checkups the possibility of changing these parameters.**


55'
33'
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PH 2+
B 2
A 1
A 1
A 1
33'
A 1
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B 1
B 1
B 2
22'
31'
35'

Construction Type	Floors	Type	Gross Wood SF	Gross Concrete SF	Podium Deck	Wood Frame Efficiency	Net Rentable SF	Retail	Apt Unit Count	Avg Unit Size	Parking	Avg Parking Stall Size	# of Parking Stalls
Wood	7	Apt	25,496 sf			83%	21,186 sf		33	642 sf			
Wood	6	Apt	26,407 sf			85%	22,470 sf		35	642 sf			
Wood	5	Apt	26,407 sf			85%	22,470 sf		35	642 sf			
Wood	4	Apt	26,440 sf			85%	22,470 sf		35	642 sf			
Wood	3	Apt/Amenity	26,784 sf		5,794 sf	74%**	19,902 sf		31	642 sf			
Concrete	2	Parking/Apt		34,450 sf			8,040 sf		15	536 sf	23,104 sf	392 sf	59
Concrete	1	Parking/Retail		33,736 sf				4,192 sf			24,071 sf	415 sf	58
Building: Total/Average			131,534 sf	68,186 sf	5,794 sf	82%**	116,538 sf	4,192 sf	184	633 sf	47,175 sf	403 sf	117
			199,720 sf										

Parking Ratio / Unit	0.64

***amenities in woodframe included in efficiency calculation*

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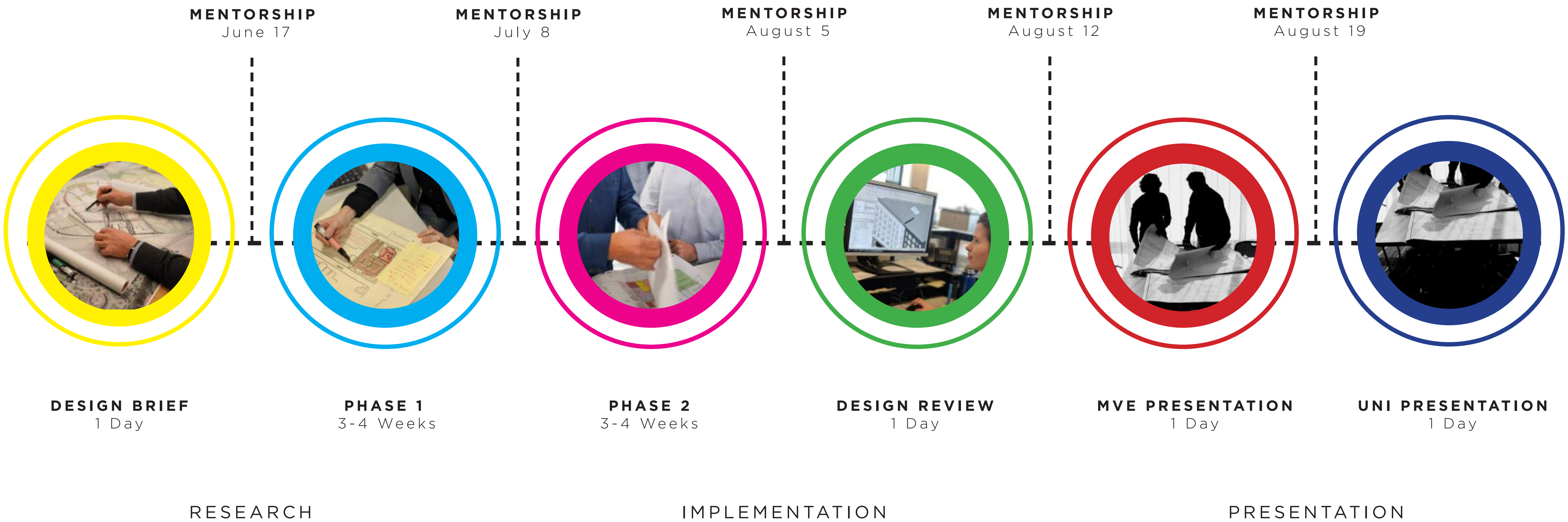


03 Research for Building Use and Hospitality

Type of Modular Construction (Wall, Facade,Panels, Tubes, Systems)
Types of Materilas (Lightweight)
Order of Processes during Construction (System / Assemblies)

04 Precedent Study

Type of Modular Construction (Wall, Facade,Panels, Tubes, Systems)
Field Visit

05 Project Implementation

Project Site
Concept Diagrams
Parking Level Floor Plans
Floor Plans
Sections
Elevations
Perspectives

CHAPTER 2 OF 3

ALL WOOD

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

Types Of Materials (Lightweight)

Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)

3D Module - Wood

Faster Schedule
Shortened construction schedule due to the ability to preform site work and building construction simultaneously

Higher Quality

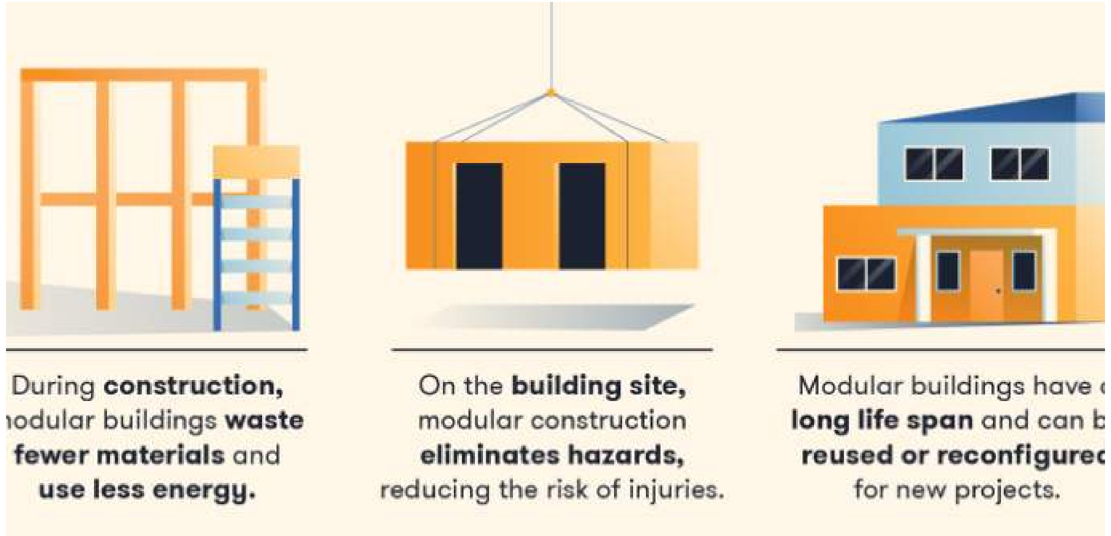
Less exposure to weather
The potential for high levels of moisture trapped in building materials is reduced

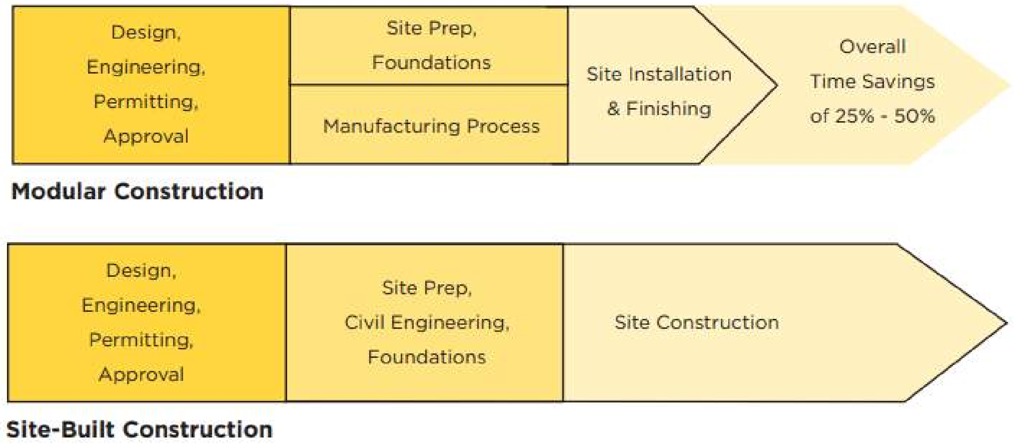
Less Material Waste
Prefabrication minimizes waste, saves resources adn simplifies recycling of waste

Less Environmental Disturbance

Typically 80-90 Percent complete before being shipped to job site

Prefabrication
in a factory allows the wood to stay dry and at constant temperature while being precisely cut and fitted to exacting tolerances





Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

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Wood Structure

Wood Modules are finished with primed gypsum wall board before shipping but appliances, mill-work, and heavy finishes are installed after

Common structural members used include 2x individual pieces used in roof trusses, floor trusses, walls, wood I joists, engineered glue laminated beams, plywood, oriented strand board (OSB) and composite panel

Module Dimensions

Determined by transportation restrictions and will vary by manufacturer

Wood modules are limited in height and require deep ceiling to floor connection

The depth of the floor and ceiling sandwich tends to be greater than with the common site- built construction methods, since each module has its own, structurally stable lid

Rules of Thumb

Max Module width: 16’-0”

Max Module length: 30’-0”

Max Module height: 14’-0”

Wood module on site; BM Modular One, Bethesda, MD; Robert M. Gurney

Wood framing system; ZETA Design Build

Phase 1: Research for Building Use - Residential & Hospitality

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

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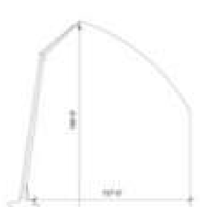
During Transit, modules often require temporary bracing since the wood framing may not be engineered to withstand transportation loads

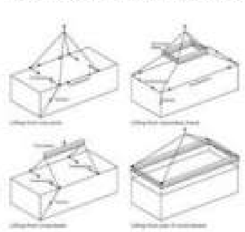
The units then are set on cribbing. Once it's time for crane setting, trucks will deliver the units (as needed in order) to the site. Cranes pick the modules directly from the trucks

Once units are all assembled, the construction crew makes final installations of electrical, plumbing, mechanical, and structural connections, generally in the corridor

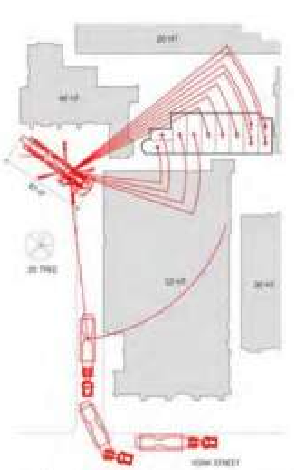
To avoid any damage at this point of construction, every unit is locked, and on site staff is not allowed in the room-units



75-ton capacity luffing jib crane 57



Methods of lifting 58



Craning site plan; Pierson College 59

Transporting Houses and Prefabricated Buildings

The dimension limits for transporting houses and prefabricated buildings have been set to facilitate the safe movement of dwellings and structures across the network.

Prime mover and semi-trailer combination towing a prefabricated building

This information sheet sets out the maximum dimensions and mass limits, access and operating conditions for a vehicle combination transporting houses and prefabricated buildings.

What is the mass limit?

The maximum mass limit for the combination is 43.0 tonnes including the steer axle concession.

What are the dimension limits?

Annual permits are available for vehicles transporting one indivisible house or prefabricated building up to the laden vehicle dimension limits in the following tables.

Table 1 Dimension limits

Dimension	Maximum limits (m)
Width	5.0
Height	5.0
Length	30.0
Trailer Deck Height	1.2

The dimensions shown in Table 1 include external fittings, such as guttering, plumbing, lighting, verandas, bay windows and eaves.

Table 2 Maximum rear overhang

Length of vehicle (m)		Max rear overhang (m)
Over	Up to and including	
-	25.0	5.5
25.0	26.0	6.4
26.0	27.0	6.7
27.0	28.0	7.0
28.0	29.0	7.3
29.0	30.0	7.6

What access can I get?

The vehicle combination can access all approved or conditionally approved arterial roads on the Oversize & Overmass network map. Access to other roads will require consent from the relevant road manager (such as local government or the Port).

What are the Load Restrai Requirements?

Houses and prefabricated dwellings be transported in such a way that the restraint system used complies with load restraint performance standards These standards are listed in the Lo Restraint Guide published by the National Transport Commission.

What operating condition apply?

- The entire length of the building must be supported by the trailer the trailer extension beams.
- Windows must be secured to withstand transportation forces.
- No part of the underframe or cro member support can protrude laterally more than 50mm for the outside wall of the house or prefabricated structure directly above it.
- A laden vehicle combination that longer than 26 metres or wider t 3.5 metres must comply with the pilot and escort chart on the wel

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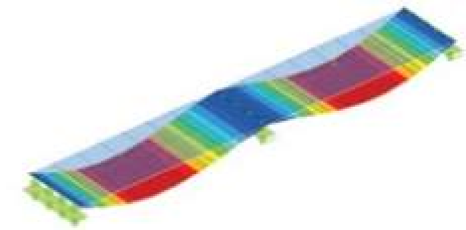


MEP Penetrations

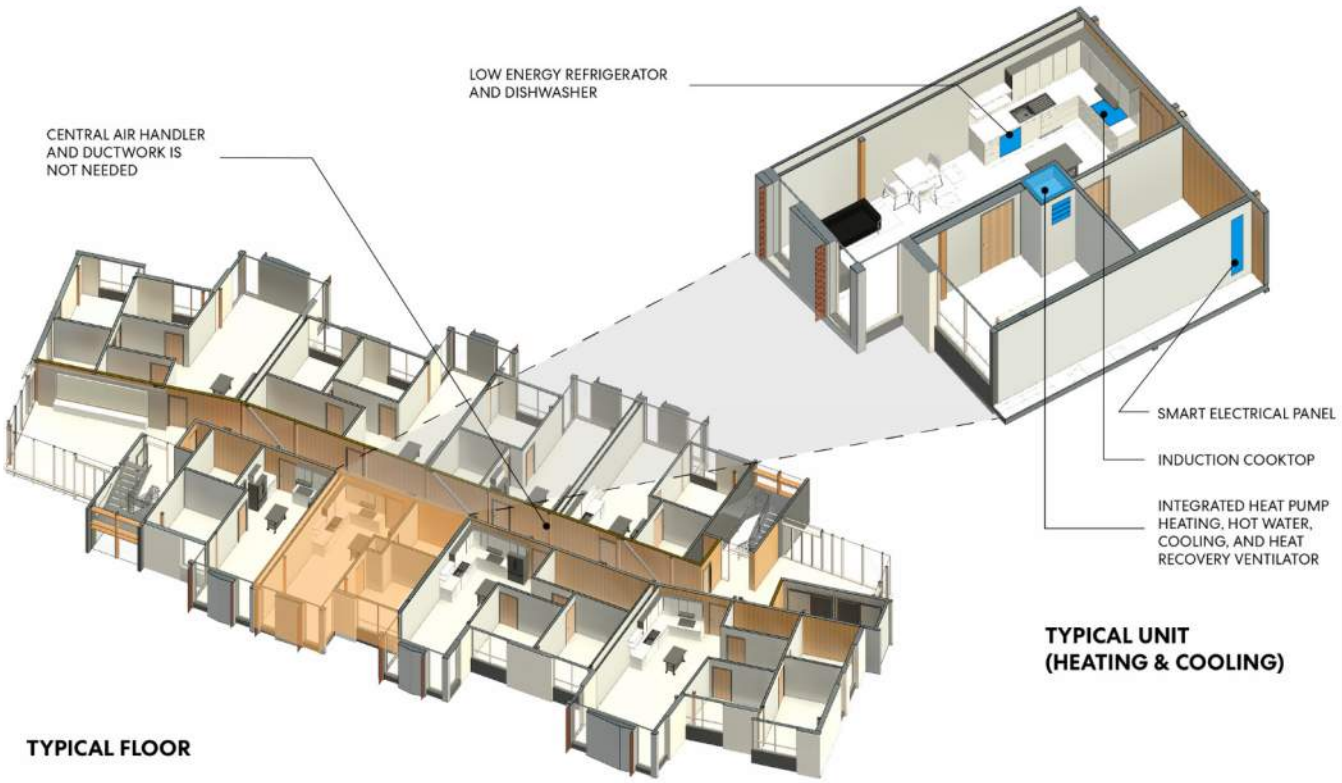
Building penetrations for mechanical, electrical and plumbing (MEP) services are easier and more economical to install if their locations can be included in the design of the CLT panel. Penetrations can be cut in the factory, saving installation time and expense. MEP services not included before the manufacture of the panel can still be easily incorporated on-site using standard construction tools.

TABLE 16:
CROSSLAM® CLT FLOOR VIBRATION PERFORMANCE

CROSSLAM® CLT SERIES	CLT PANEL (in)	CONCRETE SLAB (in)	VIBRATION CONTROLLED SPAN (ft)
87 V	3.43	5.31	10.5
105 V	4.14	5.91	12.1
139 V	5.48	7.48	14.8
175 V	6.90	8.46	16.7
191 V	7.53	9.25	18.4
243 V	9.58	10.24	21.0
245 V	9.66	10.83	21.6
315 V	12.42	12.40	24.9

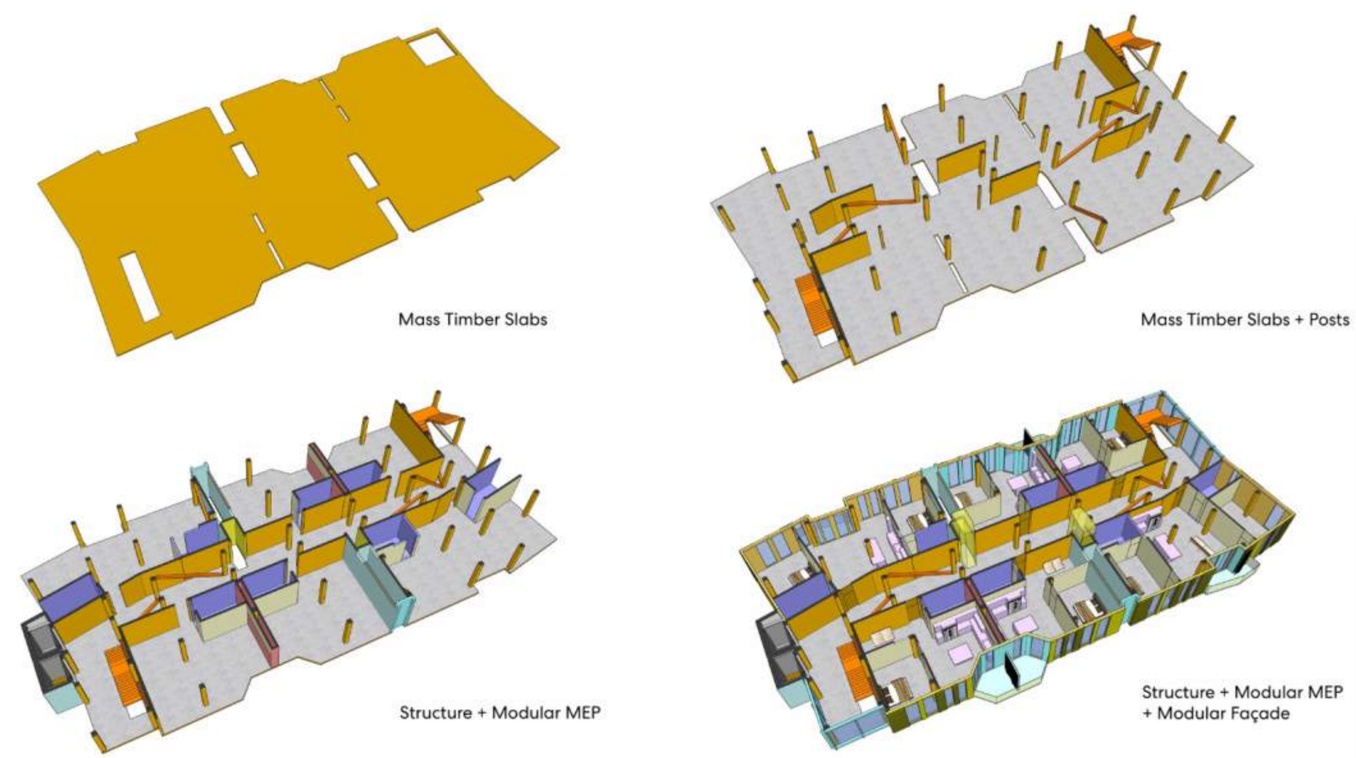
50 psf live load plus self weight plus 21 psf miscellaneous dead load

Indicates CrossLam® CLT thickness advantage



TYPICAL UNIT (HEATING & COOLING)

TYPICAL FLOOR



MODULAR APPROACH – KIT OF PARTS

Phase 1: Research for Building Use - Residential & Hospitality

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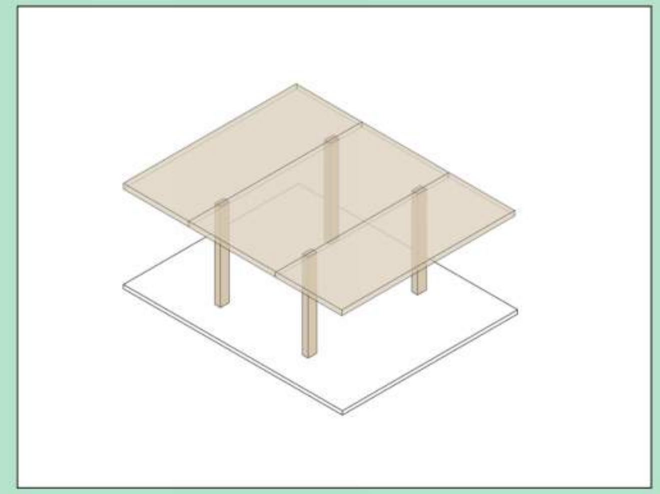
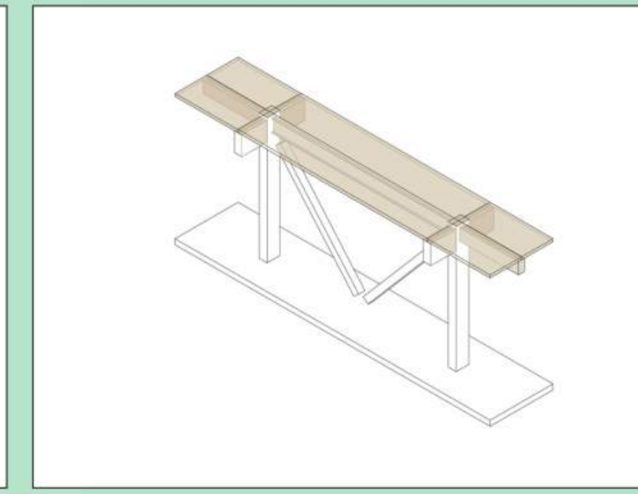


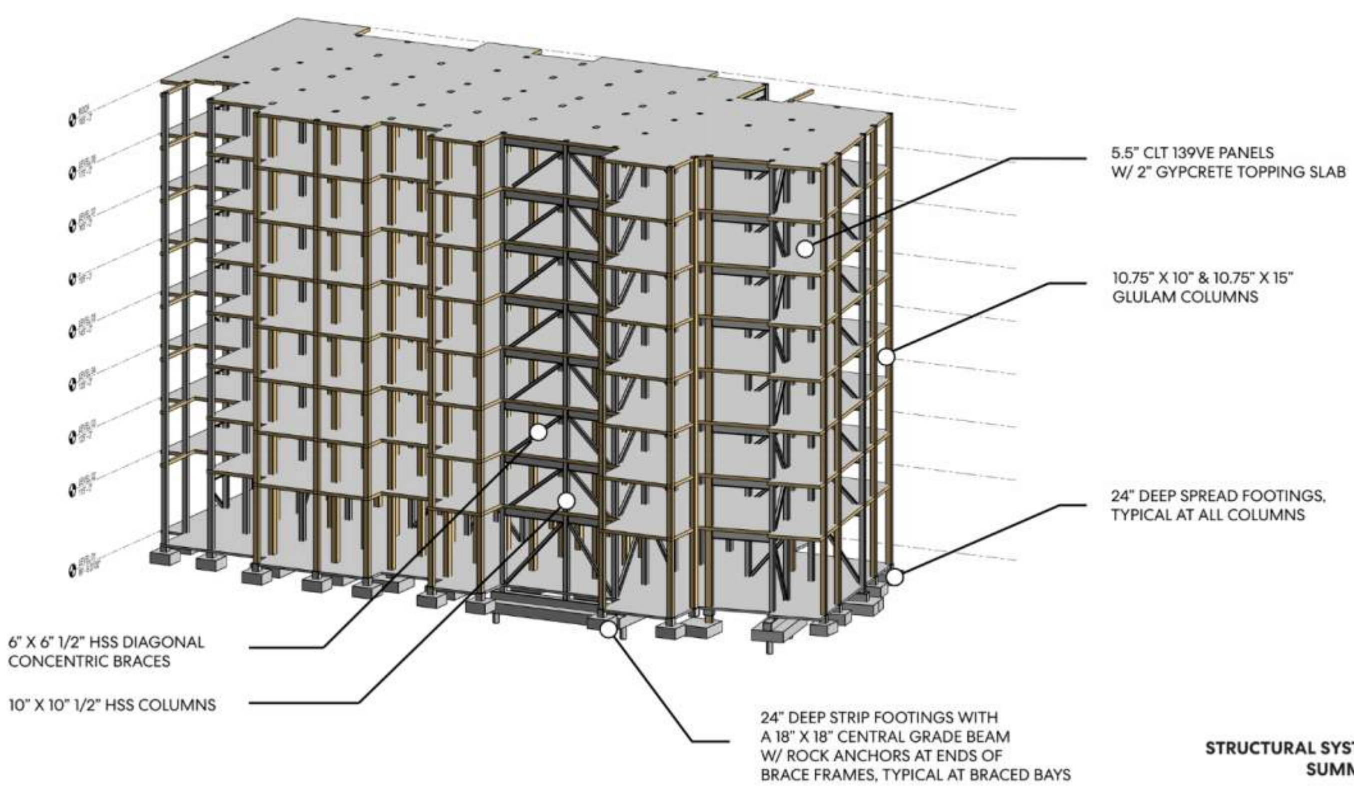
Gravity System - Wood

Design for the building's structural gravity system is a mass timber post and panel configuration. Cross-laminated timber panels are supported by glulam timber columns. CLT Panels are 5.5" thick 139VE with a 2" thick gypcrete topping slab. Foundation system consists of 5" thick slab on grade with 24" deep spread footings at columns. At brace frames 24" deep strip footings with a 18" X 18" central grade beam and rock anchors at ends of brace frames are utilized.



Lateral System - Steel

Design for the building's structural lateral system is a steel brace frame system, utilizing steel columns and diagonal braces. Concentric HSS 6" x 6" x 1/2" diagonal braces frame to 10" x 10" x 1/2" HSS columns. The California Building Code currently requires mass timber structures to have a steel or concrete lateral system. The hybrid structural system of wood and steel as utilized by this case study is currently one of the most common approaches to building in mass timber in California.



STRUCTURAL SYSTEMS SUMMARY

NOTE:
PREFABRICATED MODULAR FACADE OPTIONS ARE AVAILABLE IN A RANGE OF MATERIALS. COST, ENERGY PERFORMANCE, AND EMBODIED CARBON VALUES VARY ACROSS MATERIAL OPTIONS. THE CASE STUDY BASIS OF DESIGN IS METAL PANELS BASED ON ITS ENERGY PERFORMANCE AND LOWER EMBODIED CARBON WHEN COMPARED TO GFRP AND CONCRETE.

PREFABRICATED MODULAR FAÇADE OPTIONS

Phase 1: Research for Building Use - Residential & Hospitality

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

Types Of Materials (Lightweight)

Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)

CrossLam® CLT Product Applications

FLOORS

CrossLam® CLT panels are ideally suited for modern floor systems because they are two-way span capable and ship to site as ready-to-install components, greatly simplifying building construction and increasing jobsite productivity. CrossLam® CLT products help ensure an optimized structural solution that allows you to install up to 400 square feet per lift.

ROOFS

CrossLam® CLT panels provide overhanging eaves and span a variety of roof layouts. Their thermal properties contribute to a more efficient envelope assembly. Panels can be as thin as 3.43" and as thick as 12.42", resulting in a maximum roof span of 40' with appropriate loading. CrossLam® CLT roofs are installed quickly, allowing projects to approach lockup and a watertight state in a short amount of time.

WALLS

CrossLam® CLT wall panels are a lighter, cost-competitive alternative to precast concrete systems. When used as a system, CrossLam® CLT wall and roof panels allow more flexibility and efficiency in building design. As vertical and horizontal load-bearing elements, CrossLam® CLT panels extend the design envelope for industrial projects and allow the use of one structural system for an entire project.

SHEAR WALLS AND DIAPHRAGMS

CrossLam® CLT panels may be used as lateral force-resisting systems for both wind and seismic loads. The Horizontal Diaphragm Design Example white paper provides a design method to determine the strength of CLT horizontal diaphragm and deflection due to lateral wind or seismic loads. See https://www.structurlam.com/wp-content/uploads/2016/10/White-paper-Rv12-June-2017.pdf.

CORES AND SHAFTS

CrossLam® CLT panel cores and shafts erect quicker and easier than comparable steel and concrete designs while still providing lateral bracing. Elevator and stair shafts can achieve two-hour fire resistance ratings.

THE CHAR METHOD

The char method allows mass timber to be directly exposed to fire. Since the timber is fully exposed, extra lumber is added during the design phase to meet the fire resistance rating (FRR). This system is designed by determining the approximate depth to which the fire would penetrate and the remaining structural strength of the member after a certain exposure time.

CrossLam® CLT and GlulamPLUS® behave as mass timber and have a predictable charring rate of approximately 1.5"/hr (0.65 mm/min). The char layer, which is formed during combustion, acts as an insulating layer for the inner layers, thus protecting the structural members from a further loss of strength. The FRR of CrossLam® CLT and GlulamPLUS® is dependent on several factors, including the member depth, span, applied loading and exposure. The most vulnerable components of this type of system tend to be the steel connectors due to the rapid reduction in steel's strength at high temperatures. To counteract this, it is required that all connectors be covered by a layer of timber or intumescent paint to protect the steel.

FIRE RESISTANCE RATING (FRR)

FRR performance is designed according to the local code and 2018 NDS. Extensive testing has been completed to allow a codified approach to cover a variety of use scenarios.

Type IV Heavy Timber Construction of the 2018 IBC Chapter 6: CLT is allowed in the IBC 2018 under Type IV Construction - 602.4 Type IV construction (Heavy Timber, HT). The hourly fire resistance rating requirements for walls, floors and roofs are found in Table 601 of the IBC.

Char calculation method of the 2015 and 2018 NDS: The NDS methodology uses wood-engineering-based mechanics to calculate the fire resistance of wood members and is referenced in Section 722.1 ILO 721.1 of the IBC. Effective charring rates calculated using the NDS methodology are also included in Section 722.1 ILO 721.1 of the IBC.

Execution of proprietary ASTM E-119 testing that is specific to the project assemblies: Standard Test Methods for Fire Tests of Building Construction Materials or UL 263, Standard for Fire Tests of Building Construction and Materials evaluate the duration for which CLT will contain a fire and maintain its structural integrity during exposure to fire.

For additional test documentation, visit https://www.structurlam.com/resources/testing/

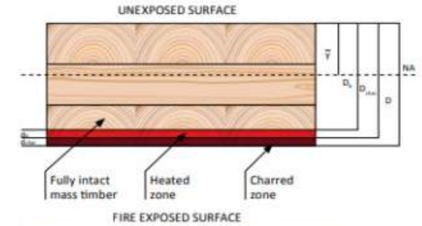


Figure 28: Cross-section of fire-exposed cross laminated timber

FIRE STOPS AND SERVICE PENETRATIONS

A number of commercially available fire-rated joint systems for concrete can achieve the same fire test ratings when used in mass timber for up to two hours. Detailing and fire caulking need to be applied appropriately around the fire sleeve. This allows solid mass timber panels such as CrossLam® CLT to be a superior part of your fire protection system.

Figure 29: Wall assembly after testing showing the depth of charring on the exposed side. NRC (2014) Fire Endurance of Cross-Laminated Timber Floor and Wall Assemblies for Tall Wood Buildings.

Figure 30: Protective "char layer" maintain structural integrity of interior section.

UPDATE: Structurlam has completed E119 fire tests for our 175V and 175E CLT panels for heavy loads that go above and beyond code allowance. Visit https://www.structurlam.com/resources/testing/ for test reports.

SYSTEM	RECOMMENDED GRID X (beams)	RECOMMENDED GRID Y (purlins/panel)	FIRE RESISTANCE	MEP	ACOUSTICS	VALUE PROPOSITION
POST AND PANEL	8'-10' (2.44 m-3.05 m)	10'-14' (3.05 m-4.27 m)	2 hr encapsulated	Surface Mounted MEP collides with nothing	Requires additional build floor system or dropped ceiling	Quick speed of installation and MEP simple layout fastening
POST-BEAM-PANEL	10'-30' (3.05 m-9.14 m)	15'-40' (4.57 m-12.19 m)	1-2 hr exposed 2+ hr encapsulated	Raised Access Floor Dropped Ceiling Surface Mounted MEP collides with beams in one direction only	Requires additional build floor system or dropped ceiling	Mass timber kits of parts, quick install, amazing performance and aesthetics, cost competitive
POST, BEAM, PURLIN, PANEL	20'-30' (6.10 m-9.14 m)	20'-30' (6.10 m-9.14 m)	1 hr exposed 2+ hr encapsulated	Raised Access Floor Dropped Ceiling Surface Mounted MEP collides with beams and purlins	Requires additional build floor system or dropped ceiling	Mass timber kits of parts, quick install, amazing performance and aesthetics, cost competitive
HYBRID LIGHT-FRAME CLT	10'-30' (3.05 m-9.14 m)	10'-15' (3.05 m-4.57 m)	1 hr exposed 2+ hr encapsulated	Surface Mounted MEP collides with nothing	Requires additional build floor system or dropped ceiling	Speed of installation of higher-quality performance product, can create overall cost savings in tight labor markets
HYBRID STEEL FRAME CLT	30' (9.14 m)	30' (9.14 m)	1-2 hr exposed 2+ hr encapsulated	Surface Mounted MEP collides with steel frame, or use raised access floor	Requires additional build floor system or dropped ceiling	Good for teams with low mass timber experience, green footprint, ease of install, ease of design
CLT TILT-UP	undefined	undefined	1-2 hr exposed 2+ hr encapsulated	Dependent on system design	Requires additional build floor system or dropped ceiling	Quick installation, single supplier, coordinated kit of parts easy for remote installation
BOUTIQUE BUILDINGS	undefined	undefined	1-2 hr exposed	Dependent on system design	Requires additional build floor system or dropped ceiling	Beautiful, customized, award-winning buildings

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

Types Of Materials (Lightweight)

Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)

Advantages of CLT Panels

The sustainable nature of wood due to carbon sequestration and minimum embodied energy is the major environmental advantage of CLT panels compared to steel and concrete construction. Some studies concluded that an average of 26.5% reduction in global warming potential could be achieved with CLT construction compared to concrete and other construction materials (Vanova et al., 2021).

CLT panels have ease of factory prefabrication of the parts and design flexibility. This allows for precise openings for doors, windows, and other mechanical elements of the structure. Figure 7 shows the building Dalston Lane, the largest CLT structure in the World.

CLT panel construction helps to reduce onsite work and assembly. It is estimated to cut construction time by a minimum of 20% when compared to concrete construction. CLT construction also helps to reduce

Disadvantages of CLT Panels

Currently CLT panels are more expensive than traditional construction such as steel or concrete. Its price depends on the need for transportation, foundation work, assimilation cost, and CLT grade. Transportation is a significant cost factor, so it is less attractive if the construction requires long-distance hauling. CLT panels could be more cost-effective for mid, and high-rise buildings only, so they will not be the primary choice for residential housing to compete with timber frame construction.

Limited availability and a long waiting time are other limitations as there are very few CLT industries in operation. CLT manufacturing requires huge lumber volumes and is adding additional demand for structural grade lumber.

Finally, obtaining desired acoustic insulation may be a problem and it requires the use of additional materials such as light concrete to increase acoustic insulation.

CrossLam® CLT Fabrication

Structurlam's CrossLam® CLT is fabricated using the latest 3D modelling software. Data is transferred directly to our CNC machines - the most sophisticated milling machinery in North America, allowing us to achieve very tight tolerances.

CrossLam® CLT projects begin with your drawings from which we develop a 3D model that is used to design panels and connectors. Our model also allows our experts to identify design optimizations to help you save money. Shop drawings for panels and steel connectors are generated from the 3D model and digital files are sent to our CNC machines for fabrication. Finally, our 3D model is used to develop a material list for efficient purchasing, loading diagrams to optimize freight, and assembly drawings for quick and efficient erection.

CrossLam® CLT Delivery, Storage + Handling

Structurlam has taken every reasonable precaution to protect your CrossLam® CLT panels during shipment to the project site. However, when not properly handled and protected, panels are subject to surface marring and damage, water staining, sun damage, and checking. We recommend you follow the guidelines outlined in our CrossLam® CLT Storage and Handling Guide available on our website or through our office.

CrossLam® CLT Installation

Detailed preconstruction planning can help to ensure installation of CrossLam® CLT is easy and efficient. We recommend you ensure there is sufficient space available to:

- Prepare panels for installation;
- Apply treatments if required;
- Add on-site hardware if required; and
- Re-sort panels according to the install sequence.

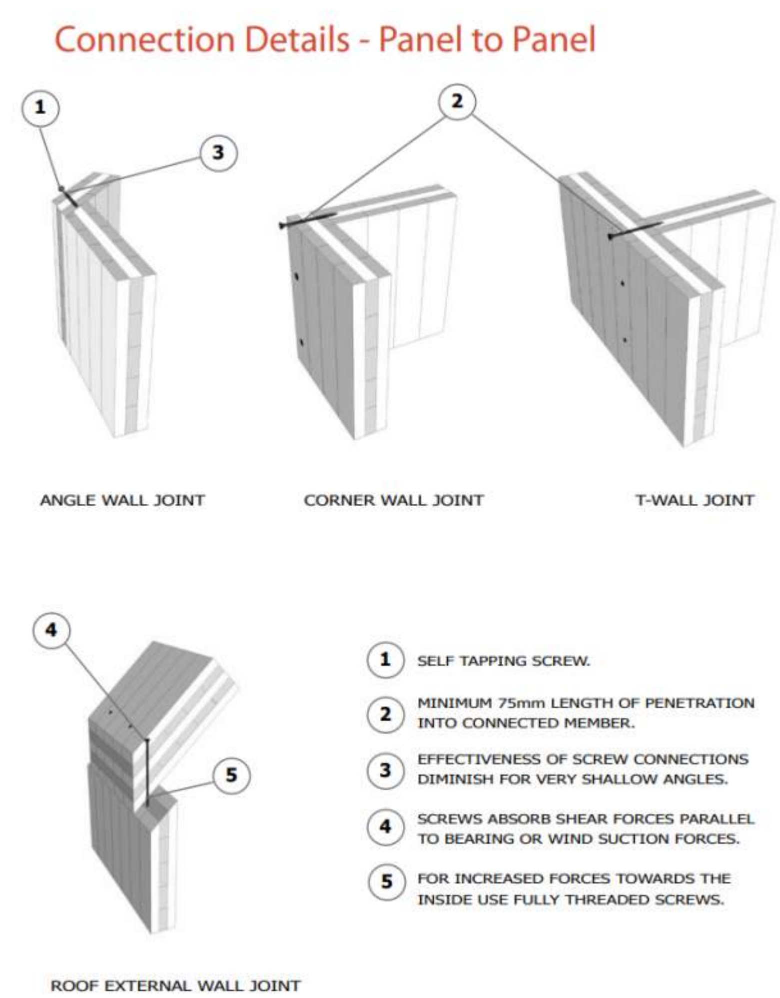
CrossLam® CLT panels can be shipped with lifting hardware installed and ready for quick installation. Please contact our office to learn more about this option. All rigging and hoisting of panels should be done in a safe manner and the lifting device should have the capacity to unload panels from the truck and place them in the desired location.

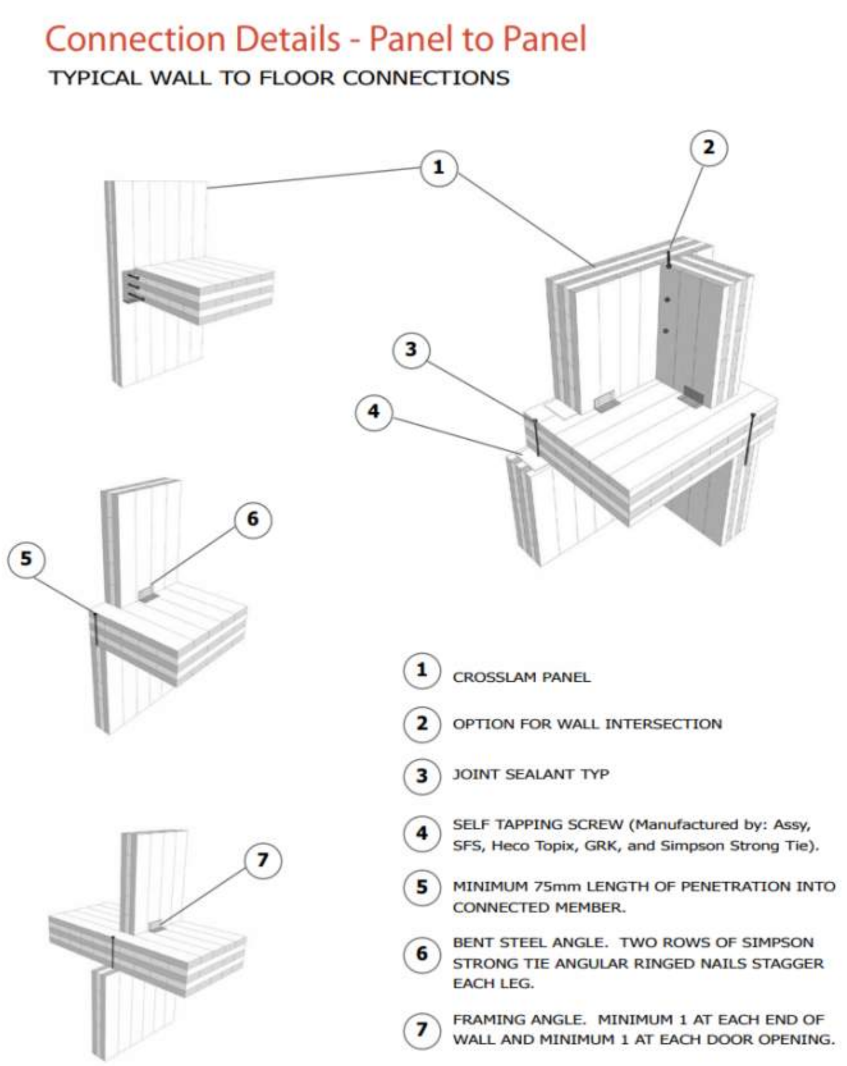
Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

Types Of Materials (Lightweight)

Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)



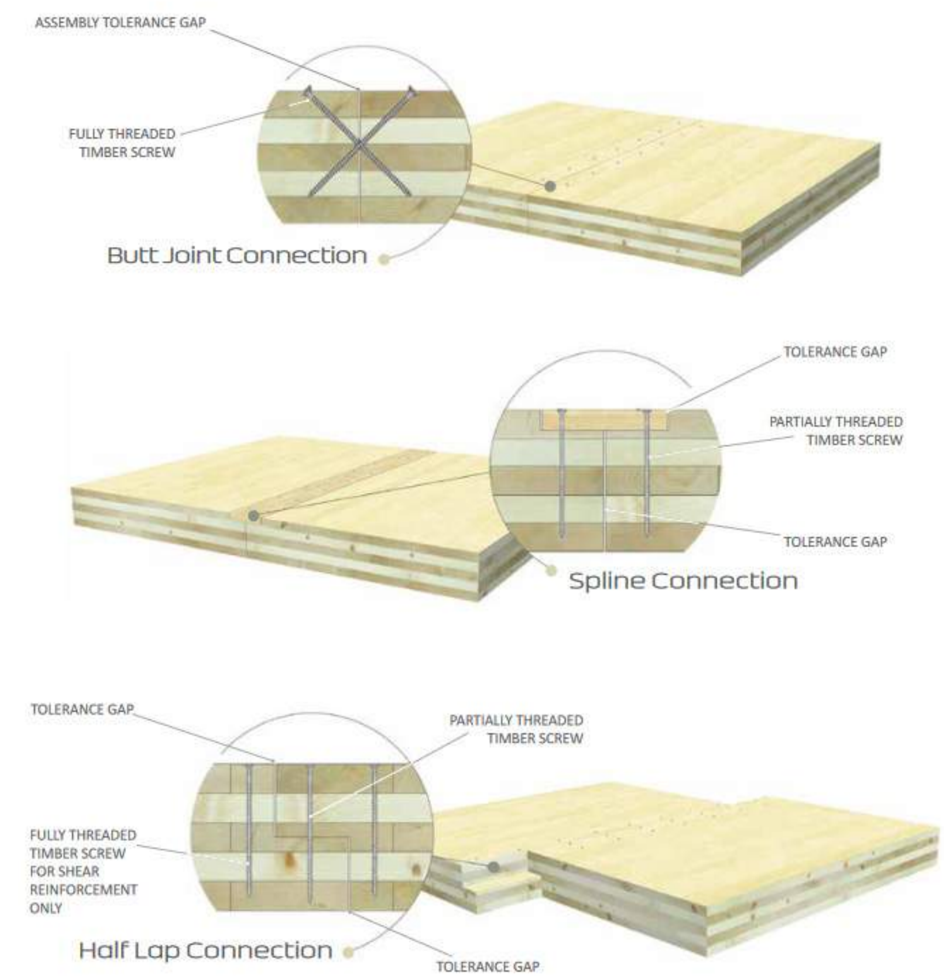


Phase 1: Research for Building Use - Residential & Hospitality

- Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)
- Types Of Materials (Lightweight)
- **Order Of Processes During Construction (Systems/ Assemblies)**
- New Technologies (Software Being Used)

CrossLam® CLT Connection Details - Floor to Roof Panel Joints

Structurlam will work with your team to identify the most cost-effective connection system for your structure. The following details show typical connection details used in CrossLam® CLT buildings.



Phase 1: Research for Building Use - Residential & Hospitality

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

Types Of Materials (Lightweight)

Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)

Surface quality grade and product characteristics

No.	CHARACTERISTICS	V (visible)	I (industrial)	N (non-visible)
1	Appearance grade	A/B	B/B; B/C	C/C
2	Mixture of spieces	not permitted	not permitted with spruce; or 10% of fir, is premitted if evenly distributed	permitted
3	Bonding	occasional open joints up to max. 1 mm width permitted	occasional open joints up to max. 2 mm width permitted	occasional open joints up to max. 3 mm width permitted
4	Blue stains	not permitted	slight discolouration permitted	permitted
5	Discolorations (brown stains, etc.)	slight discolouration permitted	slight discolouration permitted	permitted
6	Texture	coarse texture permitted	coarse texture permitted	permitted
7	Resin galls	A/B single up to 3 x 50 mm permitted	single up to 5 x 50 mm permitted	permitted
8	Bark ingrowth	A/B occasional occurrences permitted	occasional occurrences permitted	permitted
9	Dry cracks / Fissures	occasional surface cracks permitted	50 mm in length permitted	permitted
10	Core – pith	occasional, up to 400 mm long permitted	permitted	permitted
11	Insect damage	not permitted	not permitted	some small worm holes permitted if worms are inactive
12	Knots – sound	no knot clusters; permitted spruce up to 20-40 mm Ø, pine up to 35-60 mm Ø	permitted	permitted
13	Knots – black	single max. 15 mm Ø	single max. 30 mm Ø	permitted
14	Knots – hole	max. 10 mm Ø	max. 20 mm Ø	permitted
15	Quality of edges and ends of panel	blemishes not permitted	single blemishes up to 5 mm permitted	max. 2 mm x 50 mm
16	Surface	100% sanded	100% sanded	no requirements
17	Quality of surface finish	occasional small faults permitted	occasional small faults permitted	small faults permitted
18	Quality of narrow side bonding and face ends	occasional small faults permitted	occasional faults permitted	occasional faults permitted
19	Rework edge with sandpaper	yes	no	no
20	Machining – chainsaw	not permitted	permitted	permitted
21	Lamella width	min. 100mm	min. 100mm	min. 100mm
22	End joints	finger joints	finger joints	finger joints
23	Wood moisture	max. 14%	max. 14%	max. 14%

V - Visible quality

I - Industrial Visible quality

N - Non-Visible quality

CLT Panel Technical Properties

Fire safety

egardless of building material, fires start in the contents and furnishings brought into homes and offices, and occur in concrete, steel, masonry, and wood buildings alike. What's most important is building to code to ensure safe buildings for occupants and first responders.

Building codes require all building systems to perform to the same level of safety, regardless of the material used.

CLT construction has a proven safety and performance record for fire protection, and the addition of sprinkler systems, fire-resistance-rated wall and floor assemblies can be used to safely increase the allowable size of solid wood structures.

CLT Fire safety research **here**

Thermal properties

Wood has natural advantages. For instance, through its low λ value and its ability to adjust to the diffusion processes CLT has the ability to regulate room humidity and climate.
CLT has relatively good thermal insulating characteristics. Heat conductivity or so-called lambda value, expressed in W/mK, comparable with, for example lightweight concrete and there is substantially lower than for concrete and steel.

CLT has a comparatively high specific heat capacity (thermal inertia). Usually it is around 1300 J/kg°C and compared to concrete which has around 880J/kg°C.

As a natural renewable product performance can vary slightly, although commercial CLT generally achieve:
- thermal conductivity: λ = 0.13 W/mK
- density: 480–500 kg/m3

Combining CLT with proper insulation materials allows to reach highest thermal performance of Passive building standards.

* https://www.crosstimbersystems.com/wp-content/uploads/2016/05/Thermal-protection-.pdf

Acoustic properties

CLT is both aesthetically pleasing and provides advanced acoustic properties. Often used in theatres and cinemas, timber and plywood contain sound absorbing and echoing reducing properties. The prefabrication of CLT panels makes onsite construction almost soundless, providing adequate protection from noise disturbance as an important factor for ensuring a sense of well-being in buildings.

Acoustic properties of buildings constructed of mass timber meet the highest standards of modern living environment.

Parametric studies were carried out on the direct impact airborne sound insulation of CLT floor assemblies (with/without various floor topping and gypsum board ceiling variants), on the direct airborne sound insulation of CLT walls (with/without gypsum board linings), as well as on the structure-borne sound transmission on a series of CLT building junctions. The results were then used as input data for predictions of the apparent impact and airborne sound insulation in real CLT buildings using the ISO 15712 (EN12354) framework that was originally developed for concrete and masonry buildings.

*http://sea-acustica.es/fileadmin/publicaciones/80_01.pdf

Environmental benefits

Wood has been used as a building material for millennia, but the health benefits of wood are only recently being studied and understood. While many people agree wood is visually pleasing, researchers are discovering that wood can contribute to the health and well-being of building occupants. With 90% of time spent indoors due to nowadays restrictions, studies have shown that indoor environment plays a significant role of person´s mental condition. As stated by Multiple researches, use of natural materials such as wood seems to reduce stress levels and improve productivity and creativity.

A common goal of environmental responsibility pushes construction industry to more sustainable solutions. As a renewable resource material with Carbon negative traits CLT has serious environmental benefits and allows to reach highest sustainability standards of modern Green building requirements. Maximizing wood use in both residential and commercial construction could remove an estimated 21 million tons of C02 from the atmosphere annually -- equal to taking 4.4 million cars off the road.
Wood also performs better than concrete and steel when it comes to air and water pollution. Wood's advantages are recognized by green building rating systems— including certified wood, recycled/reused materials, local sourcing of materials, waste minimization, indoor air quality and life cycle impacts.

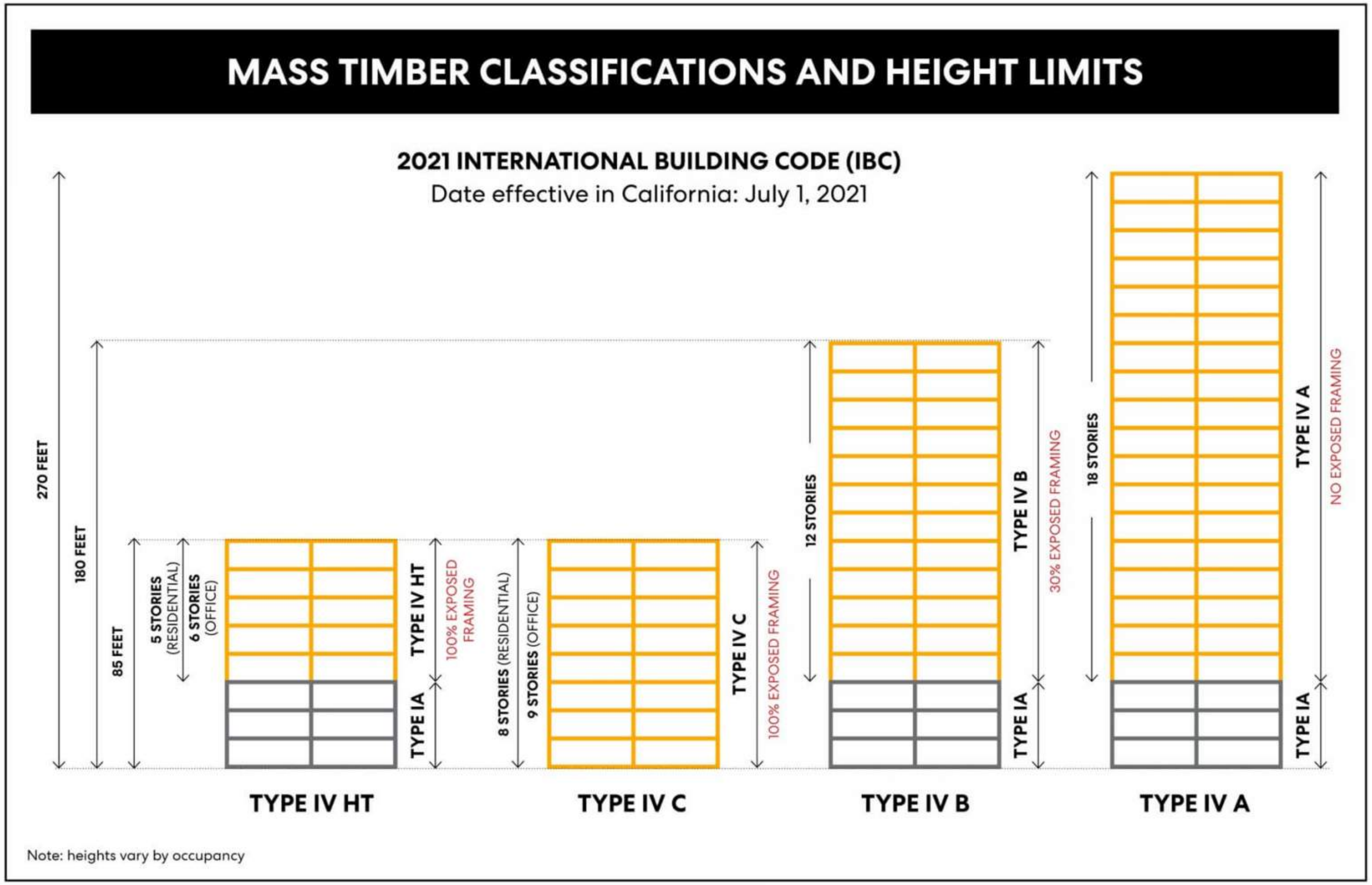
Due to high degree of prefabrication, the mounting of CLT panels take much less time, has better logistics because of minimal panel weight and modular dimensions. There is a need of much less human resources on site and the installation process is much quieter and cleaner than with traditional building methods.

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

Types Of Materials (Lightweight)

Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)



Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

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Include prefabricated elements or sections that are then delivered and assembled on-site.

May include the roofing package (roof panels, fascia, gutter, etc.), roof structure (ceiling deck and beams), glazing package (windows and entrances) and building structure (wall panels, beam pockets, columns and shear paneling).

The kit-of-parts approach, via panelization, is typical for mid-rise wood buildings.

Two types of panelization: open structural panels and closed structural panels.

Open structural panels are a pre-assembled wall framework that is later fitted with other elements such as insulation, exterior cladding and weather barriers on-site. While this aids in time savings and flexibility, there is still a lot of site work involved.

Closed structural panels are complete pre-assembled wall panels that may include windows, doors, plumbing, ducting, electrical, finishes, etc. Closed structural panels are larger and heavier, so a crane is typically needed for on-site assembly.

Frequency of Using Panelized Modular Construction

The chart at upper right shows the percentage of projects on which respondents, by company-type, say some type of panelized modular construction was used over the past three years and the percentage on which they believe it will be used during the next three years.

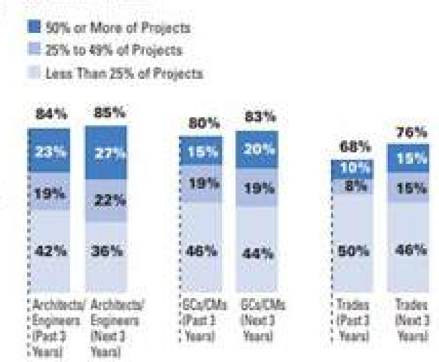
- **Design firms report the greatest current use,** and while the overall number predicting future usage does not increase, the percentage of projects using panelized modular construction shows growth.
- **Trade contractors show the most future growth,** although their overall usage is lower than the other groups because not all of them do work where panelized modular construction applies.

Types of Panelized Modular Construction Being Used

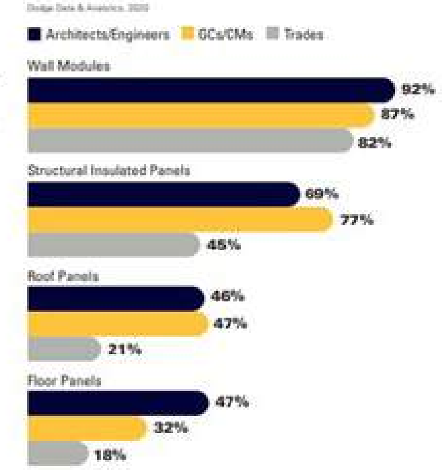
The respondents reporting some level of panelized modular construction usage were asked to identify, from a list of four specific types, which ones they have had experience with on their projects over the past three years. The chart at lower right shows that breakdown.

- **Wall modules are the most frequent among the four types of panelized modular construction,** especially by the architects who participated in this part of the survey (95%), who report higher usage than the engineers.
- **High proportions of both design firms (69%) and GCs/CMs (77%) report using structural insulated panels over the past three years.** It makes sense that fewer trade contractors (45%) report use because many do not work on the building envelope.
- **Nearly half of design firms and GCs/CMs have utilized modular roof panels.**
- **The relatively high percentage (47%) of design firms using modular floor panels may generate a future uptick among contractors** (currently at 32%) because they will ultimately be implementing the design solutions that involve the modular floors.

Percentage of Projects Using Panelized Modular Construction
(Past 3 Years and Forecast for Next 3 Years)



Percentage of Projects Using Types of Panelized Modular Construction (Past 3 Years)



Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

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New Technologies (Software Being Used)

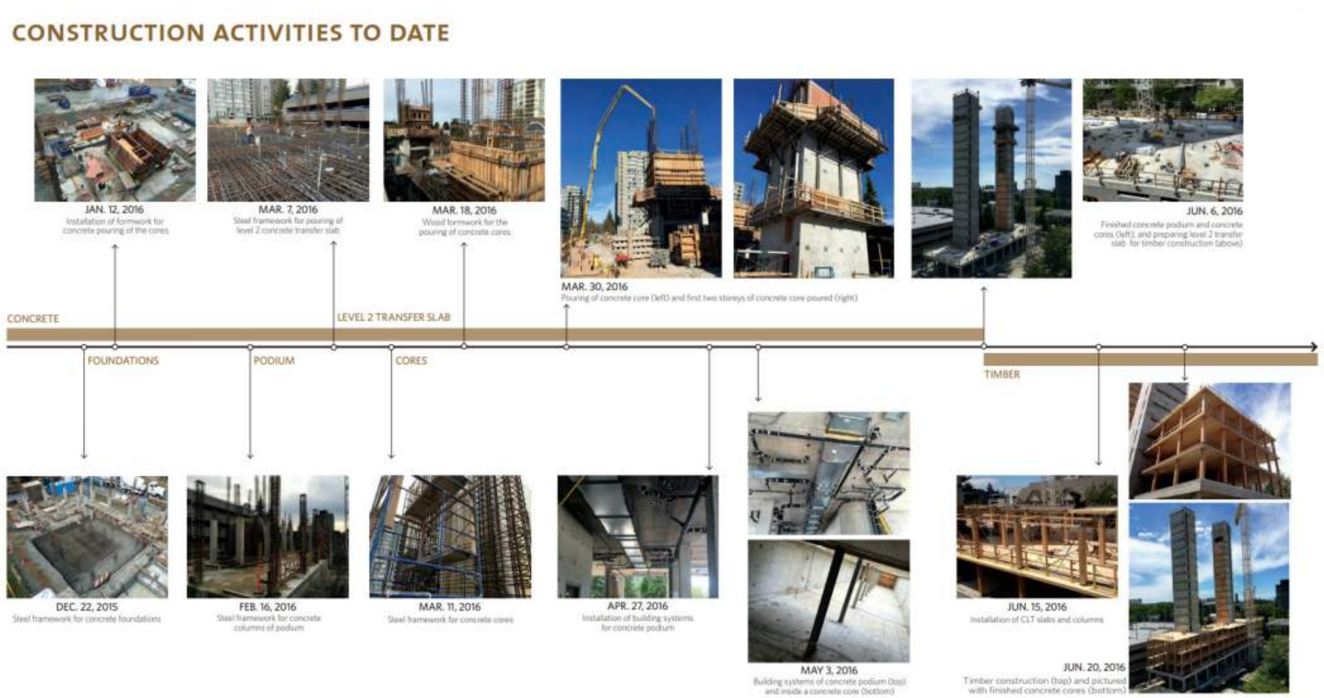
18-story, 53 m tall, student housing complex in The University of British Columbia campus

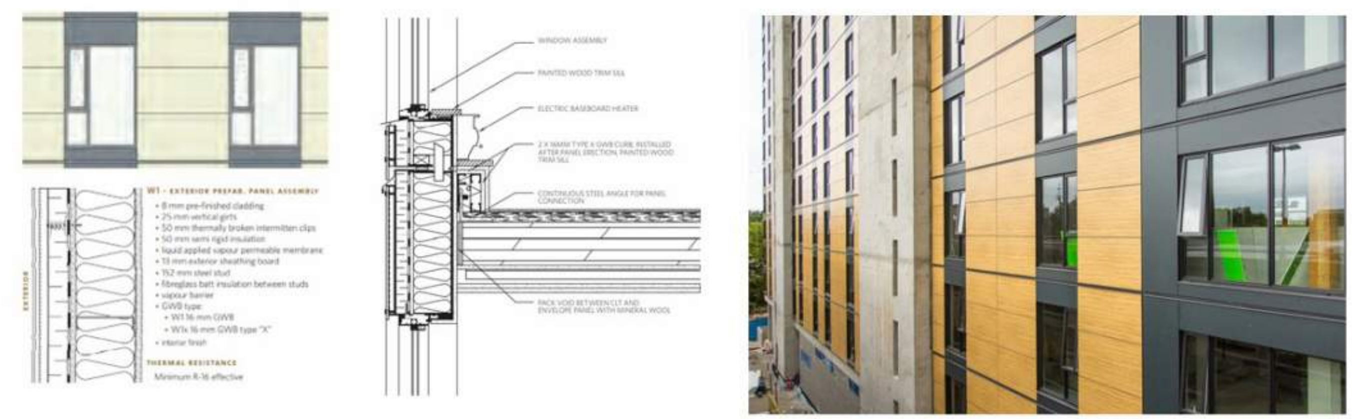
The first mass hybrid timber residential high-rise building in North America

Part of building construction utilizes prefabrication (Building envelope and exterior system)

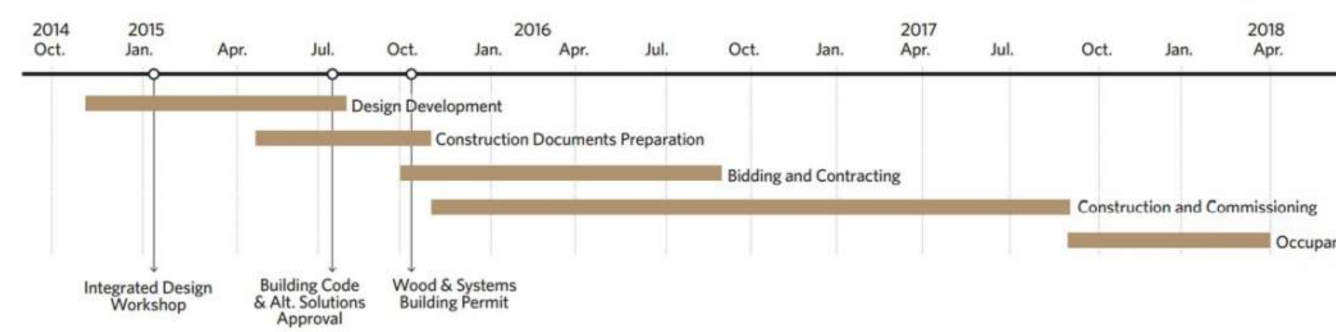
The wood structure was complete less than 70 days after the prefabricated components arrived on site, approximately four months faster than a typical project of this size.

Mass timber structure with concrete podium and core.





Brock Commons Tallwood House | Education, Multi-family + Residential Wood Design + Construction | naturally:wood (naturallywood.com)



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MVE + PARTNERS

Phase 1: Research for Building Use - Residential & Hospitality

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

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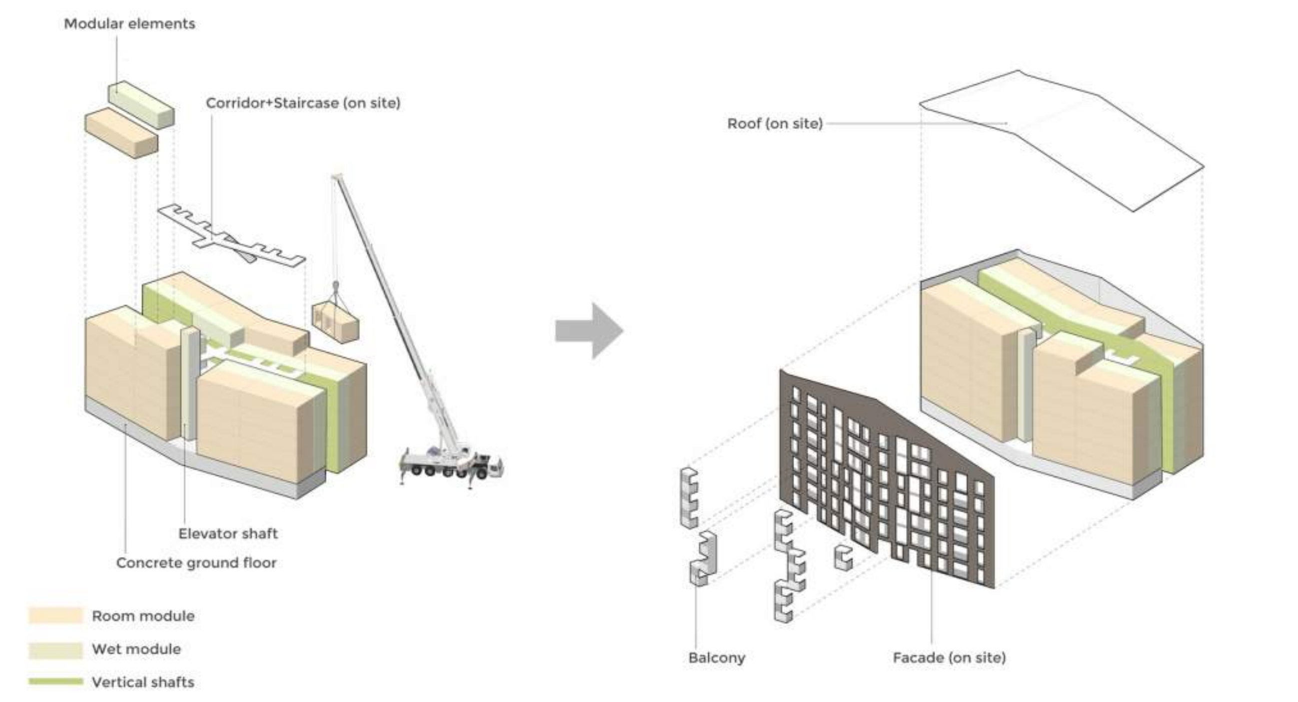
The Puukuokka Block is an illustration of the potential of a system of volumetric modules made of CLT in creating multi-story apartment buildings with a fully wooden frame and structure.

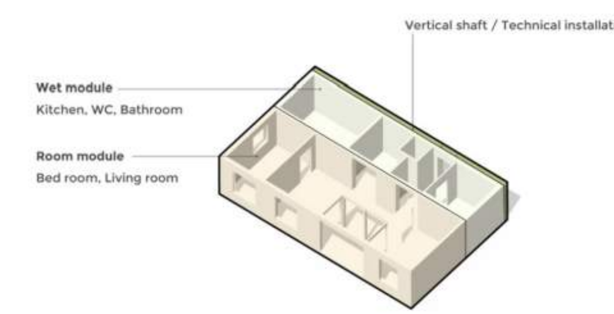
The Global Concept for the Allas Sea Pool Family is an example of applying the modular principle in a scalable concept with the capacity for flexible adaptation for sites in different parts of the world.

Koota is a new wooden housing block to be built in Porvoo, a small historical city with a significant heritage of wooden buildings from the 19th century.

It explores the potential of new methods of timber construction in providing a contemporary addition to the tradition of wooden housing. It creates a new solution for urban living in a way that is both ecologically and socially sustainable and promotes a sense of community amongst the residents.



Typical floor plan



Modular elements

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

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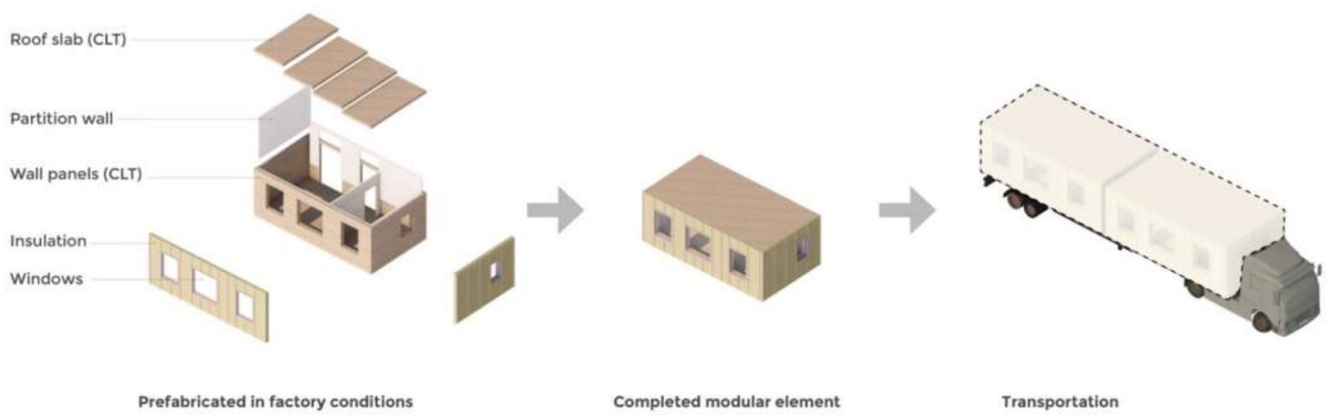
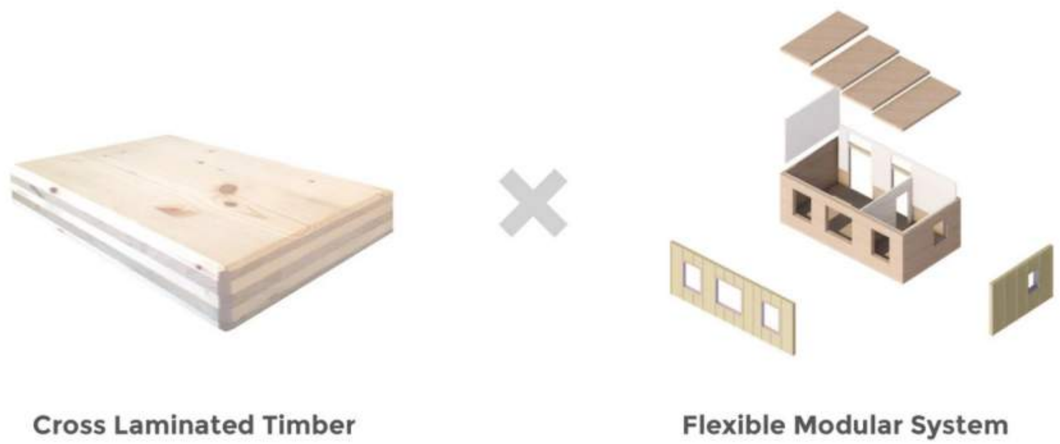
Flexibly customizable modular system



Concept

Flexibly customizable modular system based on the use of prefabricated volumetric CLT



Phase 1: Research for Building Use - Residential & Hospitality

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

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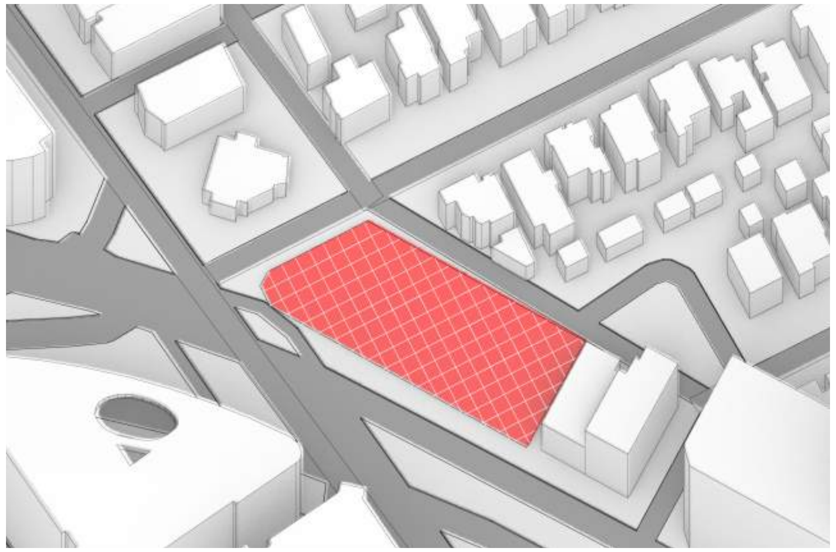
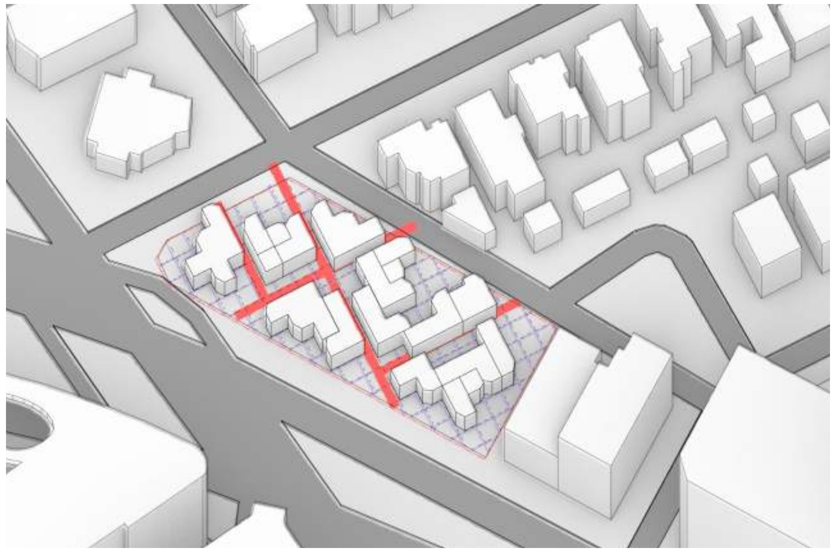
1. Site Axes



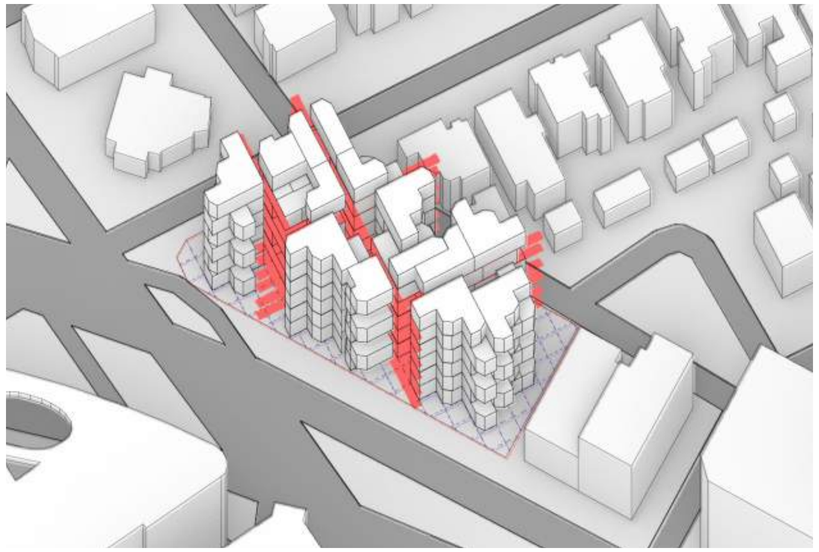
2. 14'x14' grid informed by axes

3. Carve Space (place units)

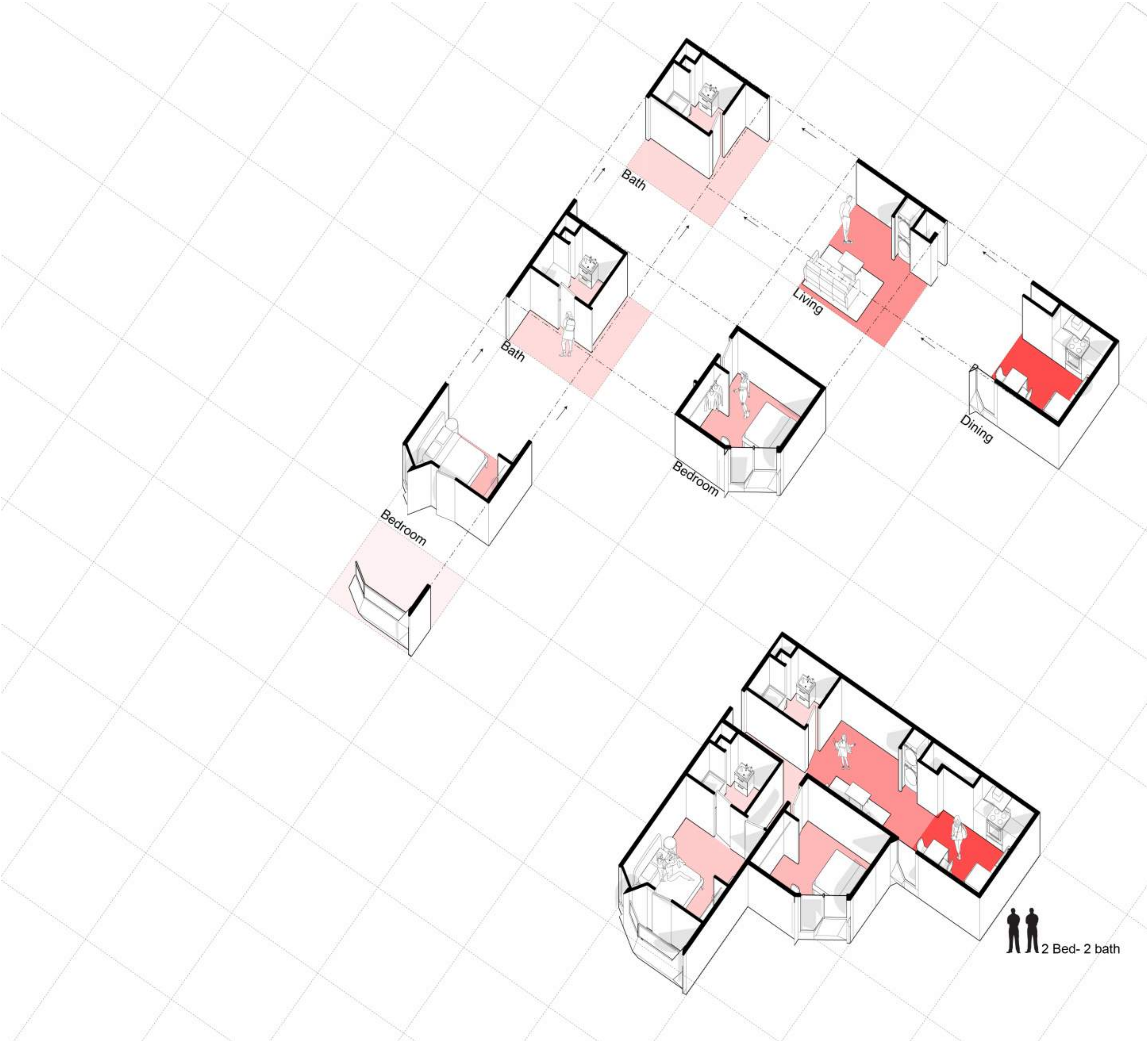


4. Split

5. Stack



6. Circulation

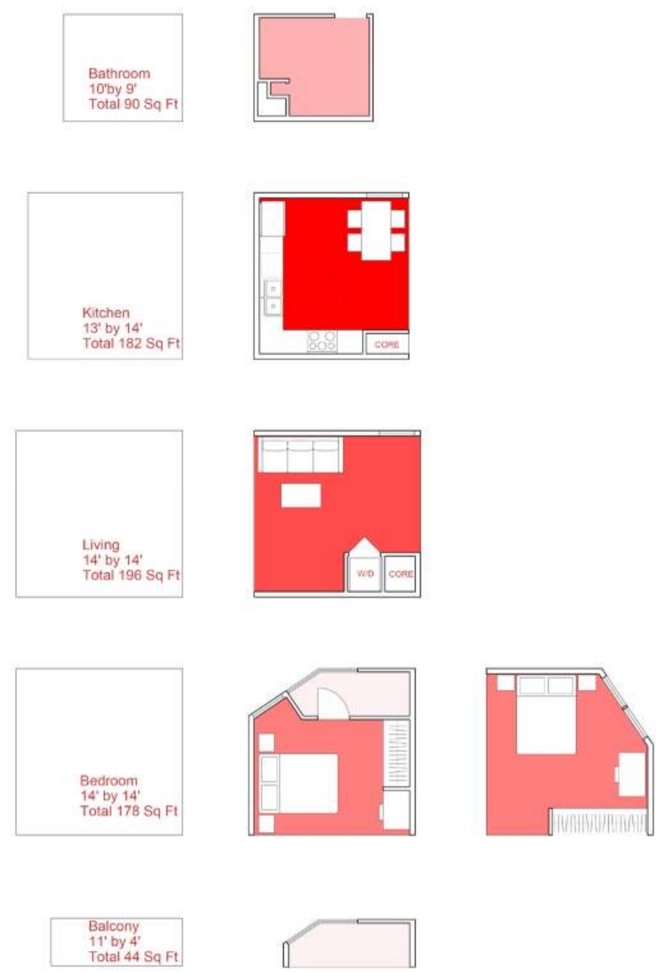

Bath
Bath
Living
Bedroom
Bedroom
Dining
2 Bed- 2 bath

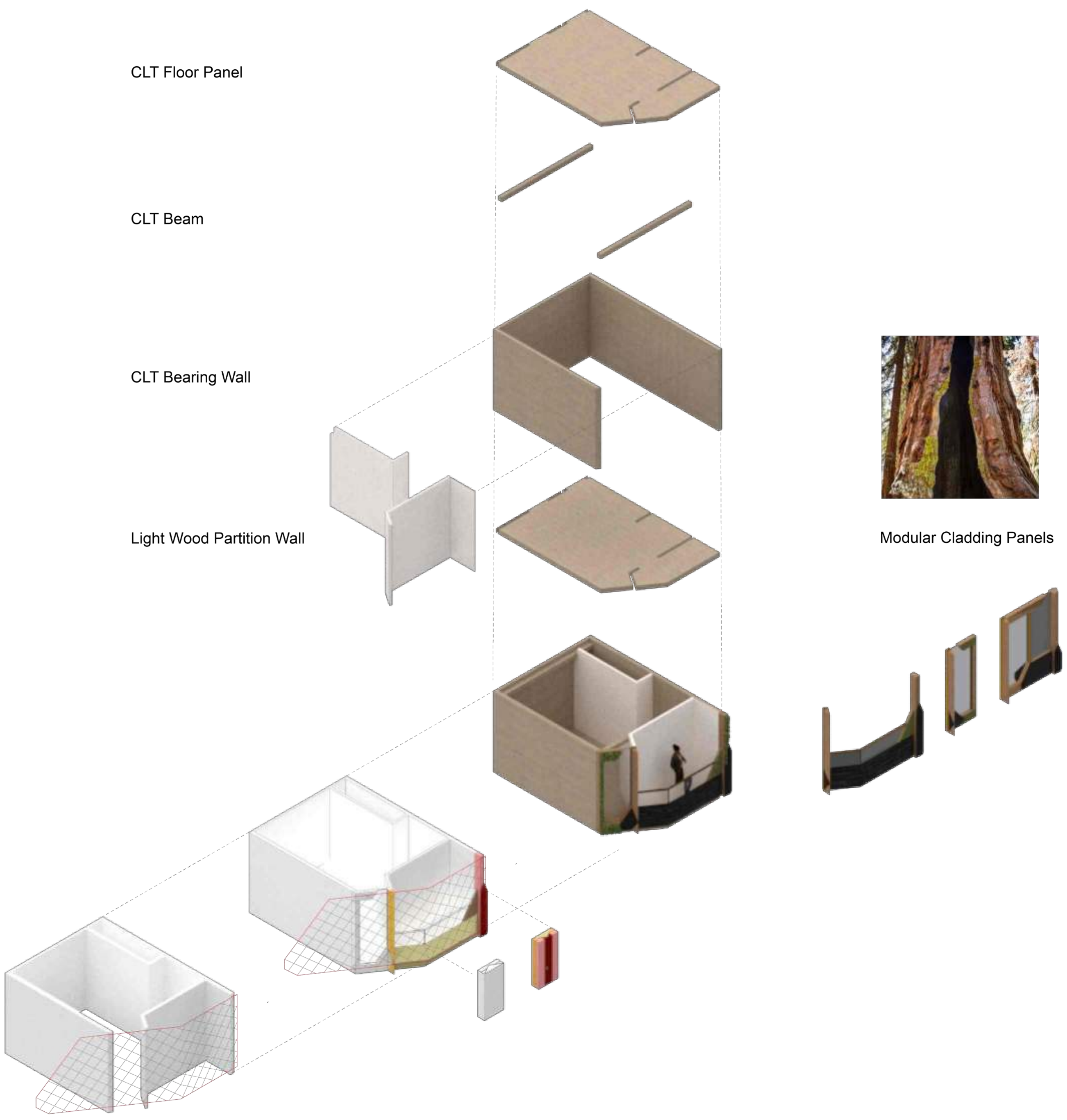
Project Site

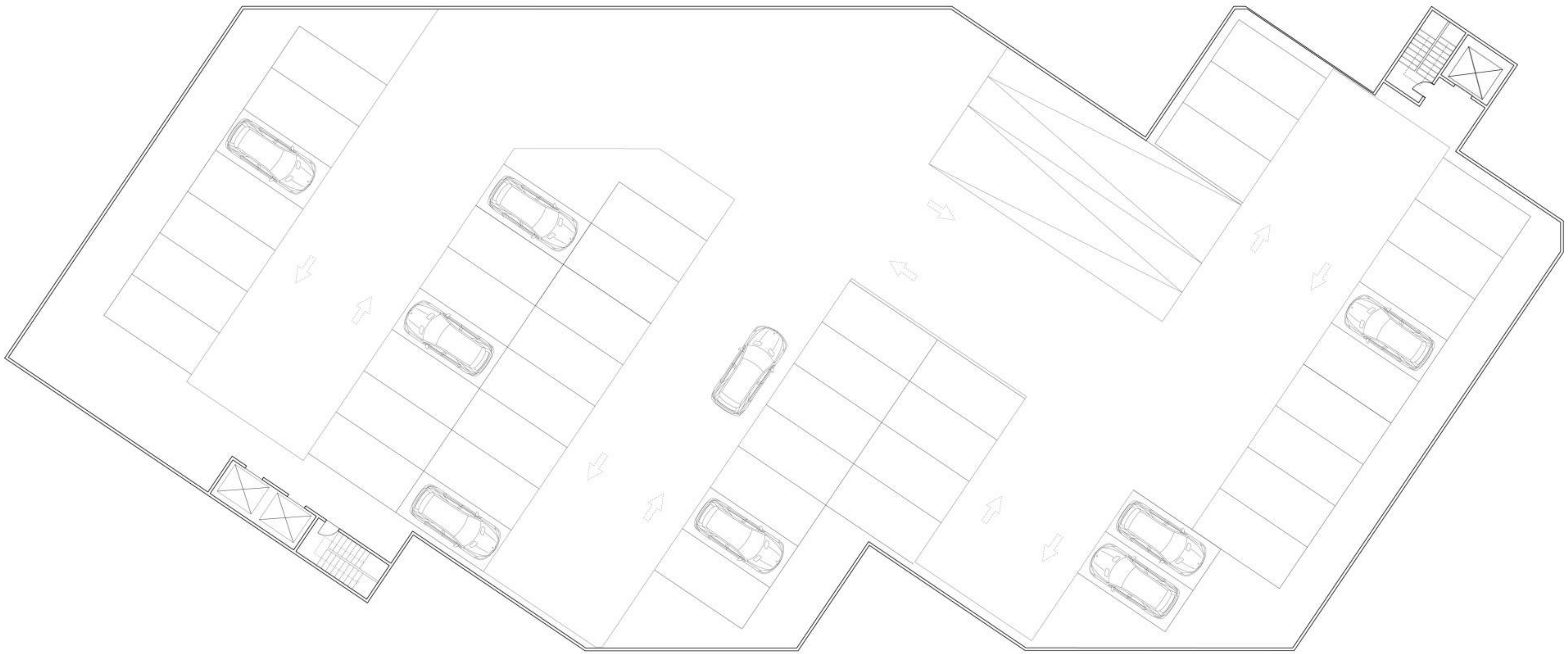
Concept Diagrams

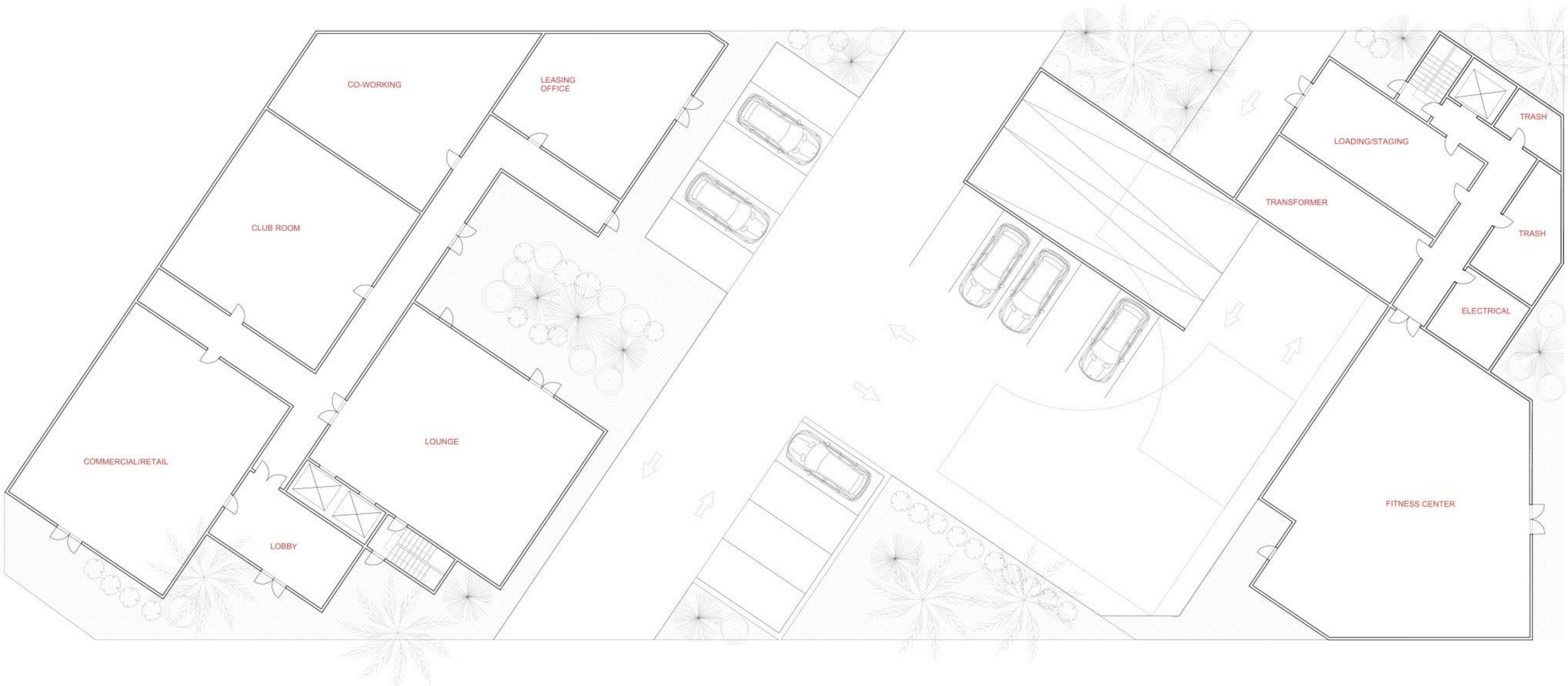
Drawings

Renders




CLT Floor Panel
CLT Beam
CLT Bearing Wall
Light Wood Partition Wall
Modular Cladding Panels

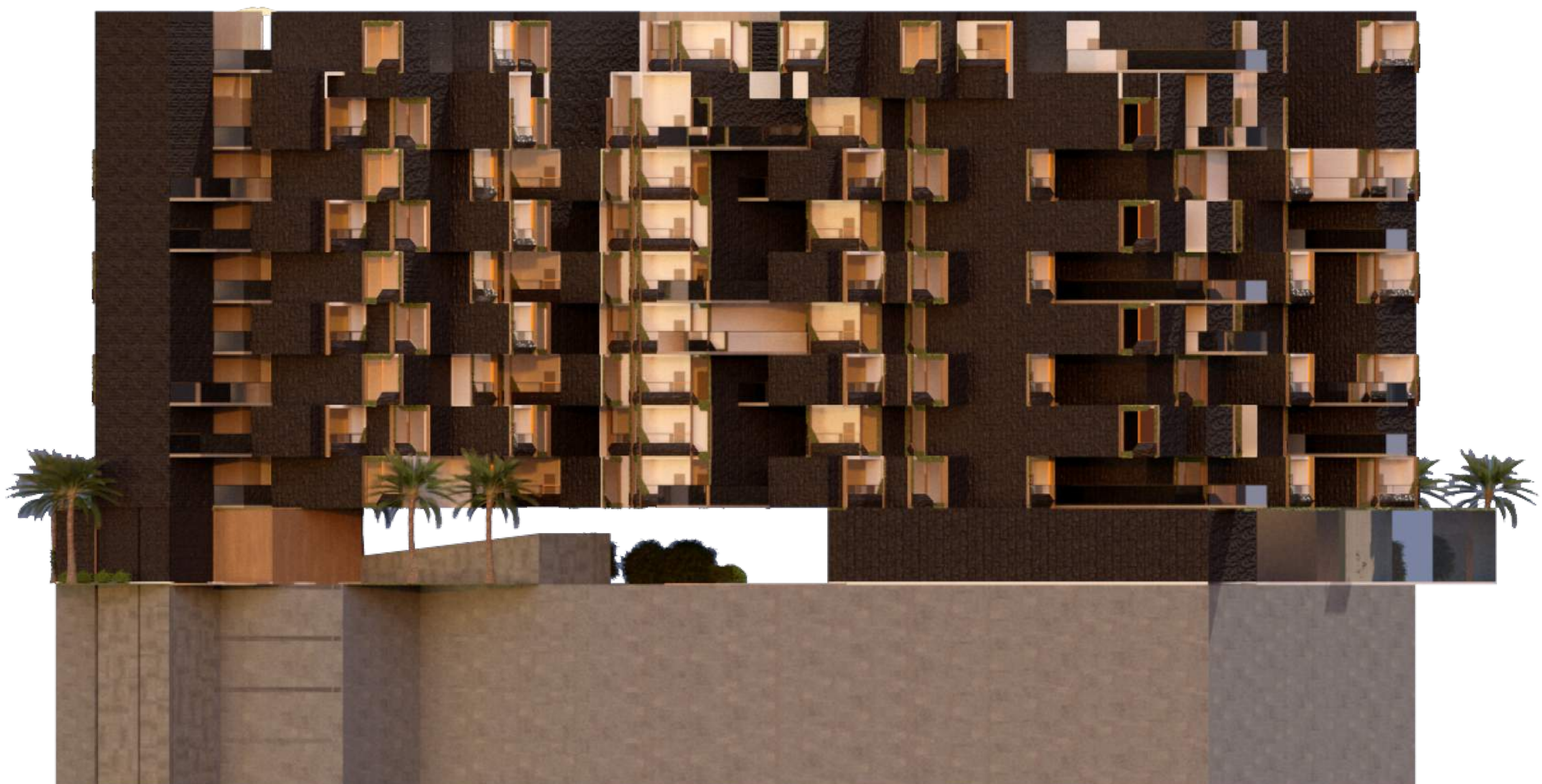


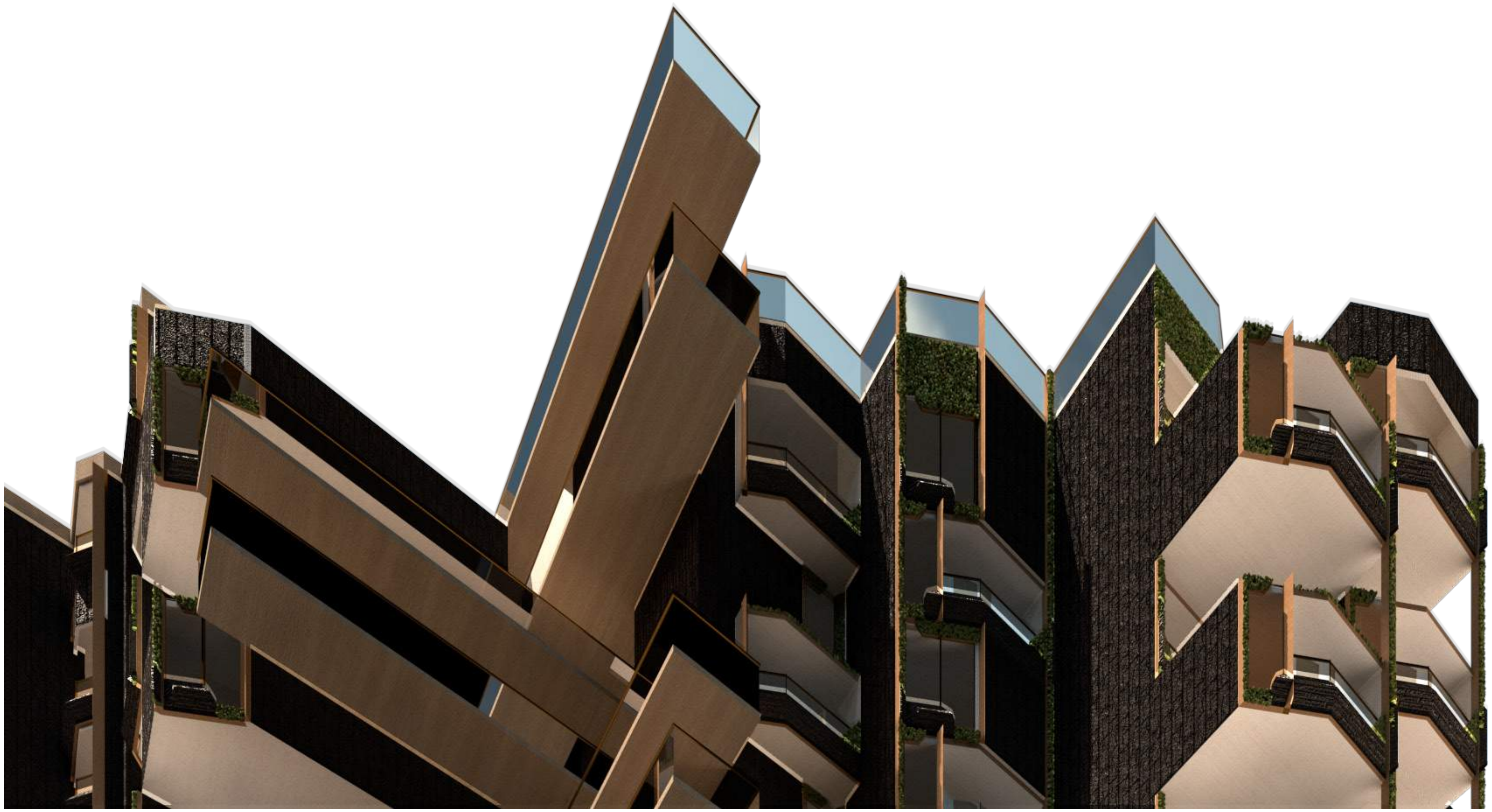

CO-WORKING
LEASING OFFICE
CLUB ROOM
LOUNGE
COMMERCIAL/RETAIL
LOBBY
LOADING/STAGING
TRASH
TRANSFORMER
TRASH
ELECTRICAL
FITNESS CENTER


ELECTRICAL
STORAGE
TRASH


ELECTRICAL
STORAGE
TRASH


ELECTRICAL
STORAGE
TRASH





Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

Types Of Materials (Lightweight)

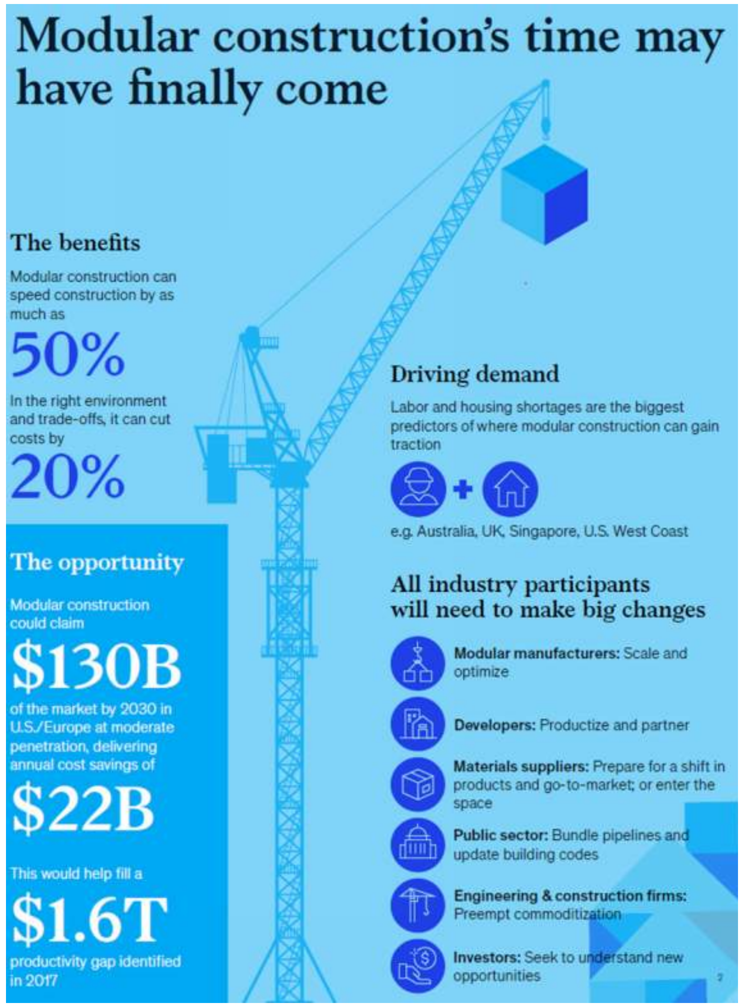
Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)

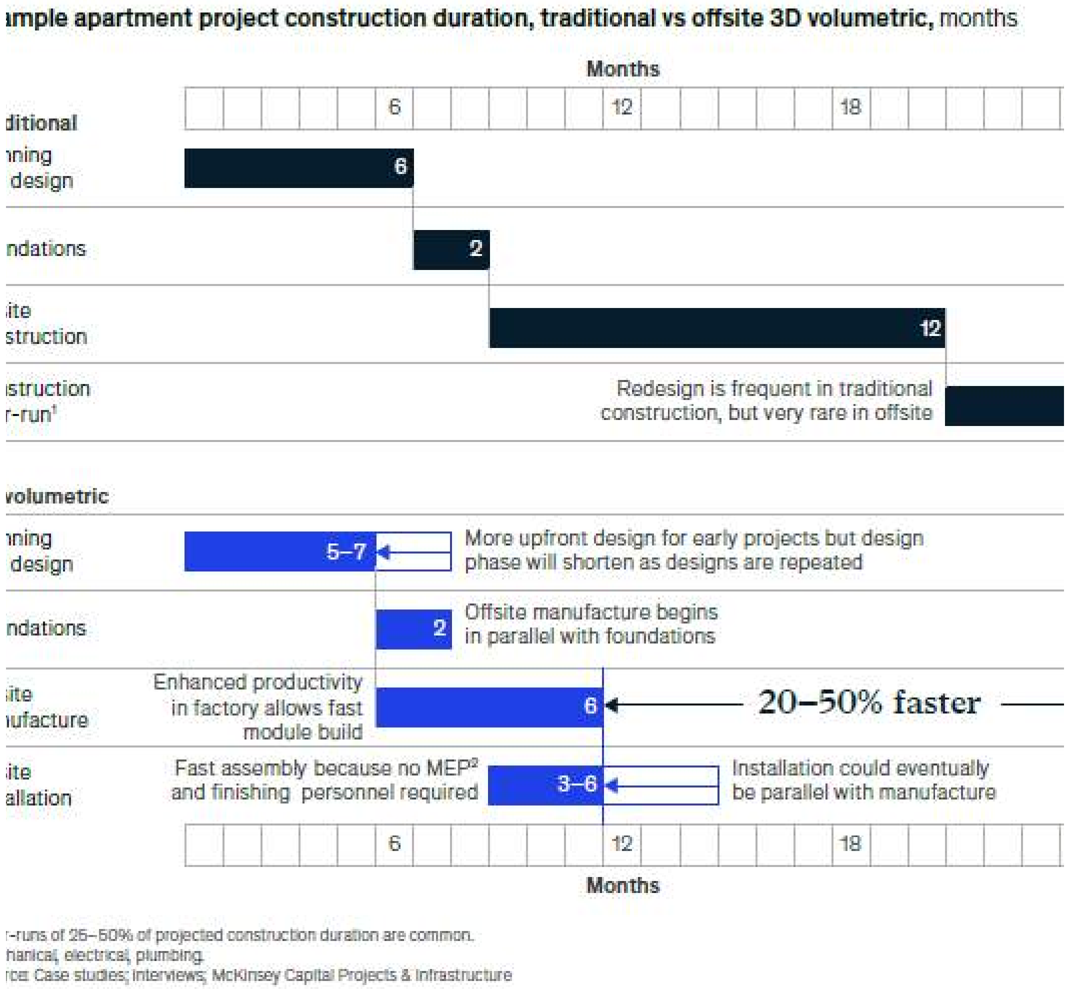
Understanding Modular Construction:

In broad terms, modular construction involves producing standardized components of a structure in an off-site factory, then assembling them on-site. Terms such as "off-site construction," "prefabrication," and "modular construction" are used interchangeably. These terms cover a range of different approaches and systems, from single elements that are clipped together using standard connections and interfaces to 3-D volumetric units with full fixtures.

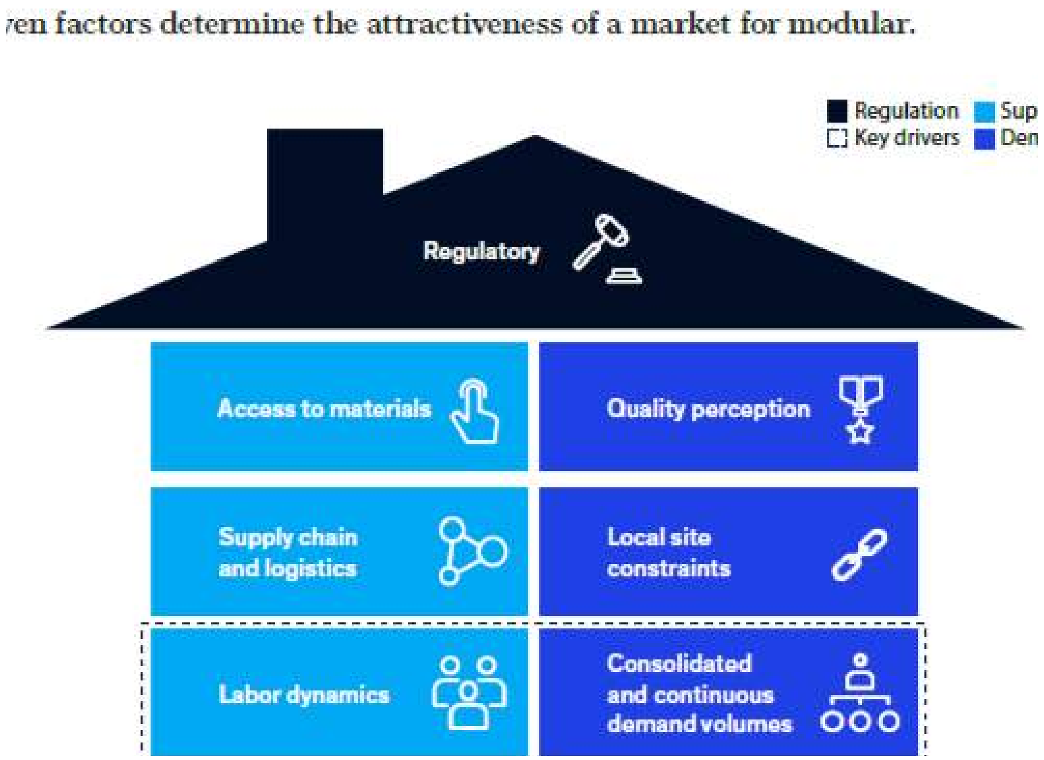
Modular Construction and its advantages



Modular Construction v/s convention construction with respect to construction timeline



Advantages of Modular Construction



Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

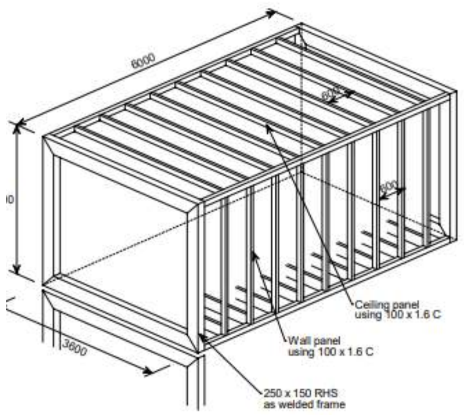
Types Of Materials (Lightweight)

Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)

Types of Steel Modules:

4 sided Modules



Isometric view of module and welded end frame

jure 16 Rigid frame used to create an open end in a modular unit

rm of construction

odules may be designed to transfer loads ntinuously through their longitudinal walls. In this rm of construction, modules are manufactured witt ur closed sides to create cellular-type spaces. The aximum width of the module that is suitable for ansportation and installation limits the cellular spac at is provided.

ıe modules are designed for the combined vertical ad of the modules above and in-plane loads due to nd action. The maximum height of buildings in fully odular construction is 6 to10 storeys, depending or cation and exposure to wind loading.

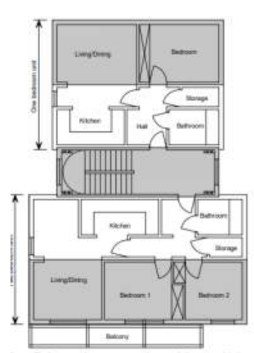
Stability

The stabilising system depends on the geometric forn of the building. Various solutions are used:

- For low-rise buildings, in-plane bracing or diaphragm action of the board materials within the modules provides shear resistance, assisted by the module-to-module connections, which transfer the applied wind forces to the group of modules.
- For buildings of 6 to 10 storeys height, a vertical bracing system is often located around an access core and assisted by horizontal bracing or diaphragm actior in the corridor floor between the modules.
- For taller buildings, a primary steel podium frame may be provided on which the modules are stacked (see page 10), and supplemented by a concrete or steel core.

The maximum height of a group of modules is dependent on the stability provided under wind actior Various cases are presented in Table 1 for scheme design (based on wind loading in the Midlands of England). Details and dimensions of particular module types differ, and so precise guidance is system-specific. Taller buildings can be designed, depending on the strategy adopted for stability and fire safety.

Partially Opened Modules



igure 7 Layout of apartments using partially open-sided modules – alternate modules are shaded
Courtesy, PCKO Architects

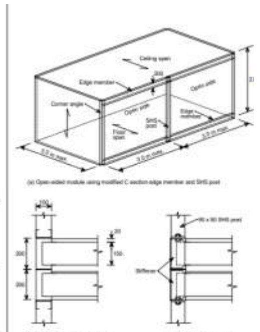


Figure 9 Use of mid-side post to provide intermediate support to the side of a module

igure 8 Completed building (above), Barling Court, Stockwell, London

Figure 10 Open-sided bathroom modules being attached to an existing building
Courtesy, Ruukki

(see opposite). *Courtesy, PCKO Architects*

Application:

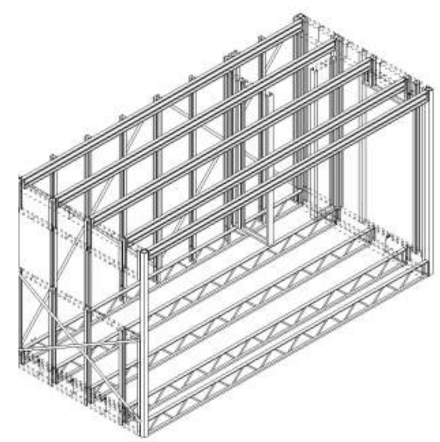
Key worker accommodation, small apartments, hotels with corridors, communal areas in student residences etc.

Technical details

The form of construction is similar to that of 4-sided modules, except for the use of additional posts, generally in the form of 70 × 70 to 100 × 100 SHS members.

Corner supported Modules

igure 11 Primary steel frame used in an open-sided modı
Courtesy, Kingspan Off-Site and Modular UK



igure 12 Smaller open-sided module using longitudinally spanning lattice joists

Form of construction

Modules may be designed to provide fully open sides by transfer of loads to the corner posts. This is achieved by bending of the deep longitudinal edge beams. The framework of the module is often in the form of hot rolled steel members, such as Square Hollow Section (SHS) columns and Parallel Flange Channel (PFC) edge beams, bolted together, as show n Figure 11.

Mixed Modular and Panel construction

recent project in Fulham that used load-bearing athroom modules to support the floor cassettes is ustrated in Figure 19.

gure 19 Mixed modular and panel building using light steel framing at Lillie Road, Fulham
Courtesy, Feilden Clegg Bradley

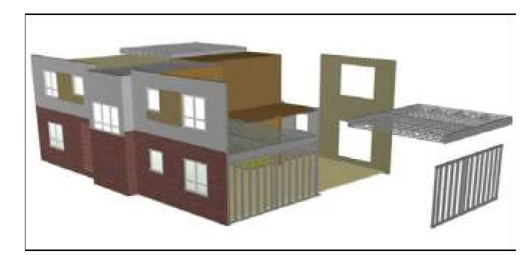


Figure 17 'Hybrid' modular and panel building showing planar floors and walls attached to the modules

Figure 18 Demonstration building system
Courtesy, Corus Living Solutions

Modules with primary structure

gure 20 Typical podium structure in which seven storeys of residential units are supported on a composite frame below

igure 21 Installation of modules behind external steel framework at MoHo, Manchester
Courtesy, Yorkon and Joule Consulting Engineers

igure 22 Modular units supported by a podium
Courtesy, Fusion Building Systems Ltd.

igure 23 Mixed use of stabilising frame and modules in a residential project in Shadwell, East London
Courtesy, Rollalong

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

Types Of Materials (Lightweight)

Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)

Transportation of Steel Modules:

responsible for checking the drawings against the work done in the factory. Because interior and exterior finishes are completed before components reach the construction site, modular construction requires periodic third-party inspections to approve works as it passes through the assembly line. Failed inspections halt payment and slow down production.

Fire ratings in modular construction present the most difficult challenge from a design and inspections perspective. Continuous rated construction across component connections and structural member enclosures is needed. Furthermore, ratings for proprietary systems developed for singular projects are expensive and time consuming. Custom cold formed steel fabrications made by modular manufacturers are the most common example.

5.2.2 Transportation Limitations

The height, width, length, and weight of components are all restricted by the physical limitations of the truck and the road. A module must be in compliance with the rules of each different state along its path of travel. Modules falling under motor vehicle laws are built on a chassis with an integral hitch and axel. Conversely, components shipped on a flatback trailer qualify as freight and can be shipped as super loads at a higher cost.

The dimensional restrictions of a flatback trailer vary based on the truck used. In general terms, a single drop trailer can handle a 13' x 50' module, but will raise it 3'-2" off of the ground. Alternatively, a double drop trailer (LowBoy) will raise a module only 2' off the ground, increasing its overall possible height by another foot, but reducing its maximum length to 40'. The maximum height, however, varies from state to state. Modules built directly on a steel chassis, with a detachable hitch, axels, and wheels, can be larger. Modules built of wood construction can be built up to 16' x 80'. The weight capacity of the equipment will however continue to restrict sizes, proportionately reducing the same module built of steel to 16' x 70', or 12' x 56' for concrete construction. The maximum height of modules including the wheels (approximately 3'-6" tall) is 12', though allowable dimensions will again vary by state.

Maximum sizes for oversized loads (requiring a permit) are listed in *Figure 5.2.2.1* (*Oversized Load, Permit and Pilot Car Requirements* 2011). The table reflects the differences in the requirements by state, with absolute restrictions being largely dependent on the route planned – low bridges can be avoided, tree limbs can be cut, and road conditions can be inspected ahead of time. If a manufacturer has multiple factories in different states, shipping through more stringent states can be avoided altogether.

The end building site also influences the design of components. Onsite labor costs vary based on location, so the amount of onsite work will be limited more so for a project in an urban area versus a project done for a rural area. Similarly, the fragility of components is a concern for shipment overseas. The ability for modules to be stacked is necessary on cargo

State	Width	Height	Length
Alabama	12'	16'	76'
Alaska	*	*	*
Arizona	14' (*)	(*)	120' (*)
Arkansas	12' *	15' (16' *)	
California	12' * (16')	(16' *)	85' (135' *)
Colorado	*	*	*
Connecticut	12'	14'	80'
Deleware	12' (15')	15'	85' (120')
District of Columbia	12'	13'-6"	80'
Florida	12'	14'-6"	95' *
Georgia		15'-6" *	75' *
Idaho	12' *	16'	100' *
Illinois	14'-6" (18')	14'-6" (18')	110' (175')
Indiana	12'-4" (*)	14'-6" (*)	110' (*)
Iowa	14'-6" *	14'-4" (*)	120'
Kansas	12'-6" *	*	
Kentucky	10'-6" *	*	75'
Louisana	12' * (16')	* (13'-6" *)	90' (125')
Maine	12' (16')	*	80' (124')
Maryland	13' (16')	14'-6"	85'
Massachusetts	12' (15' *)	13'-6" (13'-11")	80' * (130' *)
Michigan	12'	14'-5"	100'
Minnesota	14'-6" (16')	*	95'
Mississippi	14'	*	95'
Missouri	12'-4" (16' *)	15'-6" (16' *)	90' (150' *)

State	Width	Height	Length
Montana	16'-6" *	17'	110' *
Nebraska	12'	14'-6" * (16' *)	100'
Nevada	12' * (17' *)	17'	105' (*)
New Hampshire	12' (14'-6")	13'-6" (*)	80' (100')
New Jersey	14'	14'	100'
New Mexico	14' * (20' *)	16' (18')	90'
New York	12' (16' *)	14' (16' *)	80' (140' *)
North Carolina	12' (15')	14'-5" (*)	100' (*)
North Dakota	14'-6" * (18' *)	18'	120'
Ohio	13'	14'-6"	90'
Oklahoma	12' *	15'-9" *	80'
Oregon	14'-1" (16' *)	14'-6"	120'-1" (150')
Pennsylvania	13' (16')	14'-6"	90' (160')
Rhode Island	12' (*)	14' (*)	80' (*)
South Carolina	12'	13'-6"	
South Dakota	10' *	*	
Tennessee	12'-6" *	15'	85'
Texas	16' (20' *)	17' (19' *)	85'
Utah	12' (17')	16' (17')	105'
Vermont	12' (*)	14' (*)	80' (*)
Virginia	10' *	*	85' *
Washington	15' *	14'-6" *	100'
West Virginia	10'-6" * (16' *)	15' *	75' *
Wisconsin	14' * (16' *)		125'
Wyoming	14' *	17'-6"	110'

Note: Rules of thumb for the requirement of an oversize load permit: 8'-6" width, 13'-6" height, 48' length, or 80,000 lbs

* Determined entirely by route travelled

XX Indicates maximum possible dimension without a pilot car escort

( ) Indicates maximum possible dimension without a police escort/state review

Table 5.2.2.1 transportation requirements by state (Oversized Load, Permit and Pilot Car Requirements 2011).

Figure 5.2.2.1 example of a module on a double-drop trailer bed

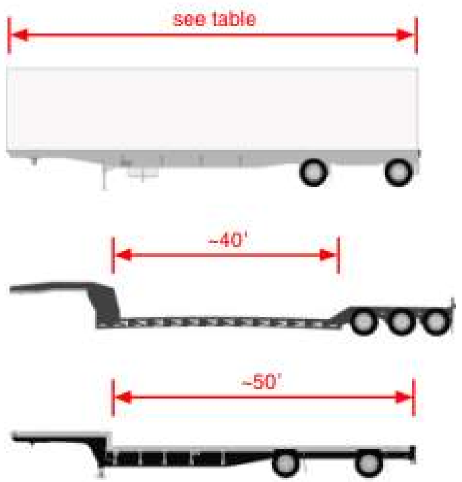


Figure 5.2.2.2 comparison of maximum module lengths base on different shipping methods

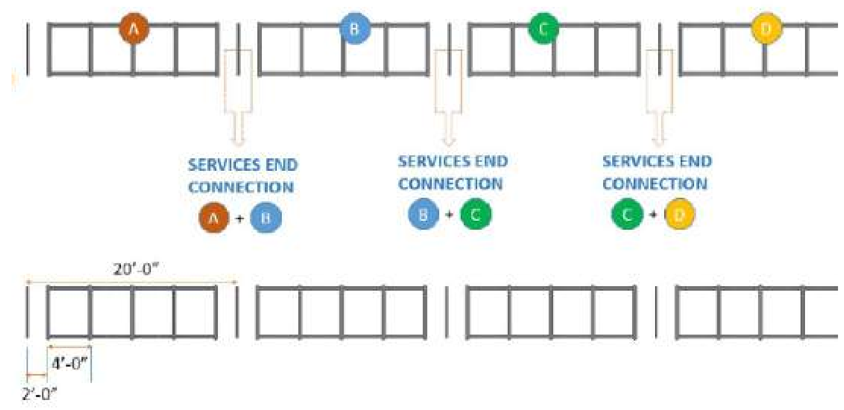
Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

Types Of Materials (Lightweight)

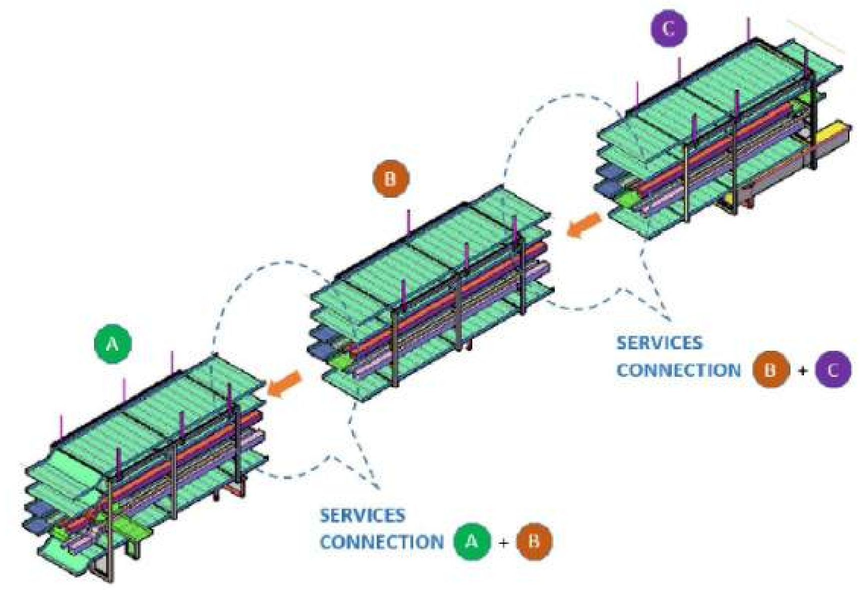
Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)

MEP and Acoustics:



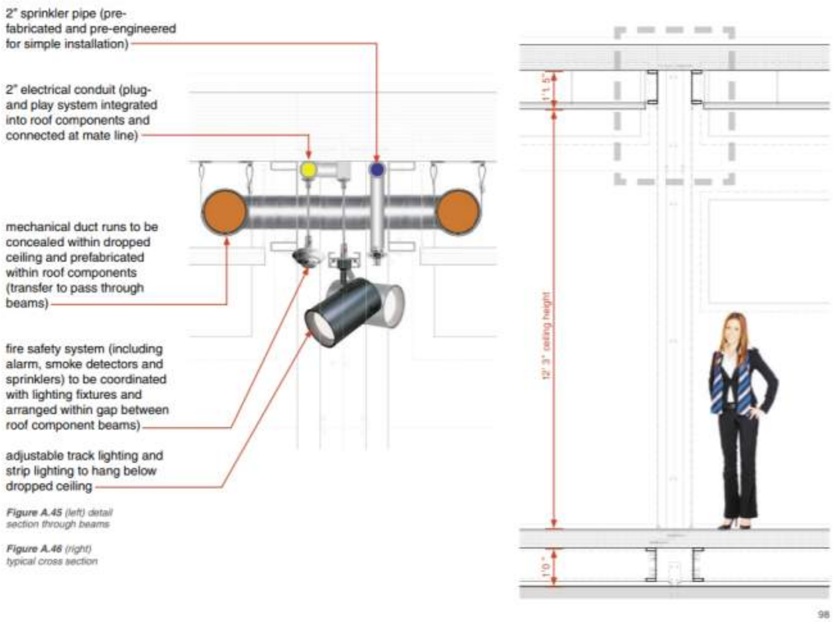
Modeling of module racks and fixing their connection and dimensions.

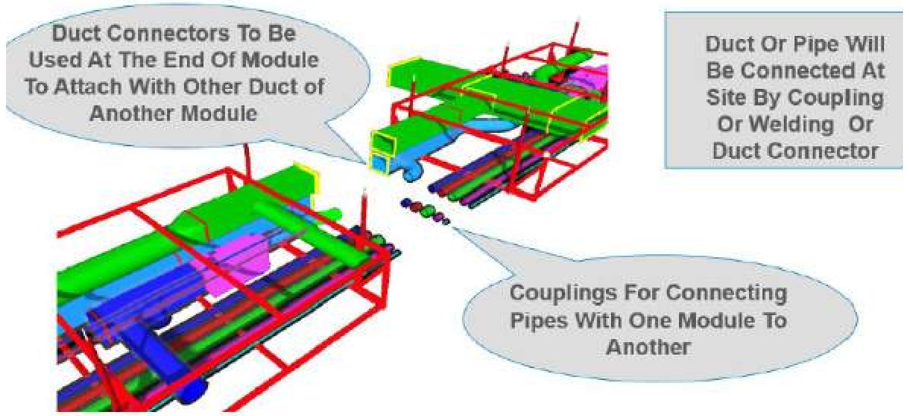


Services accommodation and connections.

Acoustics

Modules are designed as independent units and can be soundproofed to block noise once they are assembled together.





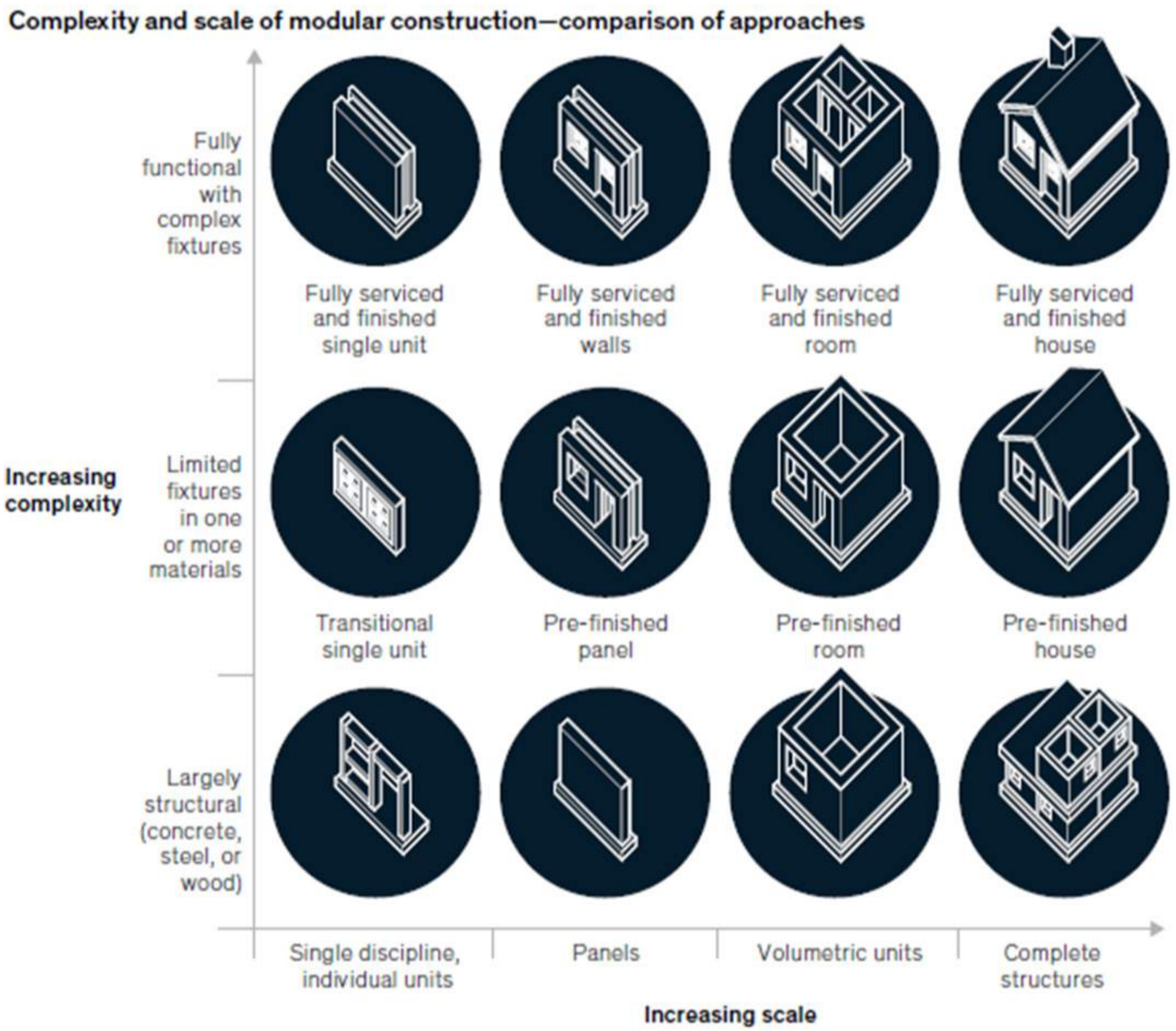
Connection process at site.

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

Types Of Materials (Lightweight)

Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)



Source: Case studies; interviews; McKinsey Capital Projects & Infrastructure

Concrete Modular Construction:

2D panelized: Optimizing logistics and flexibility

A 2D panelized solution resembles a flat-pack assembly approach used in home furniture. Where necessary, panels contain the necessary conduits for services such as heating, ventilation, and air conditioning (HVAC), and plumbing that can be linked together with standard connectors.

The assembly work onsite is much simpler than a traditional build, but it is more complex than putting together 3D modules and requires more internal finishing. On the upside, it is much easier to transport panels than bigger 3D modules. In an ideal case, the components required to build several rooms can fit in a single standard 25-foot container. Flat-pack panels therefore make it possible to transport materials for a significantly greater floor area at one time. It costs approximately $8 per square meter floor space to ship 2D panels around 250 kilometers, but almost $45 per square meter for the 3D equivalent.

3D volumetric: Maximizing productivity benefits

3D volumetric solutions are fully fitted-out units, which could constitute a room, or part of a room, that can be assembled onsite like a series of Lego bricks. They are being developed in timber, steel, or concrete, with the first two materials being more common due to weight and logistics advantages. Onsite assembly involves lifting the modules into place and connecting services such as electrical and plumbing. Most of the work is done in a manufacturing facility offsite.

A 3D volumetric approach delivers the potential for maximum efficiencies and time savings—but the trade-offs include transportation costs and size limitations. The maximum width for road transport that does not require a police escort is typically around 3.5 meters. This either increases the cost of transporting larger units or limits the size of modules, making 3D volumetric most suitable for hotels, hostels, or affordable housing. It is also advantageous for rooms with more intricate finishing, particularly wet rooms such as bathrooms and kitchens. A 3D volumetric approach is most suitable for projects with a high level of repeatability and a high ratio of wet to dry rooms. It should be noted that repeatability does not mean all products need to look the same. Instead, a variety of standardized modules can be pieced together differently to produce a customized end result.

2D panelized: Optimizing logistics and flexibility

2D & 3D hybrid: Combining the best of both worlds

It is also possible to use a mix of 3D modules and 2D panels on a project or to combine those approaches with traditional site work (for instance, for the basement and first floor of a larger project). Typically, wet areas are manufactured as bathroom pods, while the remainder of the building is made from 2D panels. This optimizes the process for the two different areas of the building, bringing high-productivity improvements to the bathroom areas and maximum flexibility to all other areas. However, the manufacturing process required to deliver both solutions becomes more complex, as does coordination of the supply chain.

Types Of Modular Construction (Wall, Façade, Panels, Tubes, Systems)

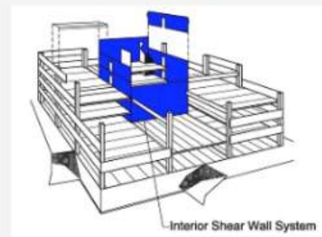
Types Of Materials (Lightweight)

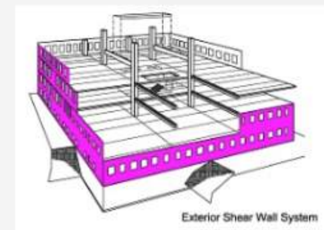
Order Of Processes During Construction (Systems/ Assemblies)

New Technologies (Software Being Used)

Shear Wall Systems and Load Bearing Walls (interior/exterior)

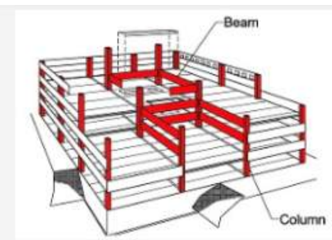
Shear wall systems use combinations of columns, beams and walls to transfer gravity loads to the foundation, but rely on walls and/or specially designed sections such as an elevator shaft to resist lateral loads such as wind. Precast concrete structures are mostly designed as simply supported shear wall systems. Shear walls can either be located on the interior or exterior of the structure.



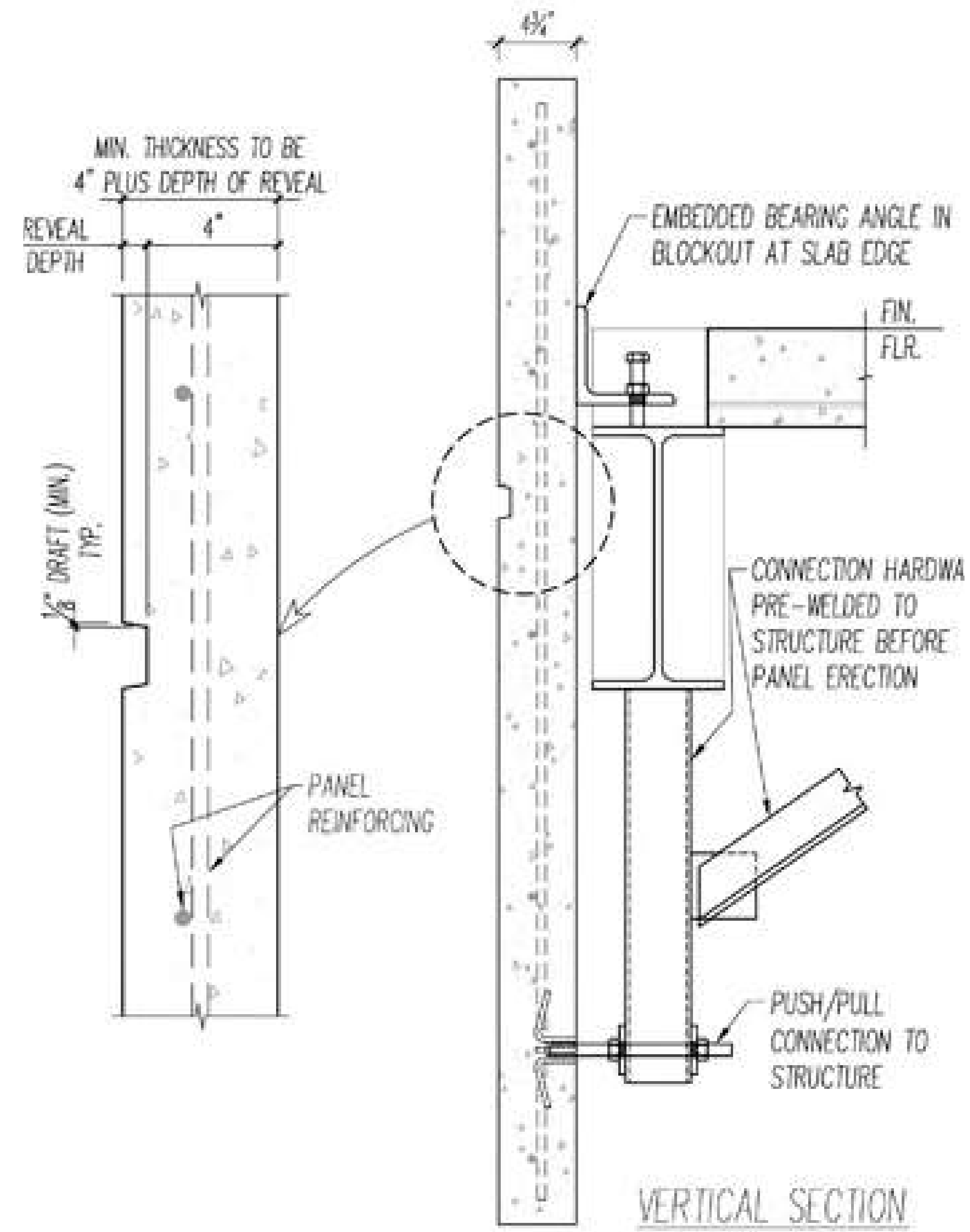


Moment-Resisting Frames

Moment-resisting frames are those in which a degree of rotational restraint is provided between vertical components (usually columns) and horizontal components (usually beams and/or spandrels). This system then resists lateral loads imposed on the structure.

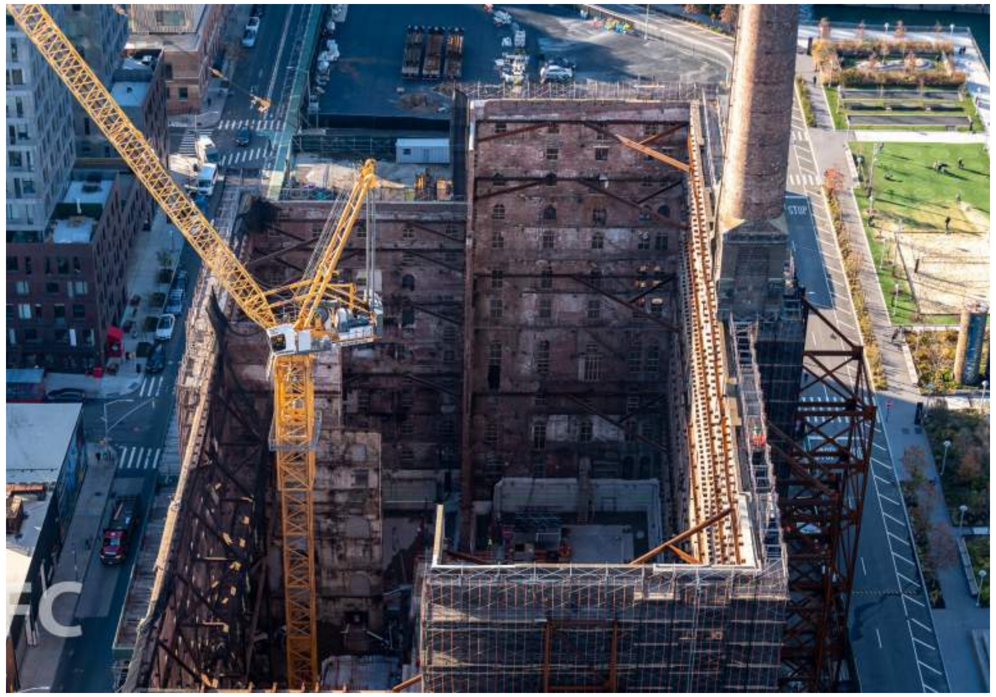


Concrete Modular Structural System:

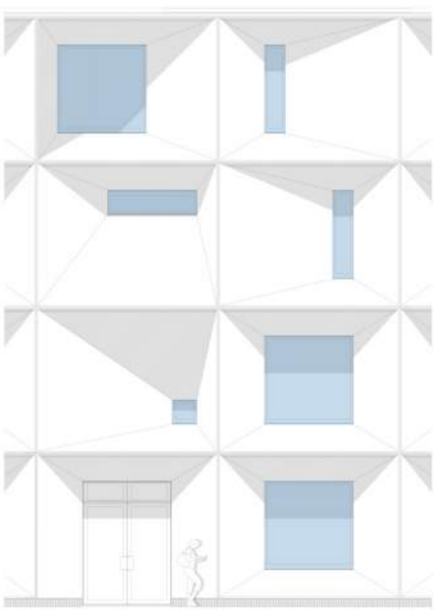


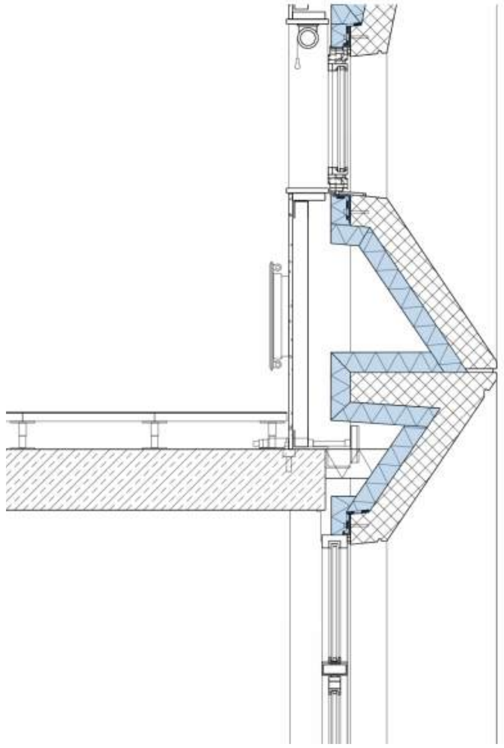
Typical Precast Panel Section

One South First and Ten Grand - Brooklyn

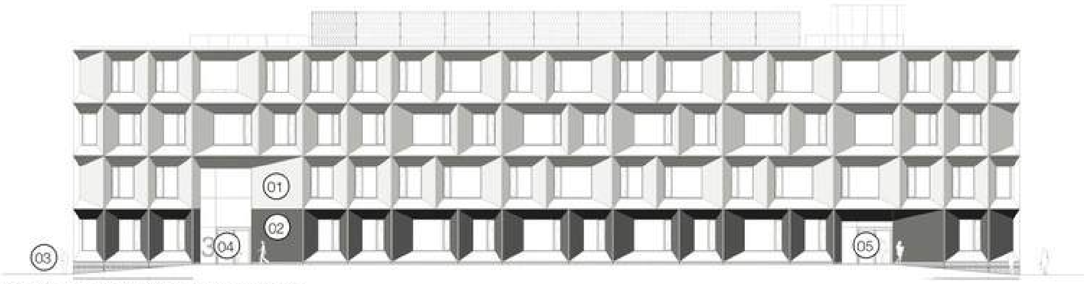


Burnwood School - London

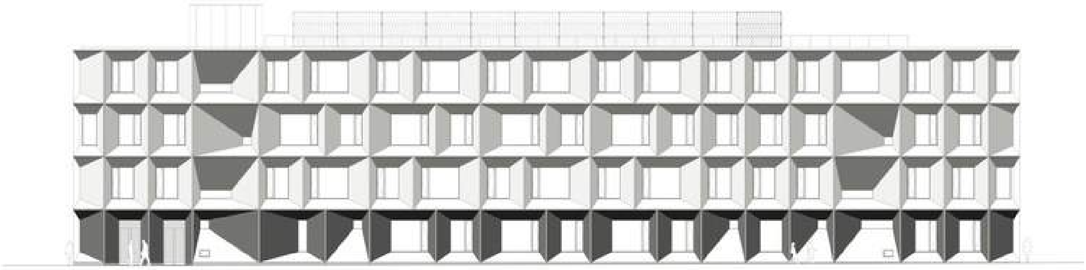




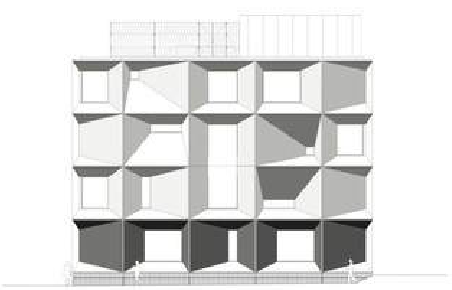
Curriculum buildings



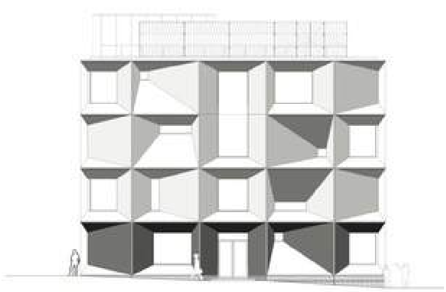
Communications building - West elevation



Communications building - East elevation



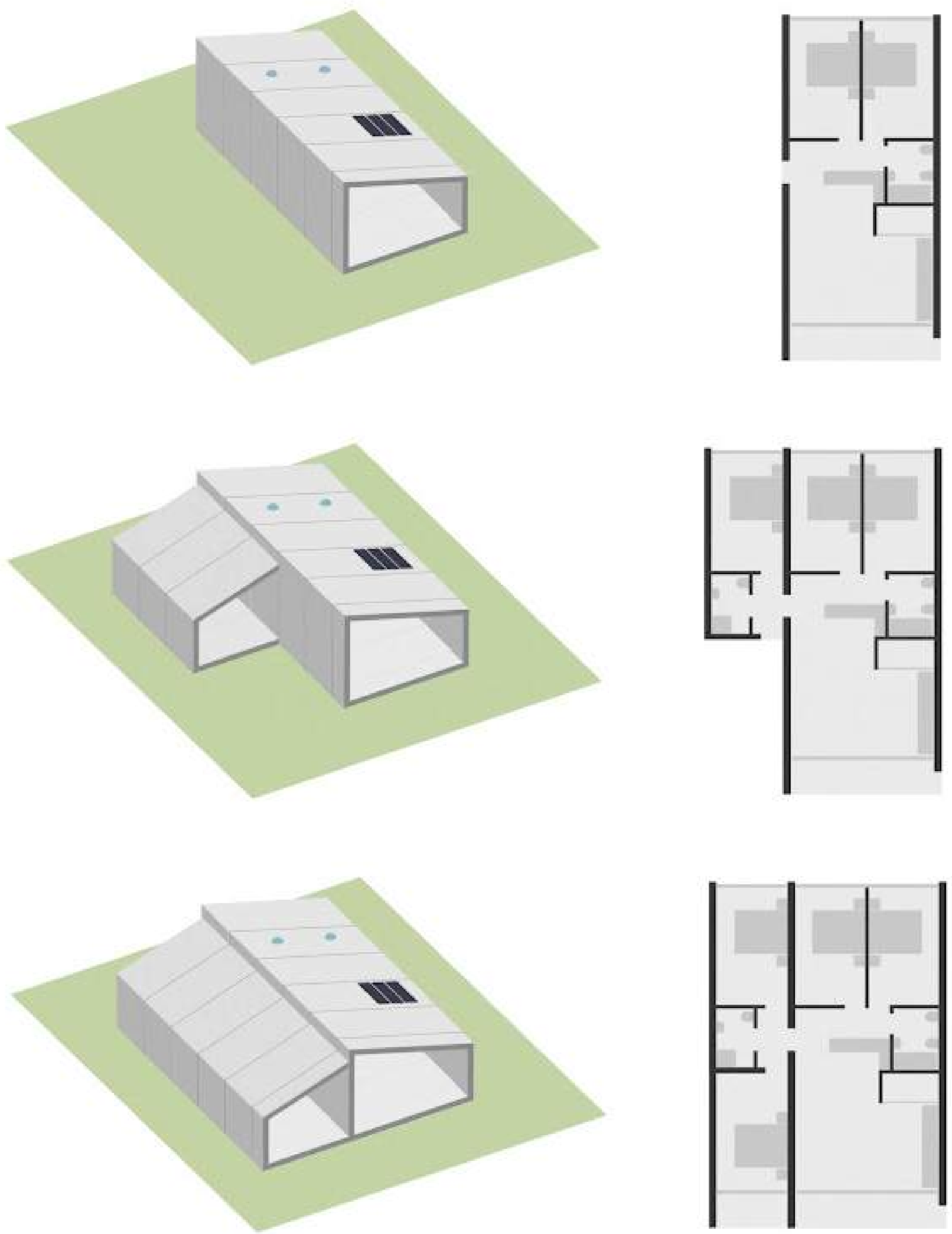
Communications building - South elevation

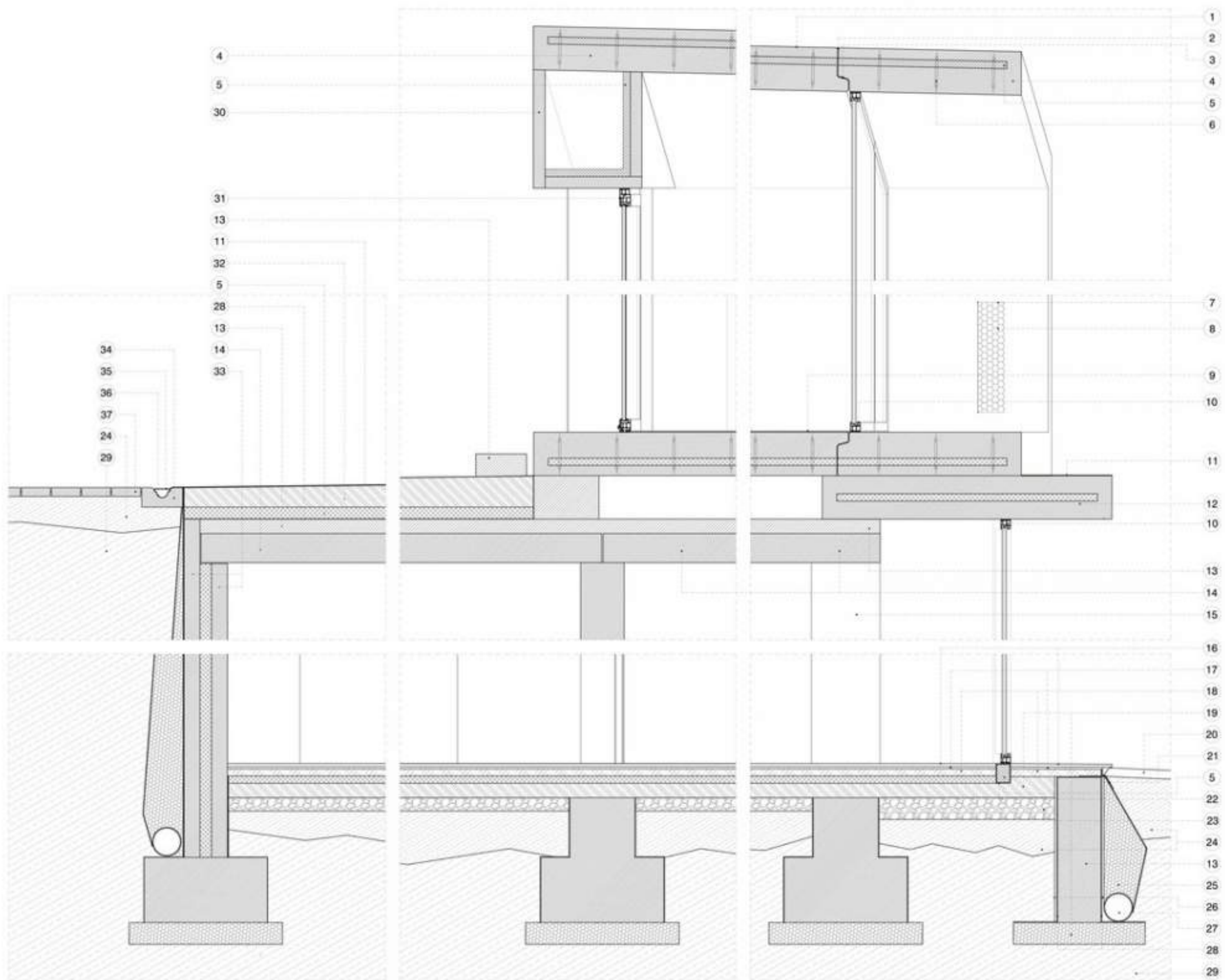


Communications building - North elevation

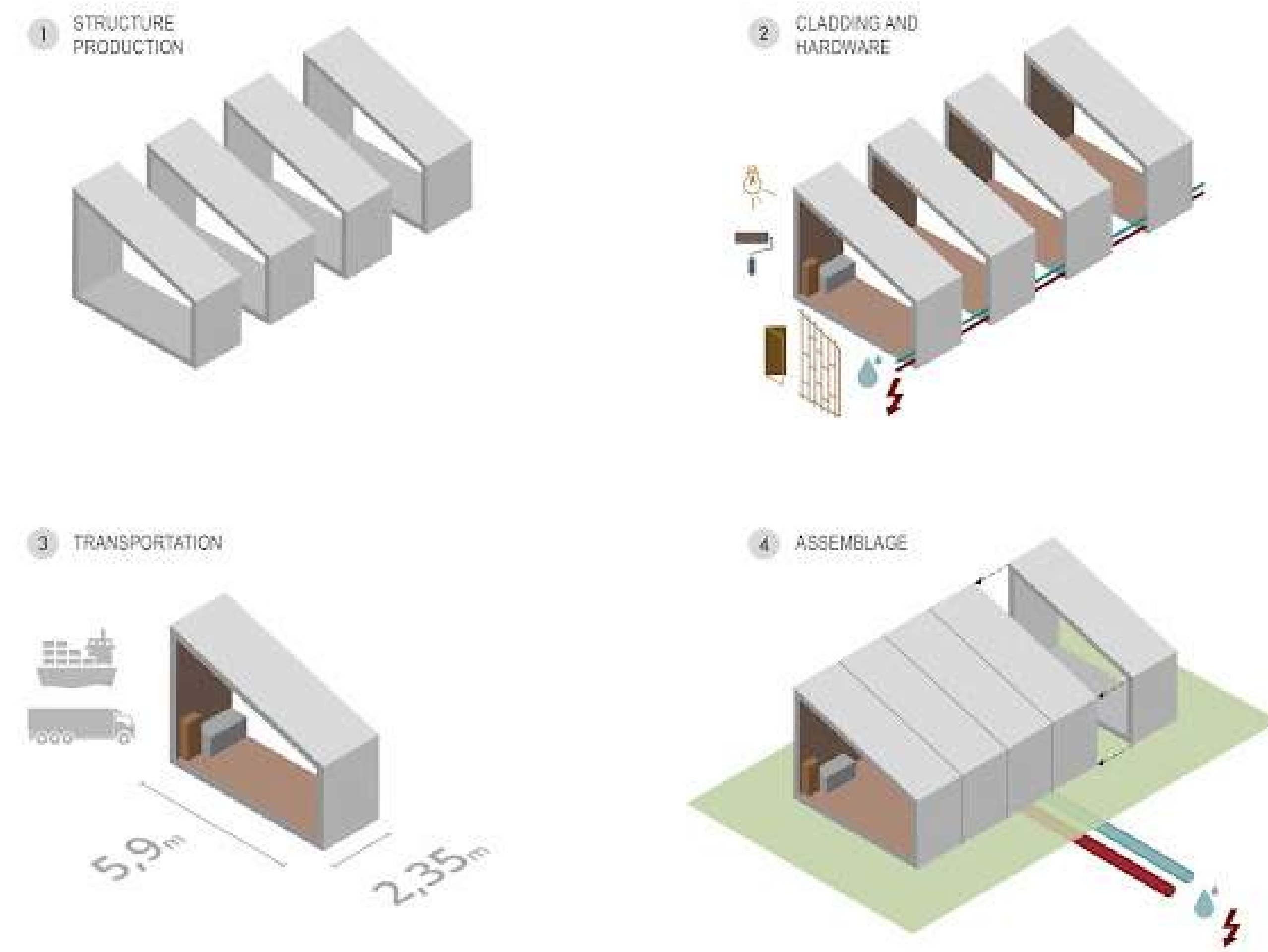
Key:
01 Precast concrete panels - white
02 Precast concrete panels - black
03 Cordrouy base
04 Main entrance
05 Secondary entrance

Gomos Modular Concrete Homes - Portugal

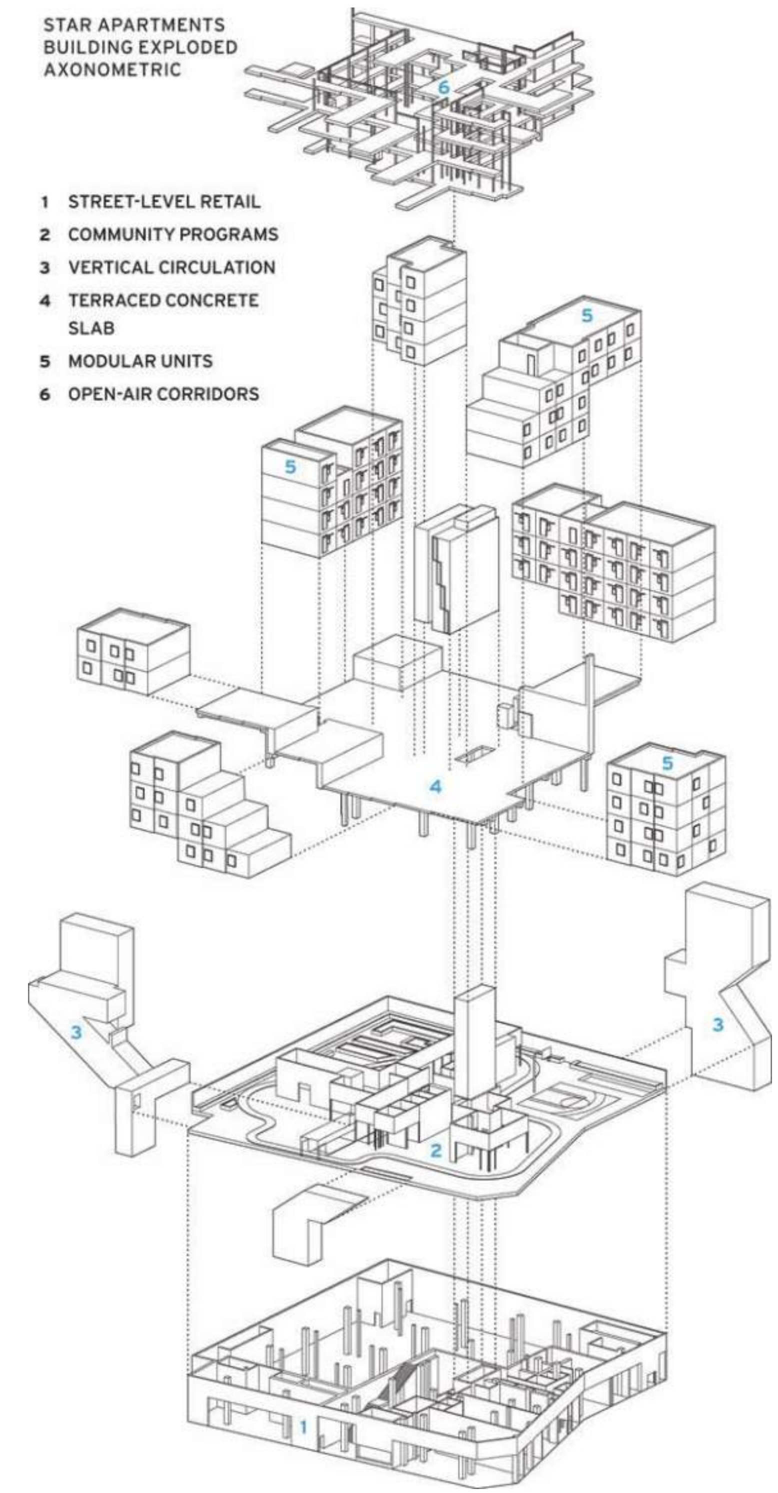




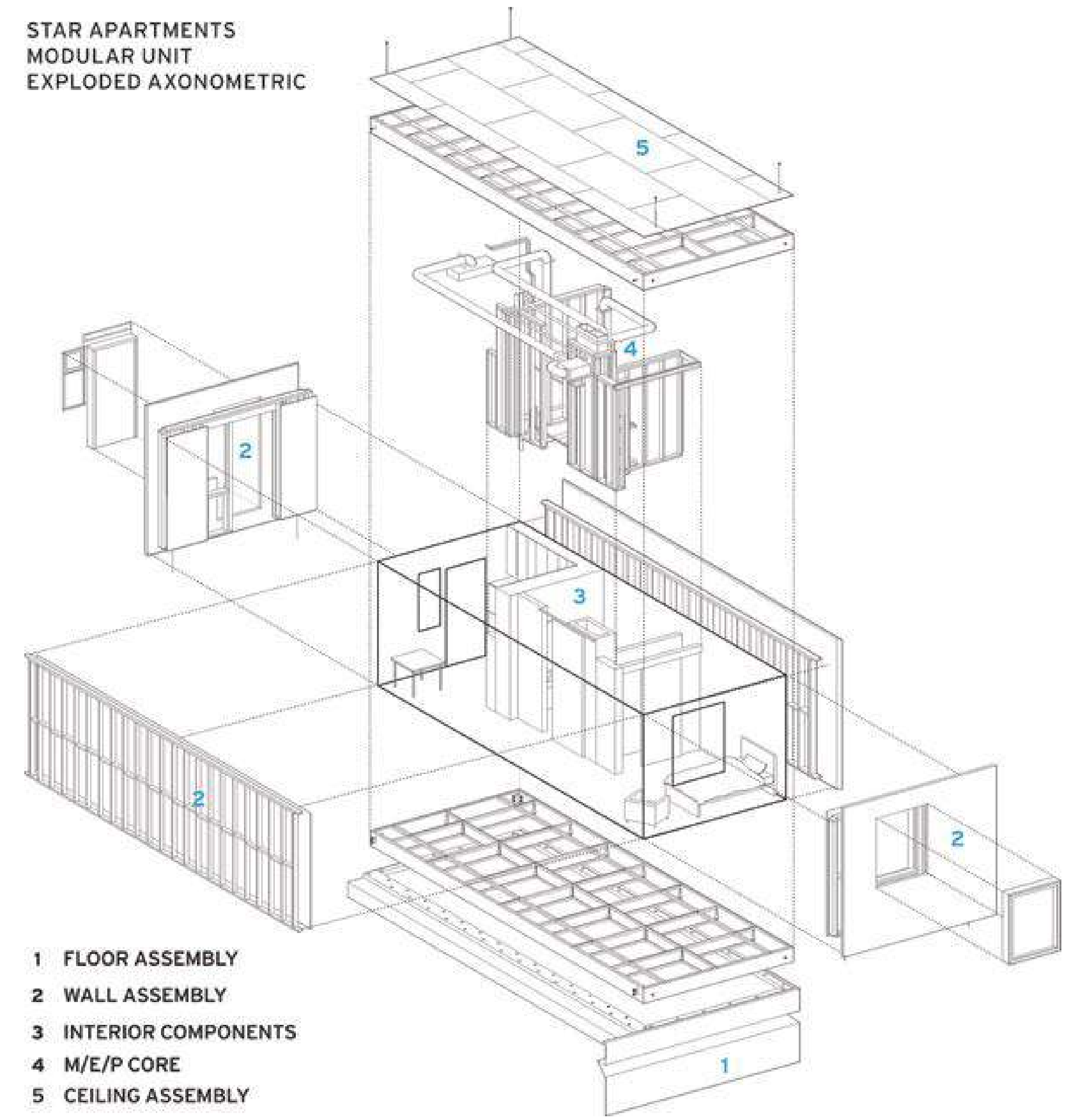
1. tela de impermeabilização.
2. cordão de selagem de juntas tipo "mastique".
3. cordão asfáltico de vedação.
4. módulo de betão armado pré-fabricado impermeabilizado, com isolamento em XPS no interior.
5. isolamento em XPS.
6. conector das peças de betão armado.
7. cabo de aço tensionado.
8. guarda em rede elástica de malha solta hexagonal.
9. revestimento de pavimento em resina epóxi autonivelante.
10. caixilharia de alumínio com vidro duplo e corte térmico.
11. pintura impermeabilizante.
12. laje pré-fabricada de betão armado.
13. betão armado.
14. pré-laje em betão armado.
15. pilar em betão armado (em vista).
16. betão afagado.
17. regularização.
18. betão de enchimento.
19. betão de limpeza.
20. macadame.
21. tela asfáltica.
22. pré-aro metálico.
23. brita compactada.
24. terreno compactado.
25. brita.
26. tela pitonada.
27. dreno.
28. impermeabilização com pintura asfáltica.
29. terreno natural.
30. painel de betão armado pré-fabricado.
31. porta de batente em alumínio com vidro duplo e corte térmico.
32. betão de limpeza - camada de forma.
33. painel de betão armado pré-fabricado com isolamento em XPS no interior.
34. guia em betão.
35. grelha metálica de escoamento de águas.
36. caleira em PVC para escoamento de águas.
37. pavimento em bloco de betão pré-fabricado.



Star Apartments - Los Angeles

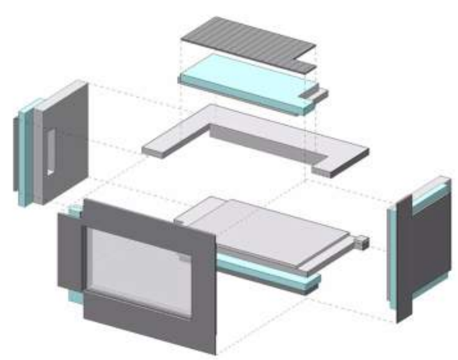


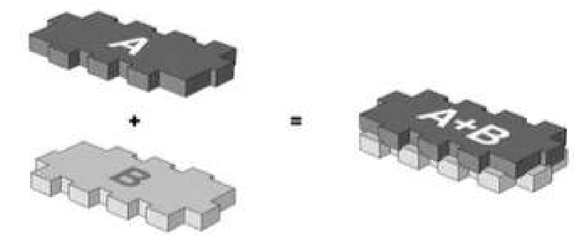
STAR APARTMENTS
MODULAR UNIT
EXPLODED AXONOMETRIC



1 FLOOR ASSEMBLY
2 WALL ASSEMBLY
3 INTERIOR COMPONENTS
4 M/E/P CORE
5 CEILING ASSEMBLY

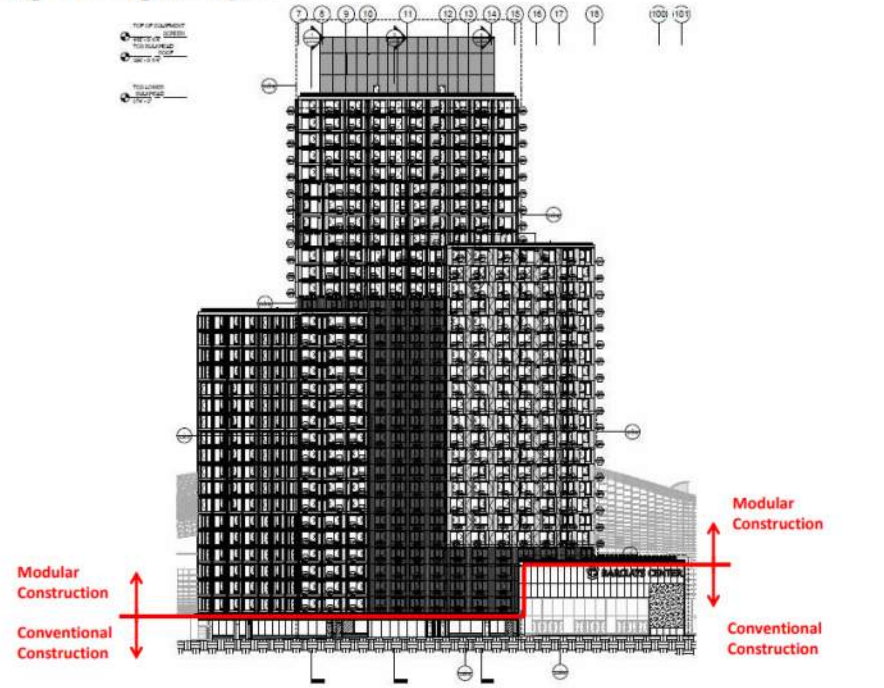
Norra Tornen - Sweden





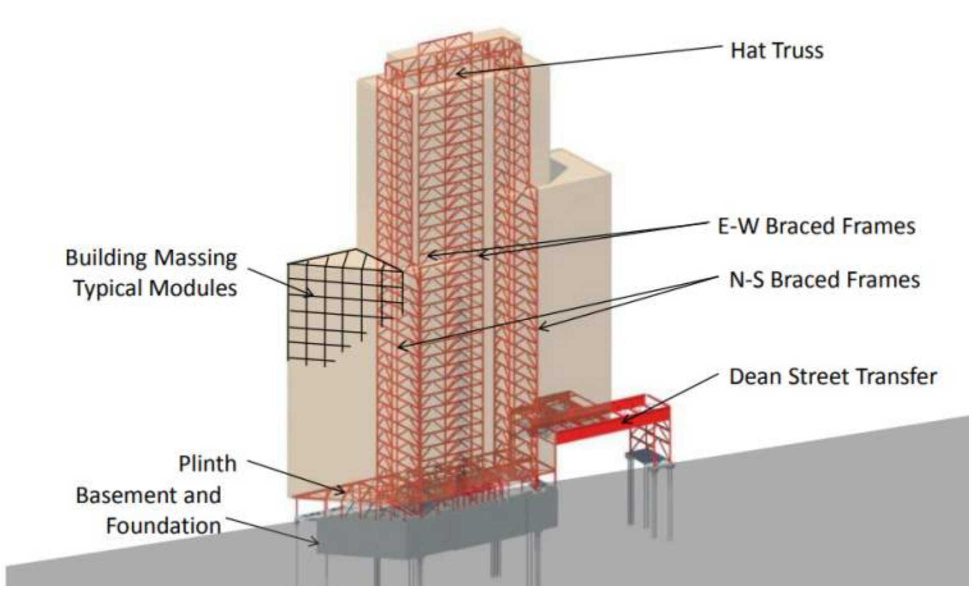
B2 - Brooklyn, NY

Building 2 Design: Engineers



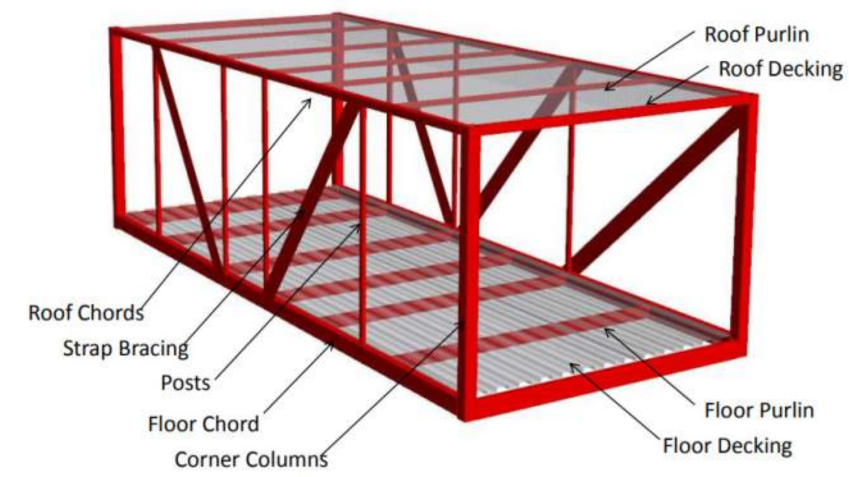
Building 2 Design: Engineers

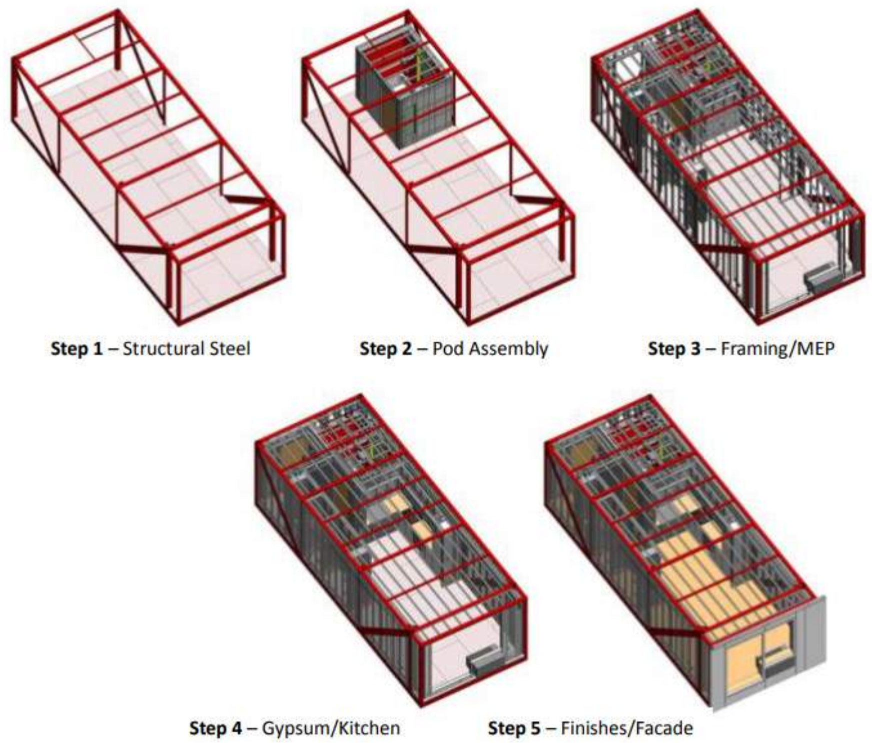
Structural Scheme



Building 2 Design: Engineers

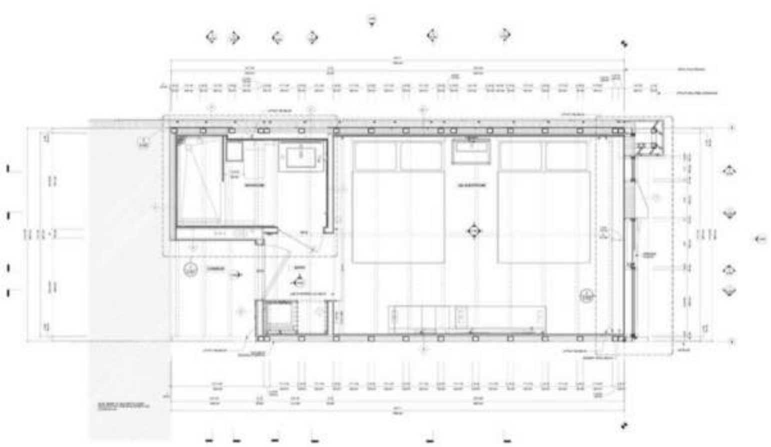
Typical Module Framing

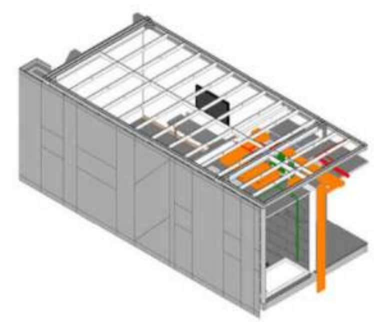




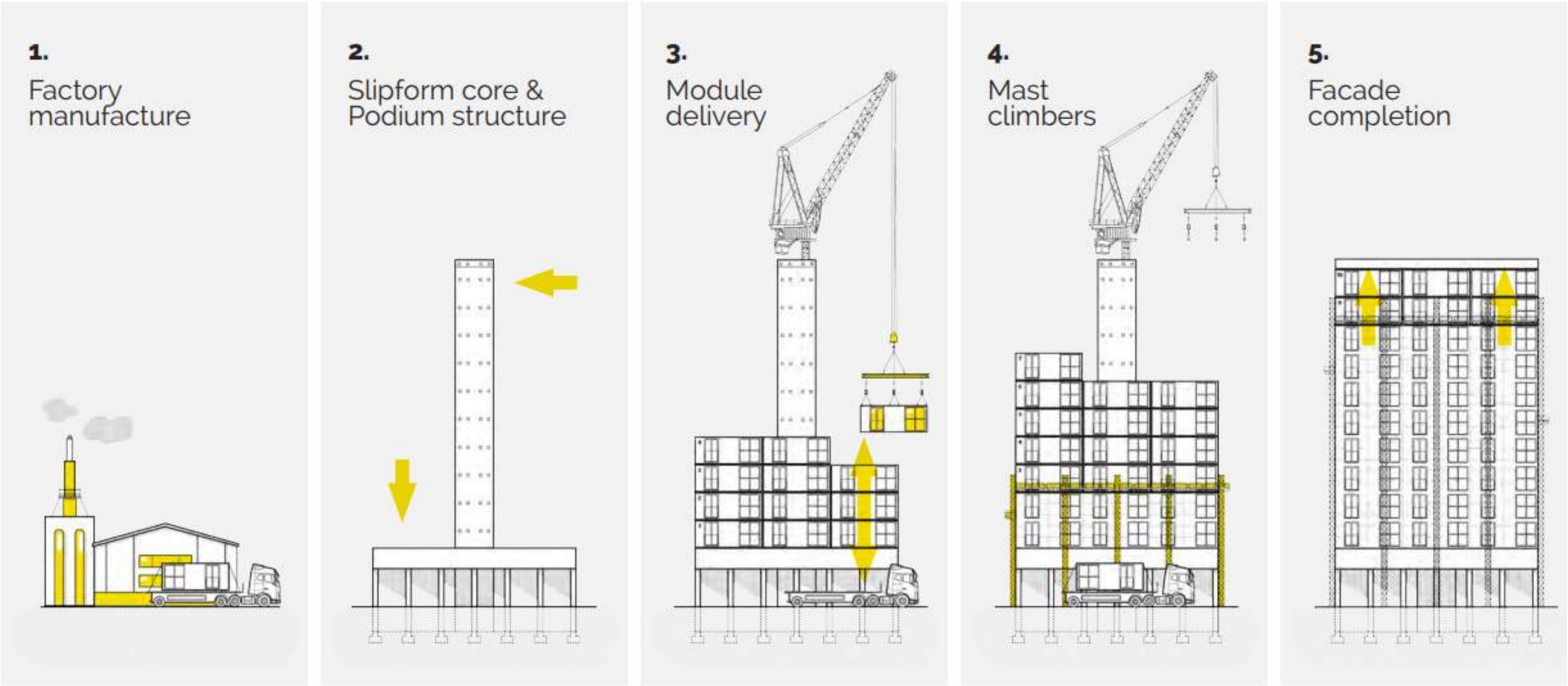
Manhattan Modular Hotel by Mariott

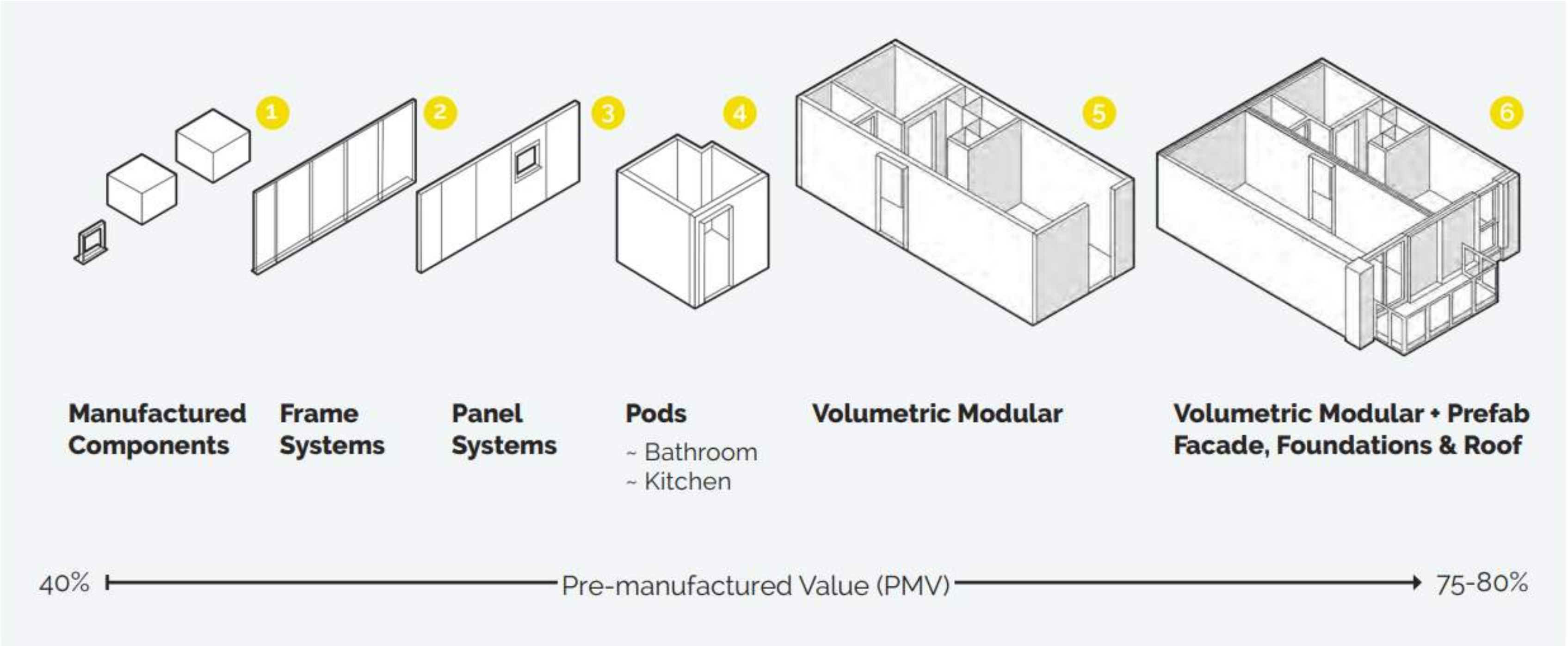
PROTOTYPE **X01**





Apex House - HTA Design - Wembley



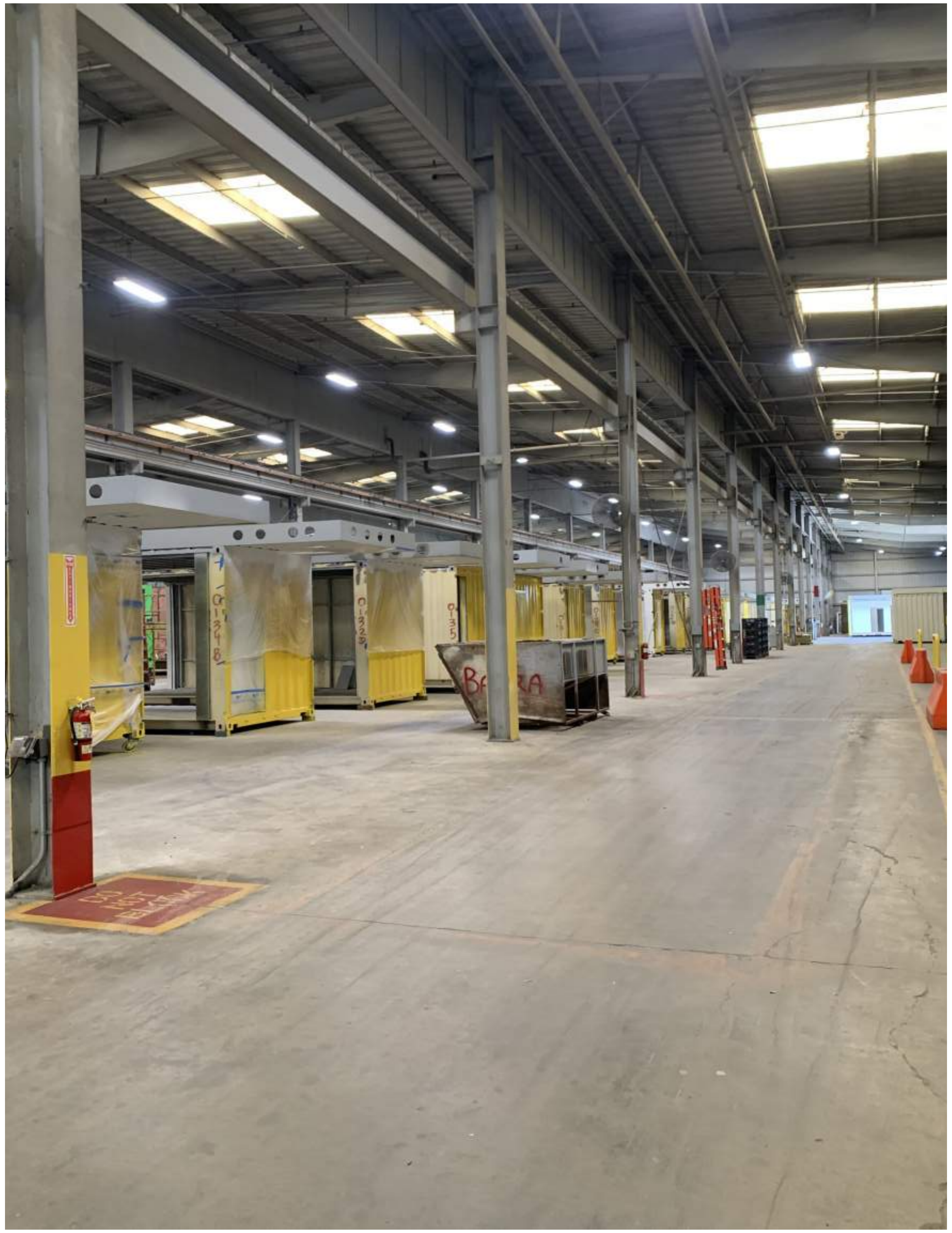


George St, - HTA Design - Croydon

Tower A

Tower B

Crate Modular, Inc. - Carson, CA



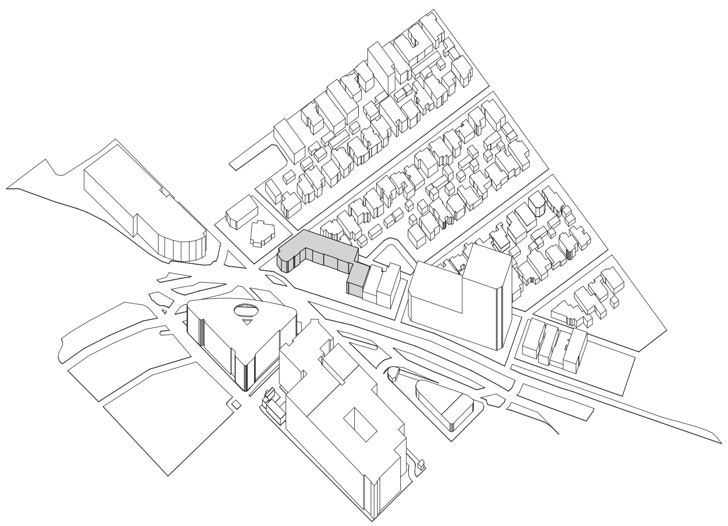
Phase 2: Project Implementation

Project Site

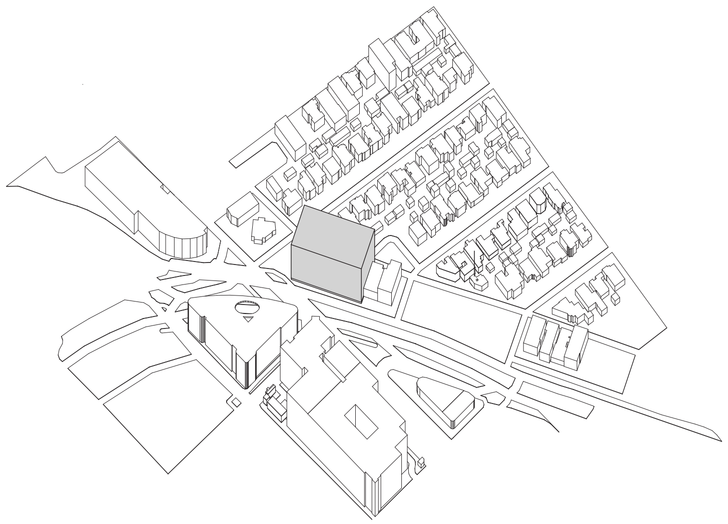
Concept Diagrams

Drawings

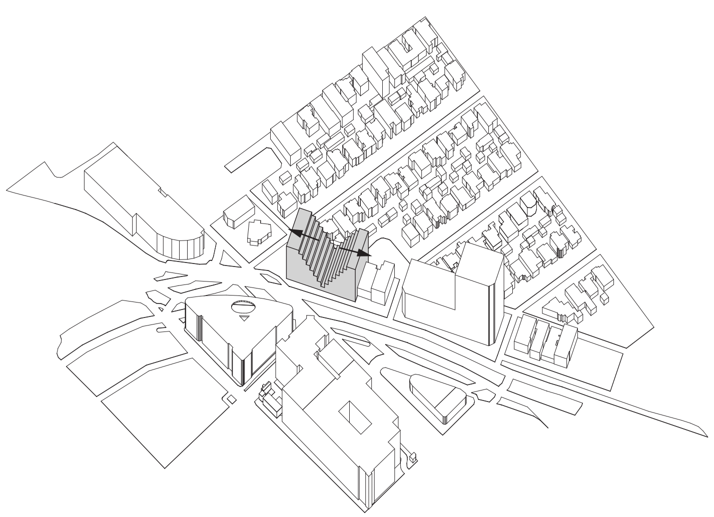
Renders



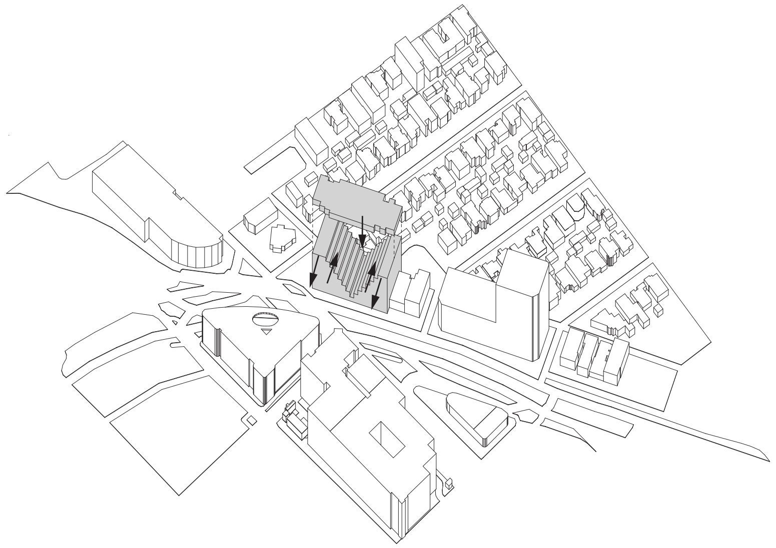
01) Current Site



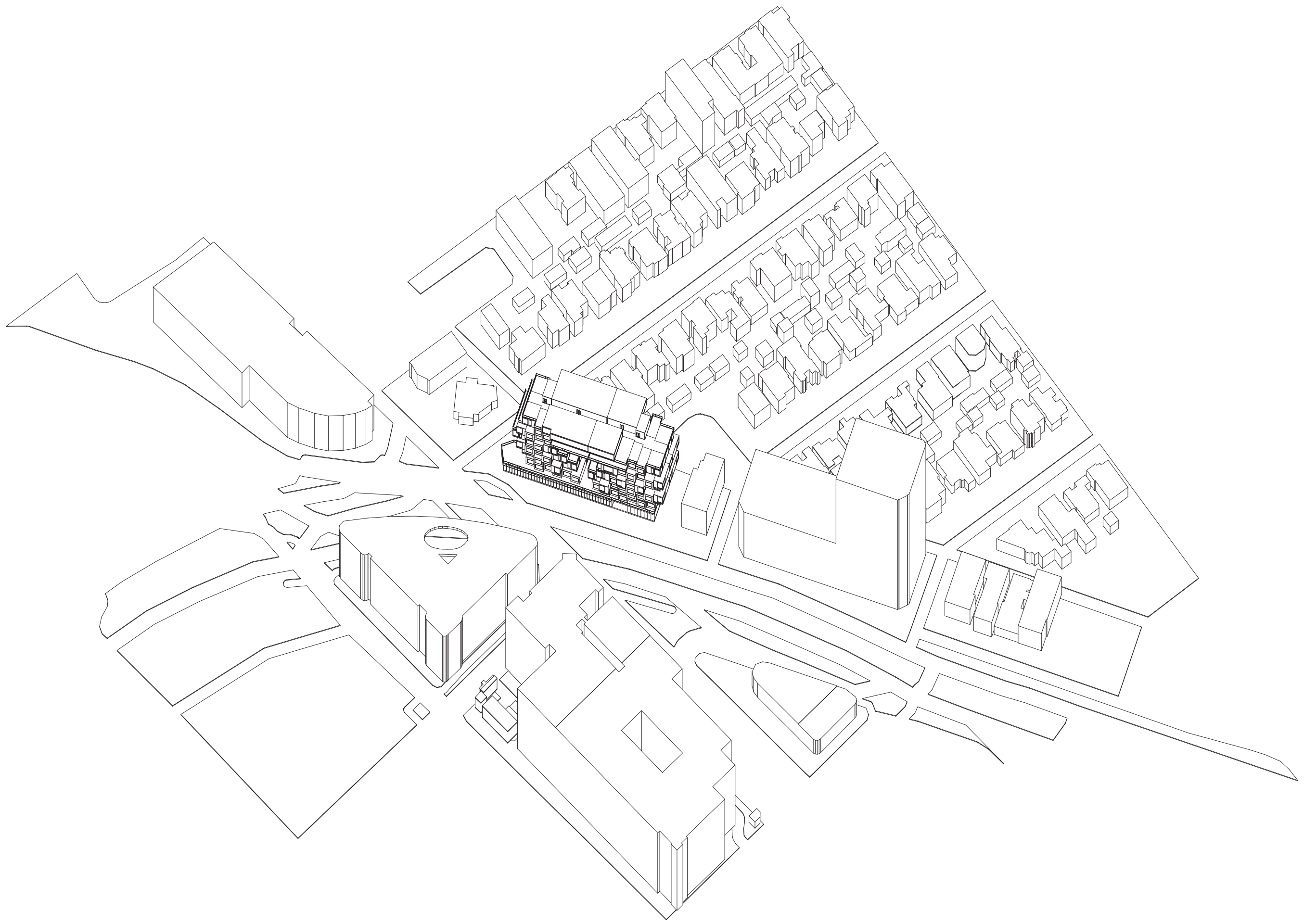
02) New Massing



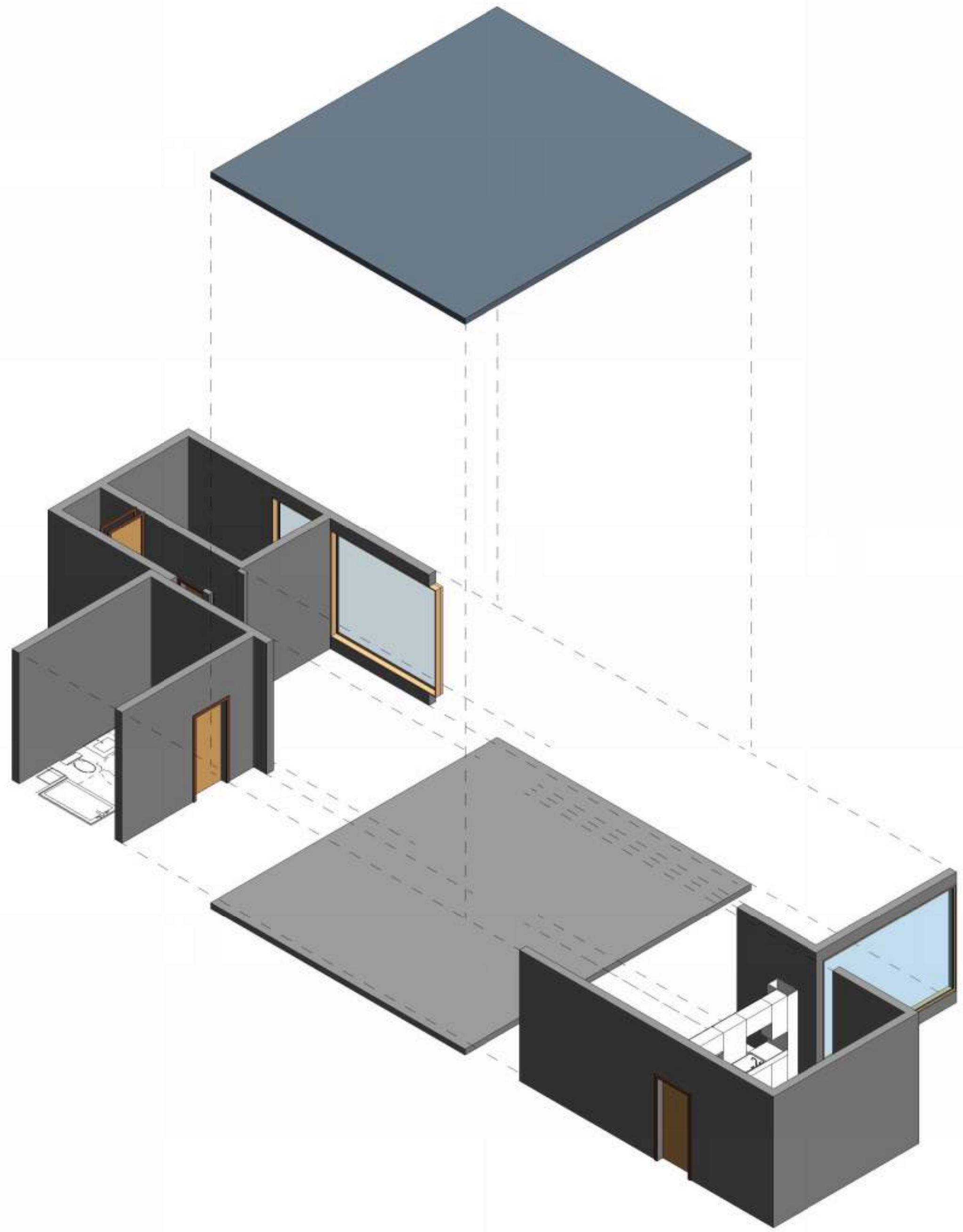
03) Carve out courtyard Areas

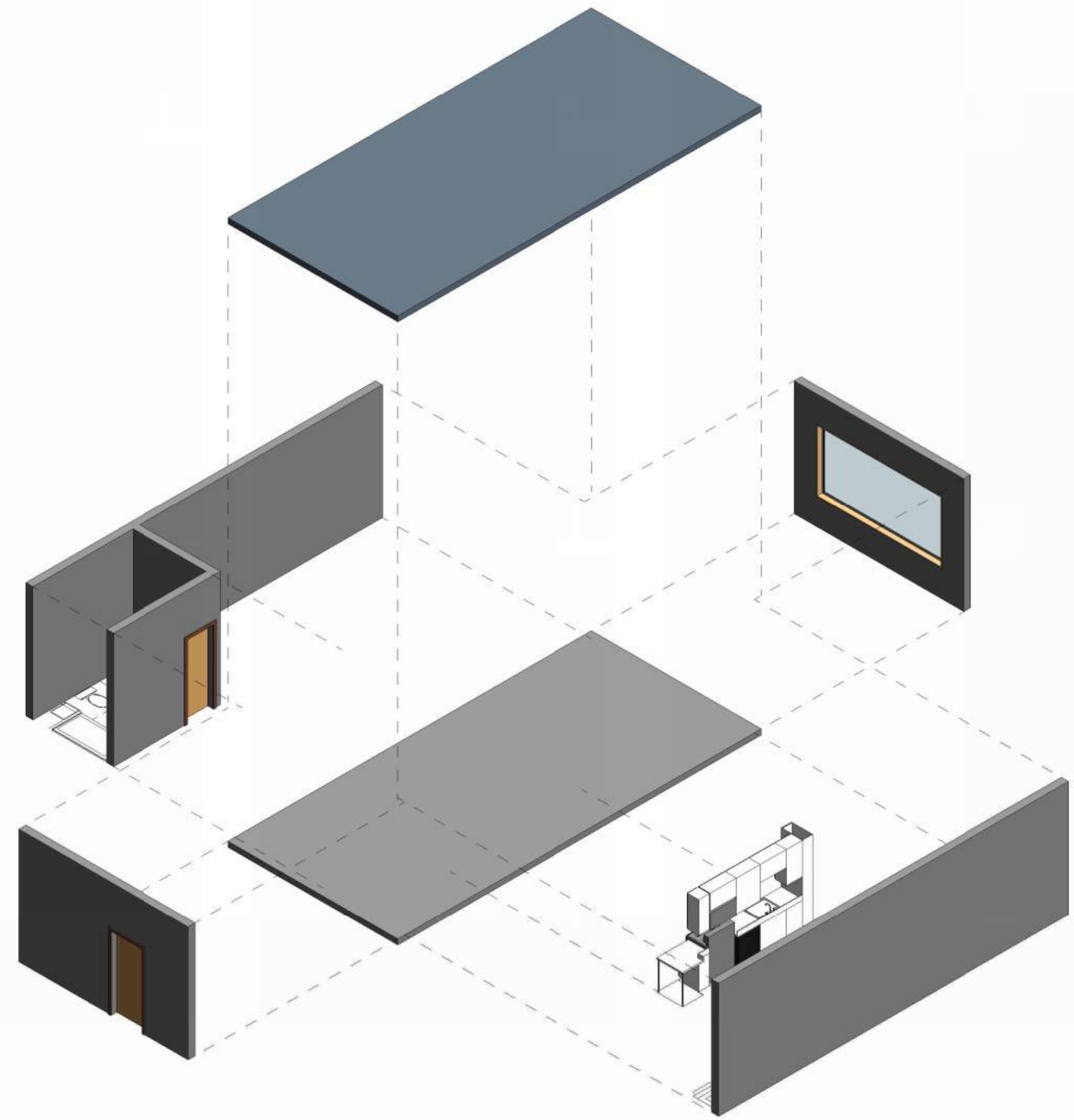


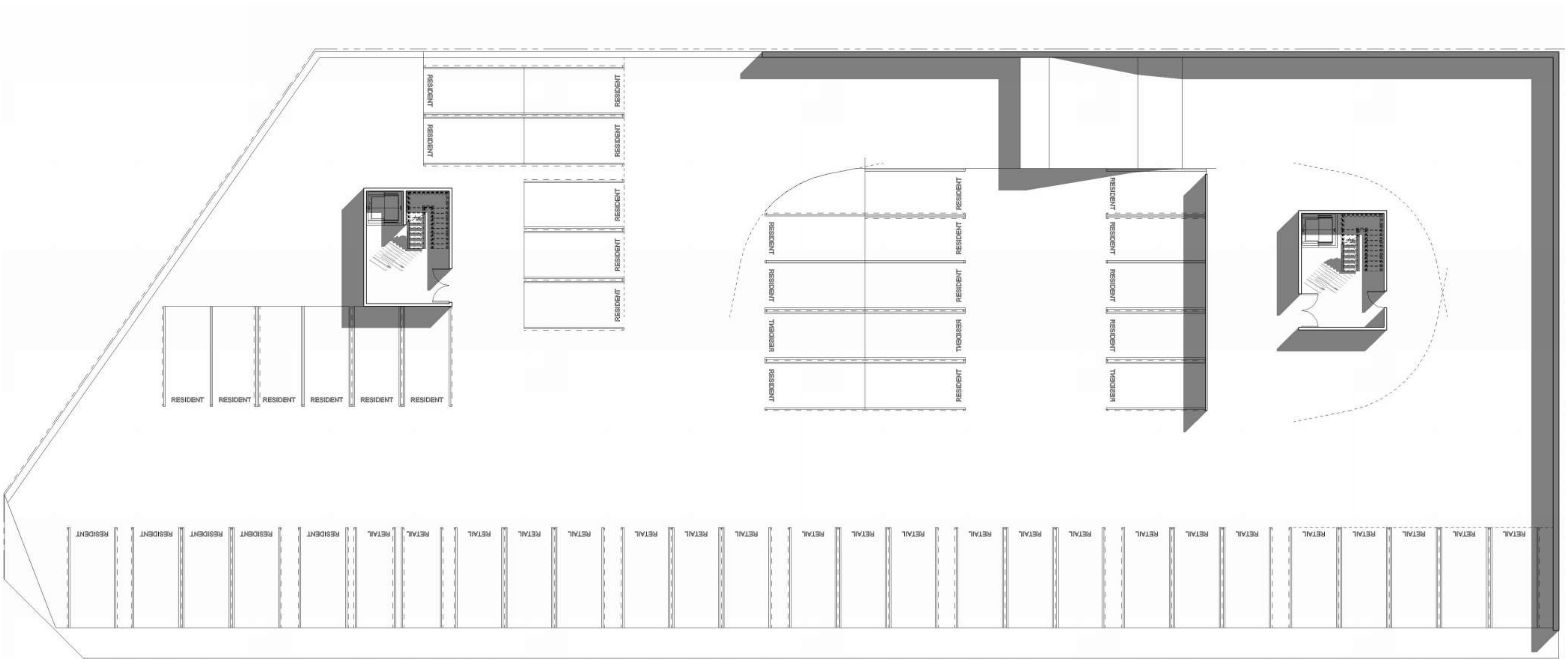
04) Pull and Push units and use top floor to connects the towers



05) Final Proposal






RESIDENT
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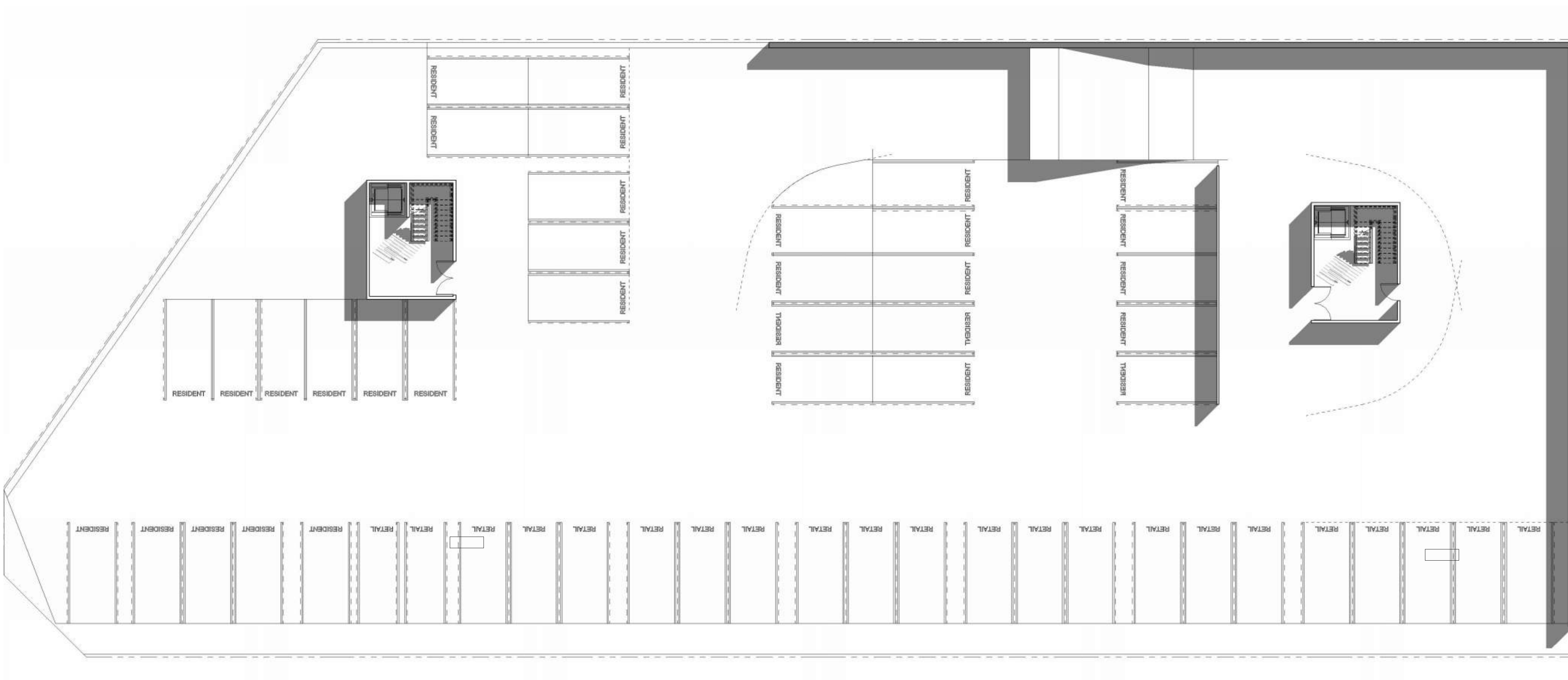
RESIDENT

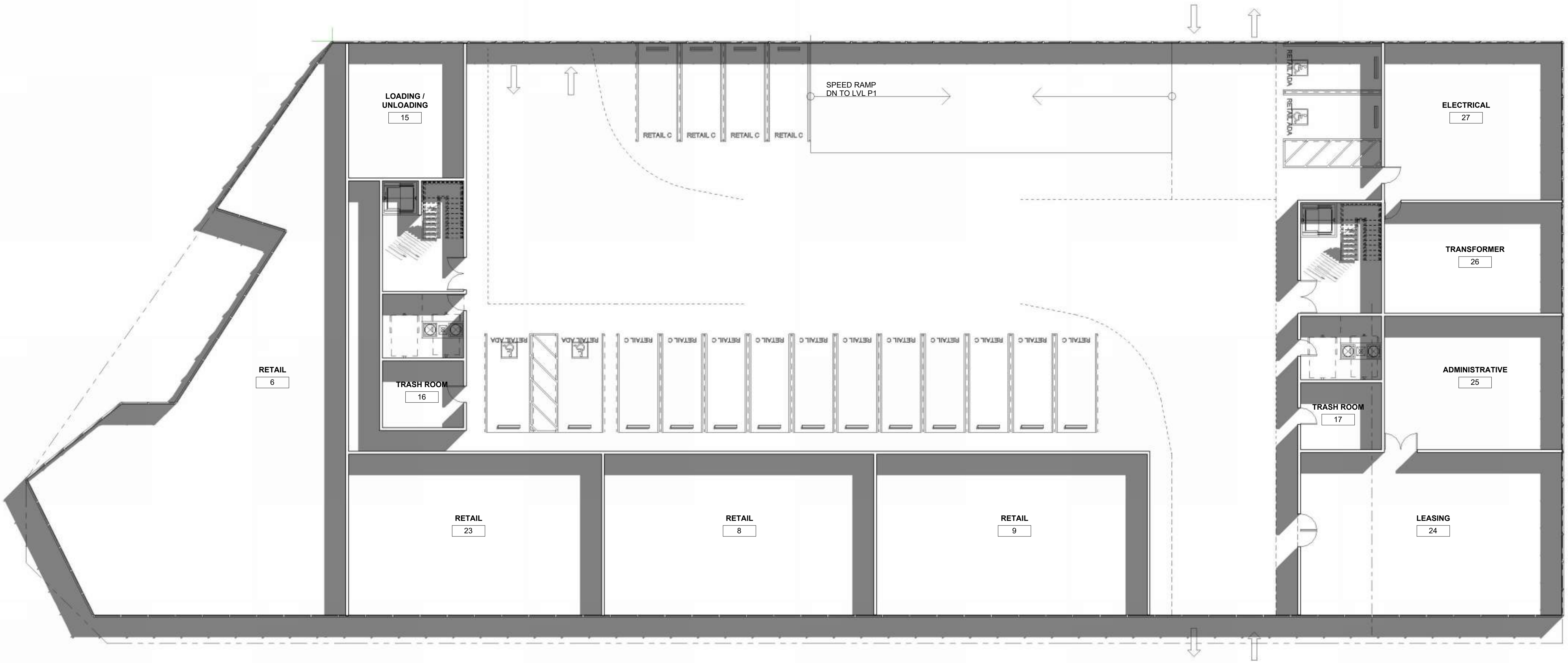
Project Site

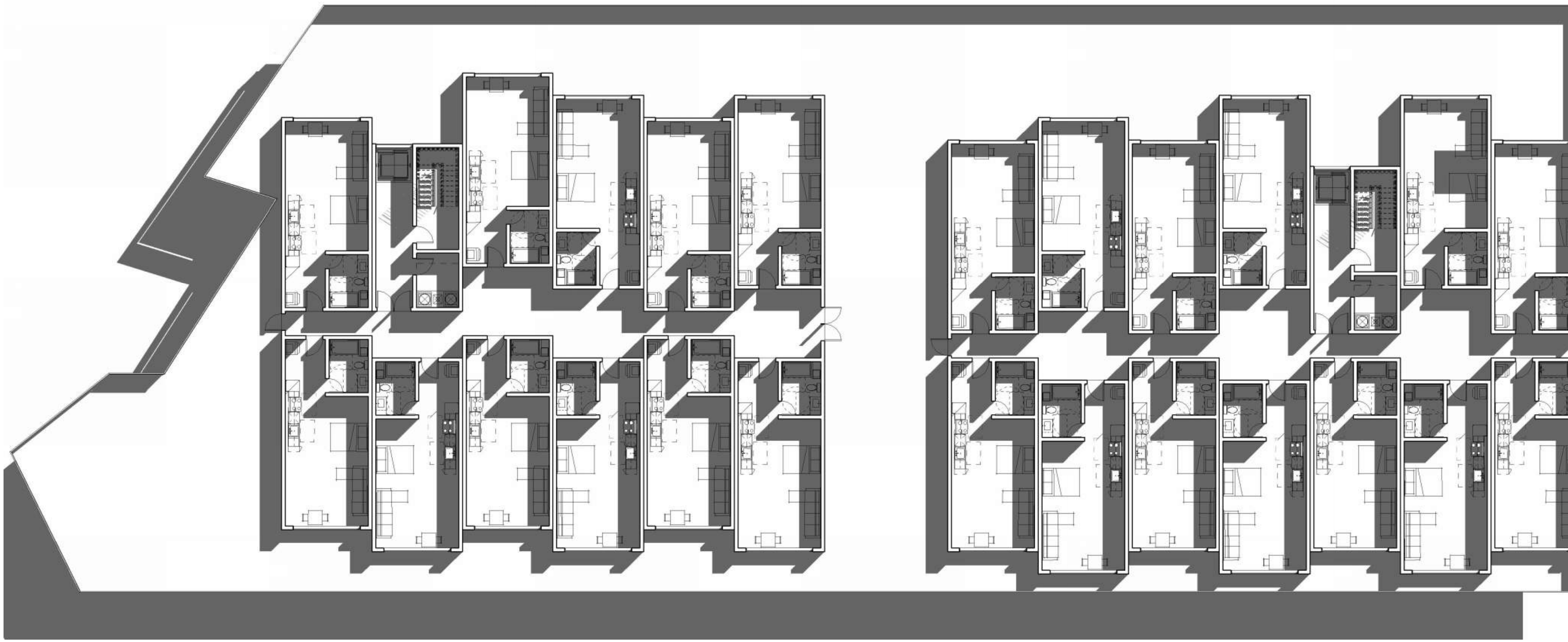
Concept Diagrams

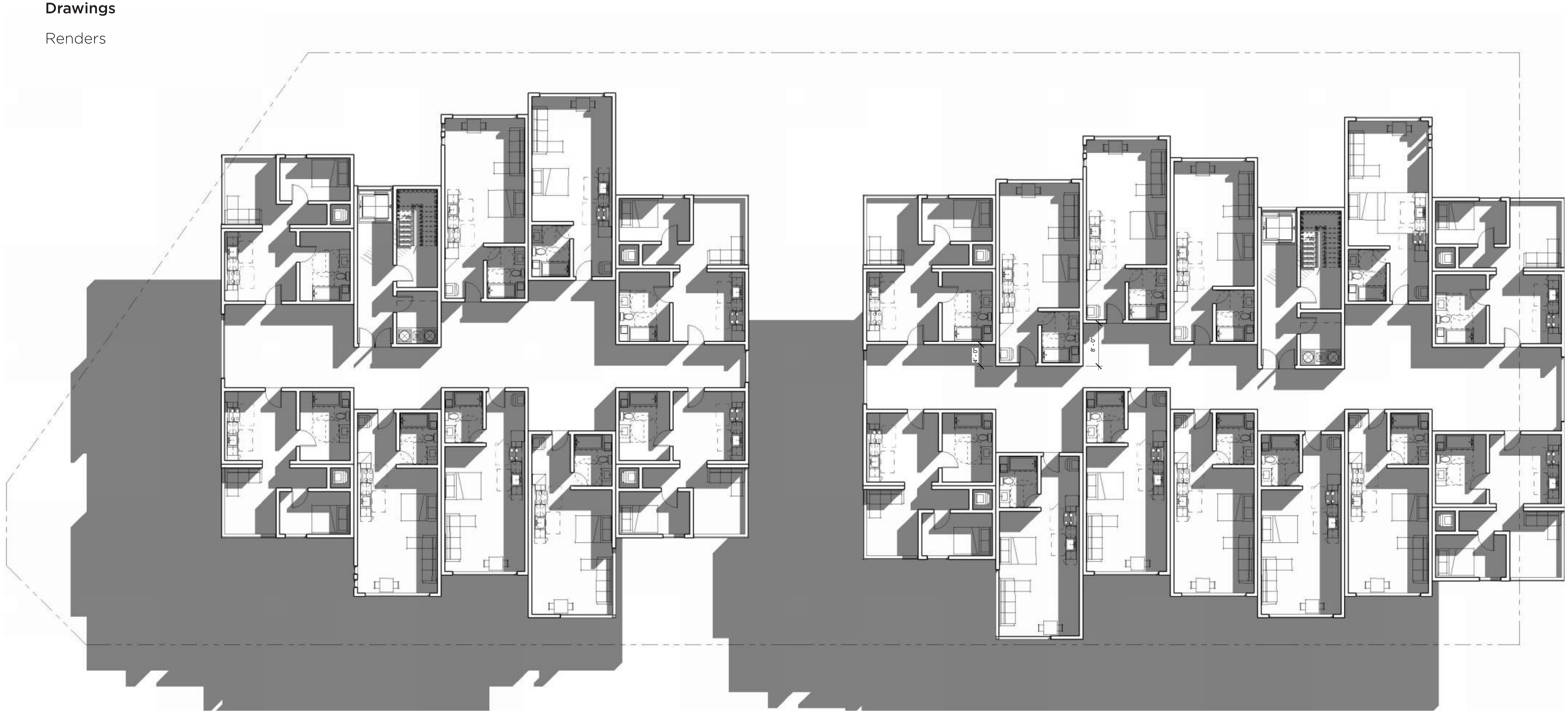
Drawings

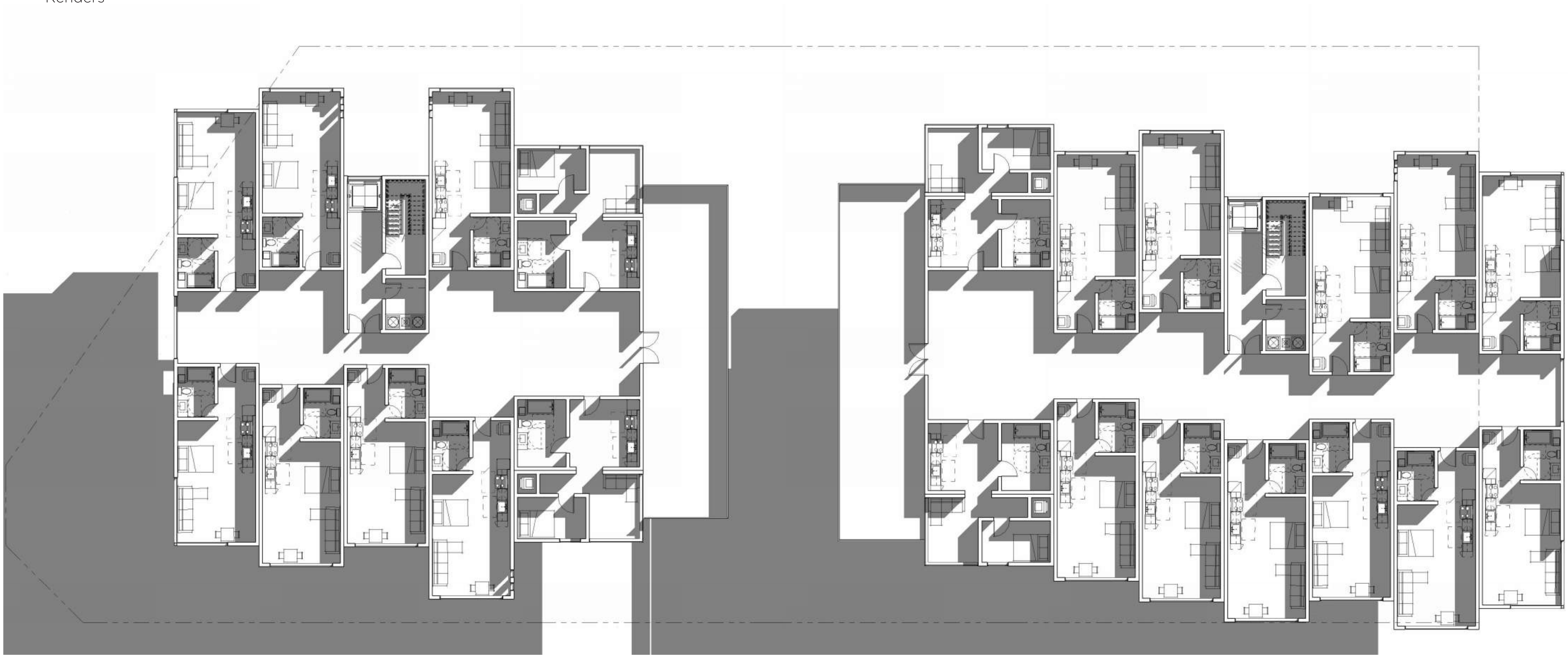
Renders

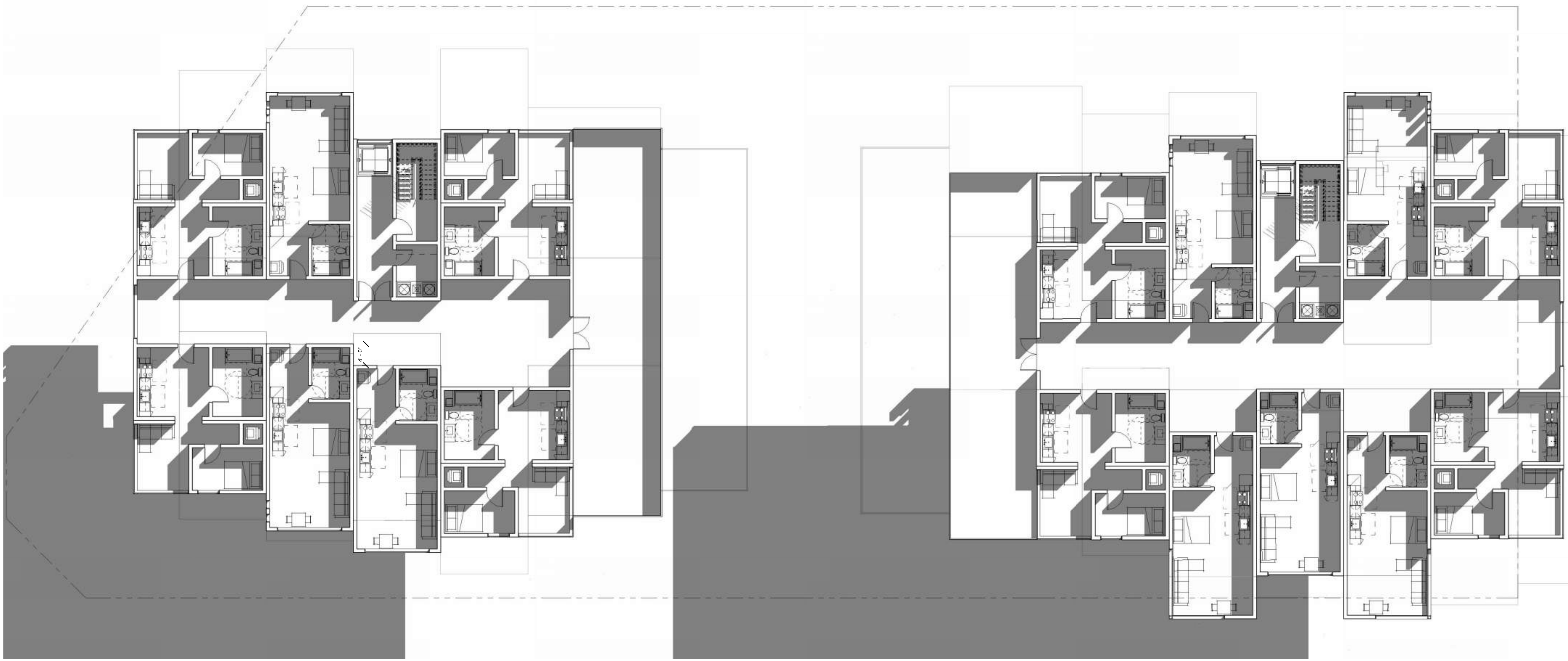


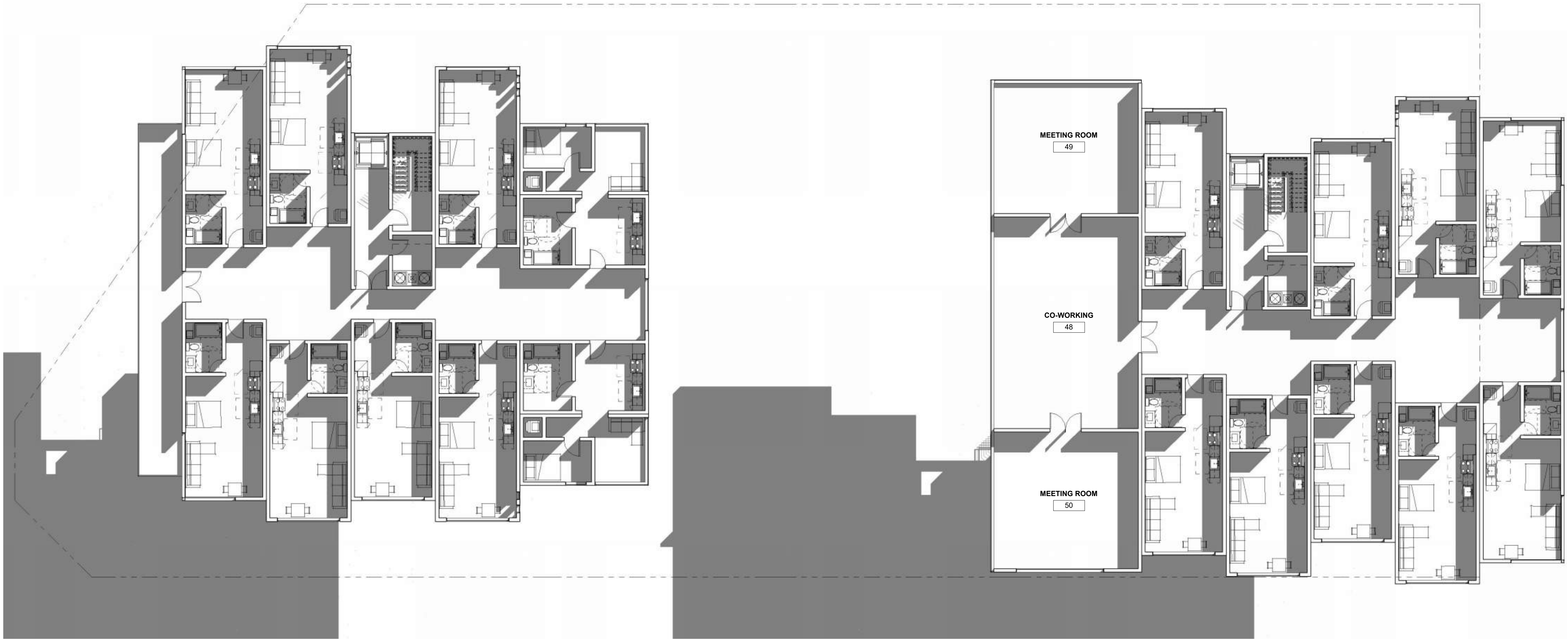

LOADING / UNLOADING
15
SPEED RAMP DN TO LVL P1
ELECTRICAL
27
TRANSFORMER
26
ADMINISTRATIVE
25
TRASH ROOM
16
TRASH ROOM
17
RETAIL
6
RETAIL
23
RETAIL
8
RETAIL
9
LEASING
24

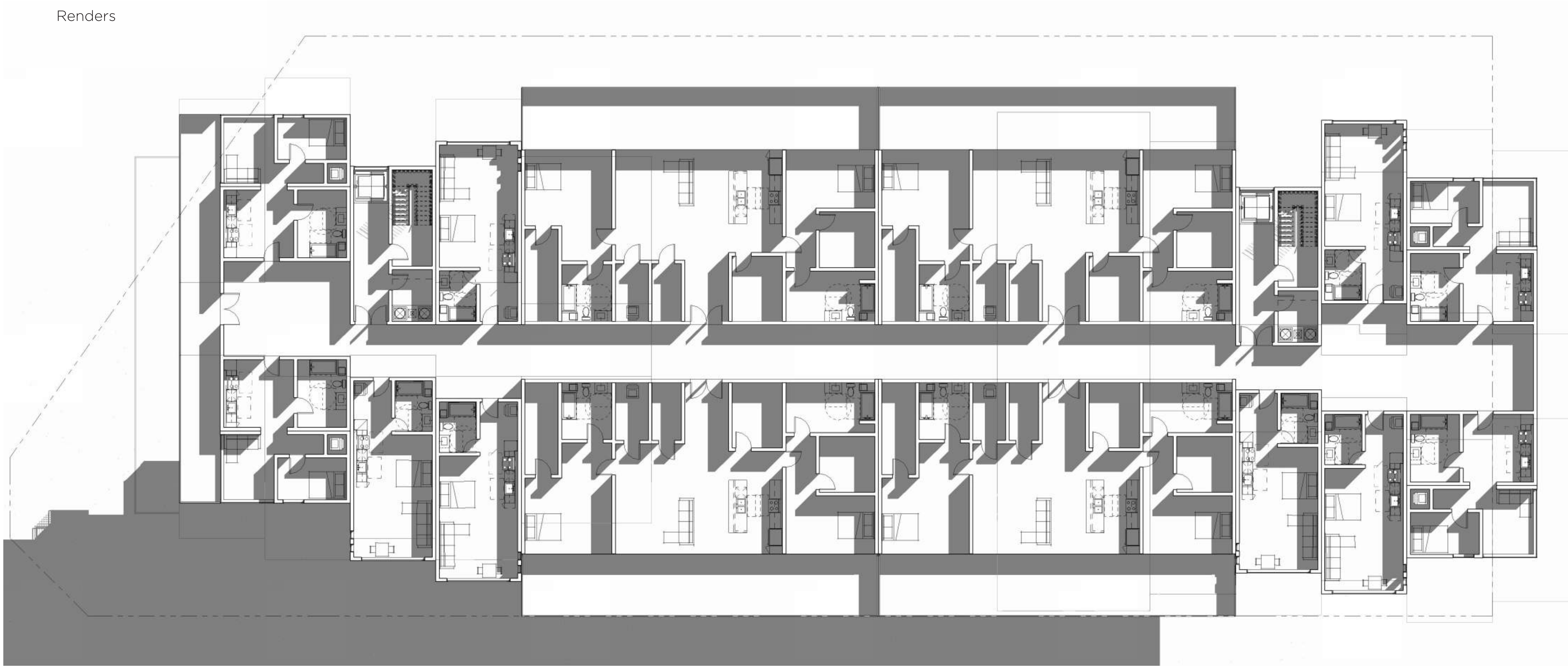






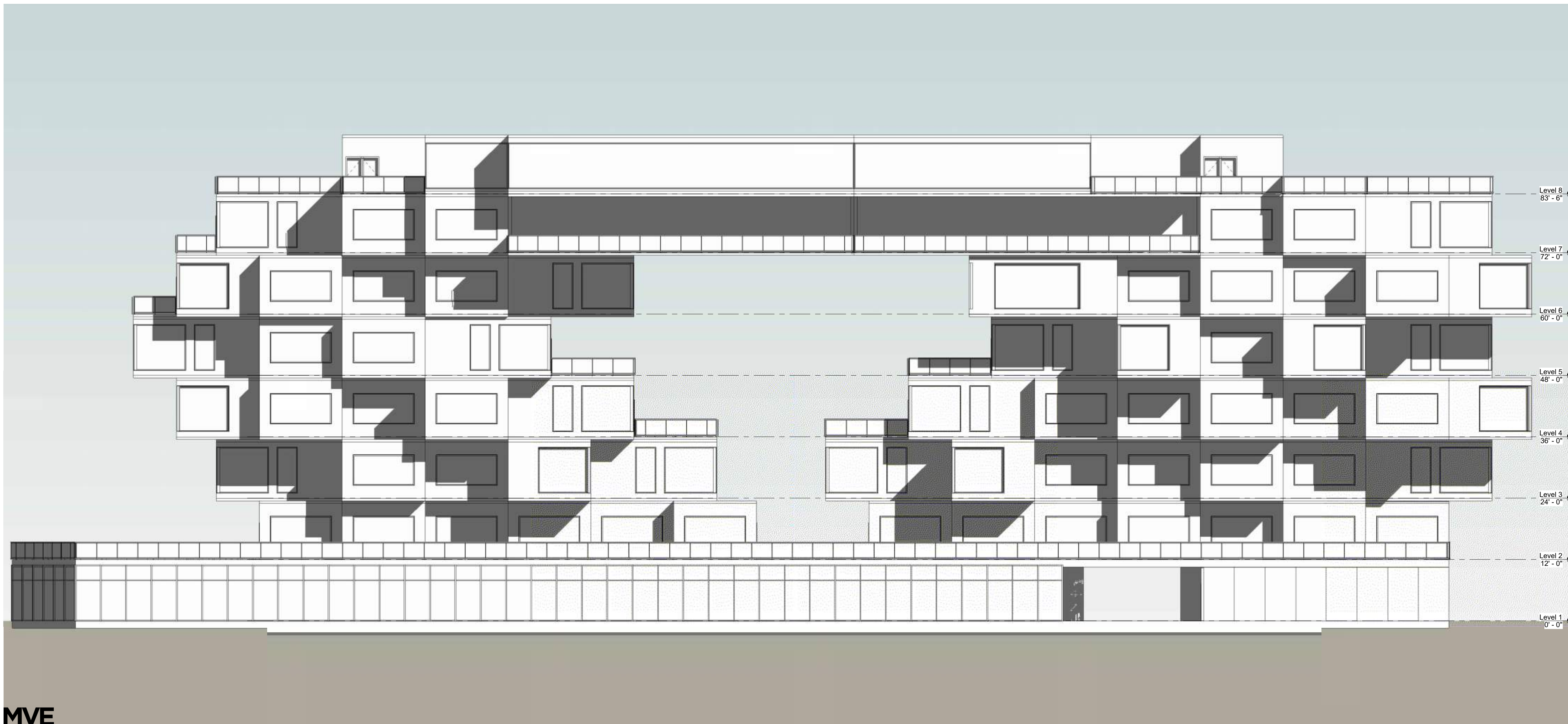



MEETING ROOM
49
CO-WORKING
48
MEETING ROOM
50




FITNESS CENTER
44
5000 SF
LOUNGE
45
2621 SF
CLUBROOM
46
SPA
47


Level 8
83' - 6"
Level 7
72' - 0"
Level 6
60' - 0"
Level 5
48' - 0"
Level 4
36' - 0"
Level 3
24' - 0"
Level 2
12' - 0"
Level 1
0' - 0"
P1
-12' - 0"
P2
-24' - 0"


Level 8
83' - 6"
Level 7
72' - 0"
Level 6
60' - 0"
Level 5
48' - 0"
Level 4
36' - 0"
Level 3
24' - 0"
Level 2
12' - 0"
Level 1
0' - 0"

TEAM

Leadership	Matthew Mclarand, AIA Kap Malik, FAIA Timothy Smallwood, AIA Mark Kim, AIA Luis Arambula, AIA
Mentors	Kap Malik, FAIA Asmaa Abu Assaf Nikhil Bang Andrea Vilcarima
Interns	Abhishek Hemant Vaidya Karen Lopez Jingwen Wu Jefferson Osorno

MVE + PARTNERS