MASTERS DEGREE THESIS

Msc. ARCHITECTURE FOR THE SUSTAINABILITY DESIGN

Pre-Fabricated Architecture For Urban Adaptability

Factory Built Constructions – Sustainable & Flexible Urban Solutions

Politecnico di Torino

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Abstract

The aim of this thesis is to study the fundamentals of pre-fabricated modular construction and comprehensively device strategies pertaining to the application of pre-fabricated construction system for flexibility, adaptability and sustainability in context to multi-functional urban needs. The research explores applications of various prefab techniques and systems, core materials, assembly and method of executions through case studies catering to user needs and contexts. The research focuses on the usage of prefabricated construction techniques to provide sustainable, flexible and adaptable urban solutions for high density urban tissues.

The research initially investigates the evolution of prefabricated building systems through out history and draws a comparison between the on-site and off-site construction systems in order to understand the advantages and disadvantages of each system. The preliminary study is majorly focused on two pre-fab systems, viz 'Timber Pre-fab Construction' and 'Steel Pre-fab construction'. The approach is to understand the properties of materials, main structural elements, construction, connection and assembly of elements, advantages and applications of each construction system respectively. To develop a better understanding, case studies of different projects are carried out and formulated into a comparative matrix which would become a guiding element in devicing a set of strategies that can be adapted to cater to the different and changing needs of an urban fabric.

Furthermore, to evaluate the probable applications of Pre-fab construction in high density settings, city of Chennai (India) is selected as a case in point to device strategies for shared community architecture in compact urban centres where scarcity of land, open-green spaces and community infrastructure are common denominators of concern. Thus, a model of co-living, co-working and shared public spaces is developed which can become a prototype reference for development in various urban zones with high density.

The end goal is to design a prefabricated modular prototype that can be adapted to unique urban needs in multiple configurations around the world. Critical parameters like transportation feasibility, availability of modular components, re-usability of the module to optimize building lifecycle and adaptability to changing requirements become the guiding priniciples of achieving the standardised module.

Methodology

Detailing our approach of using sustainable strategies with Prefab Construction to tackle the major issue of Urban Adaptation/ Flexibility, we have devised our research in the following two parts :

Part 1. Research: Prefab Modular Construction

- Initial research starts with a study on history and evolution of prefabricated modular architecture through the past century and covers an introduction about fundamentals of design with offsite prefab architecture techniques.

- Two major materials - Timber and Steel, have been selected and analysed in detail with theories and details about junctions, fabrication and assembly referenced from books and market surveys carried out on various manufacturing factories to realise the practical aspects in industry.

- The case studies are selected based on materials and degrees of prefabrication to explore technology driven adaptable solutions devised for co-living, co-working or communal utility sharing spaces.

- The case studies have been classified under the following common structure of study:
- Project Image
- Site Context and Introduction
- Project Statistics
- Architectural Drawings
- Use of Spaces
- Assembly Detail & Material Specifications
- Construction Images
- Detail Observation
- Construction Process

- A matrix is devised to understand , analyse and compare the systems used in different case studies.

- Inferences drawn from the case study research have been highlighted which can be useful as a set of strategies for design intervention.

Part 2. Design Intervention

- Chennai (15th most densely populated city in the world) located in south India with a hot and humid climate has been identified as a case in study to devise a proposal.

- Mapping the city growth, morphology and urban fabric of Royapuram.

- Understanding the land use and distribution of functions with relation to the communities living in the context.

- Character Mapping - Architectural Facade Of The Street.

- Design Intervention with an objective to address the issues identified in the urban fabric and generating a model of development which can be flexible and adaptible to multiple configurations around the world.

Objectives

-To develop a thorough understanding on prefabricated factory built construction systems developed with Timber and Steel.

- To study in depth, the entire process of pre-fabrication from production to on-site assembly, its advantages over conventional construction methods and ways to optimise modular construction system.

- To design a system of Community Sharing, Co-living/ Co-working modules which can offer flexible and affordable solutions to the urban context.

- To Design prefab modules which can be standardised and incorporated as a global model of development in different configurations for an Investor Company.

- To provide vibrant urban spaces for community engagement based on the analysis of Immediate Context.

PROJECT

Structure of Thesis

Part 1
RESEARCH

Pre Fabricated Modular Construction Technology

Part 2
INTERVENTION
Site Study & Design

Project Theme

Co Living, Co Working Spaces to provide flexible solutions to emerging urban needs which can be standardised and incorporated as a global model of development.

Problem Statement

Dhaka, Bangladesh (36,941 inhabitants per sq km)
Source- The making of a megacity: how Dhaka transformed in 50 years of Bangladesh

Hong Kong (25,503 inhabitants per sq km)
Source: Aerial view of downtown Hong Kong

Mumbai, India (29,650 inhabitants per sq km)
Source: Mumbai's Tardeo

URBAN DENSITY V/S URBAN ADAPTATION

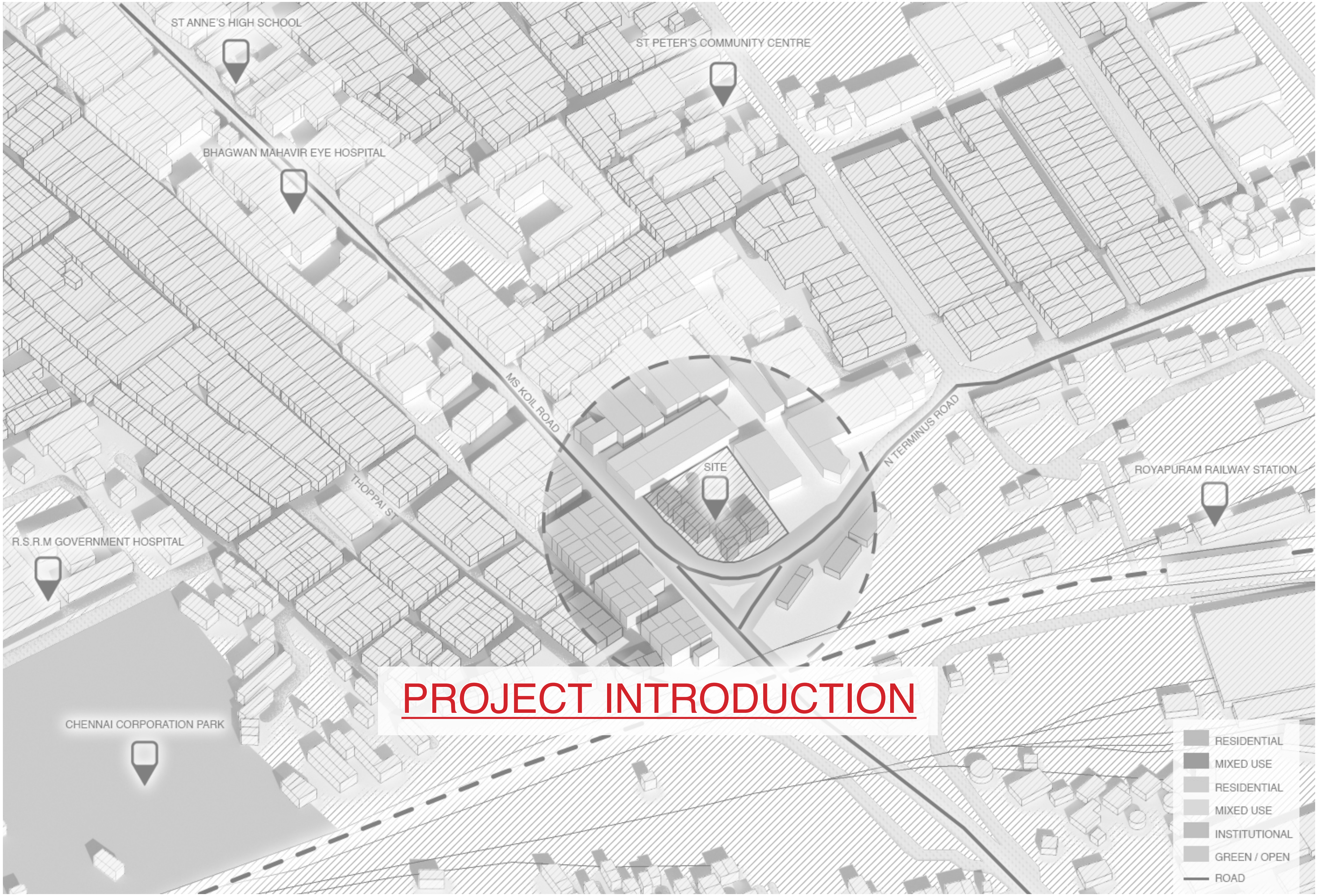
Issues faced by High-Density Compact Cities

Urbanisation and human increment are increasing the pressure on our planet's precious resources with visible signs of anthropogenic damage. **High-density developments** are widely claimed to create a vital contribution to achieving sustainable growth of cities in developed countries. The 'compact city' model is claimed to be an sustainable model for such cities.

However, how far the high-density compact city model has relevancy for sustainable urban growth in cities in developing countries which have already got higher densities than those in developed countries is til now unknown. the problem lies within the relationship between the built-up urban areas and therefore the population concentrated in them. In developing countries, the much strived urban density does exist but it's not well co-ordinated, located and designed. The growing concentration of individuals poses a fundamental challenge to the supply of economic opportunity, the event of adequate infrastructure and **livable housing**, and also **the maintenance of healthy environments.** In poorer cities, a big proportion of the population is usually forced to measure in ill-serviced housing in areas highly at risk of natural disasters like flooding or landslides.

Increasing urbanization, not to mention limited urban planning, puts cities in danger from temperature change. In many countries, temperature change is anticipated to bring more extreme rainfall resulting in flooding, water scarcity, and disasters. Increasing temperatures and hot days also pose health risks and threaten agricultural production in peri-urban areas.

Text Retrieved from Compact Urbanism and the Synergic Potential of its Integration with Data-Driven Smart urbanism - Research Gate.



PROJECT INTRODUCTION

URBAN DENSITY V/S URBAN ADAPTATION

How can Flexibility influence a Sustainable Future?

In order to tackle the issues of **unplanned urban densification** a new approach needs to be deviced which provides better living and infrastructure conditions without drastic disruption. In the ever-changing world, factors like rapid urbanisation, constant social shifts and corresponding demands, technological advancements, climate emergencies, and economical instability many a times render the buildings and infrastructures obsolete.

Moreover, with the growing concern of climate change, **sustainable development** has become imperative for any future developments. It is estimated that two billion square metres of new building stock are needed every year between 2019 and 2025, especially for housing. Global carbon dioxide emissions (CO2) have increased by almost 50% since 1990. The construction industry alone produces around 36% of these global emissions. There is an urgent need to limit global warming to 1.5°C to prevent the worst impacts of climate change, as stated in the Intergovernmental Panel on Climate Change (IPCC) special report on climate change released in October 2018.

Consequently, attention to the flexibility principle as a dynamic of qualified urban space creation can facilitate spaces to provide multiple opportunities for the general public. Urban adaptation, **flexible and adaptable multi-functional spaces** and infill development can aid in addressing the issues of urban density in unplanned urban centres. Additionally, **pre-planned reusability of buildings,** components and materials is vital for a sustainable development in this unpredicatble era of humankind.

Text retrieved from Rethinking timber buildings. Arup.

THE FUTURE IS SHARED

How can we leverage emerging construction methods to address the critical demand for flexible solutions in cities?

PRIMARY TOOLS
Shared Community Living

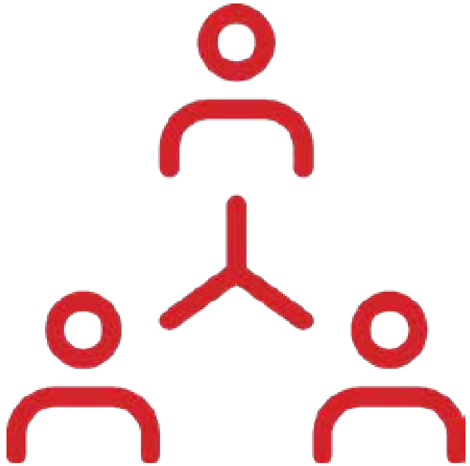
Live

CO-LIVING

Work

CO-WORKING

Play



COMMUNAL AMENITIES

CO-SPACE

How can we interconnect generous shared spaces with compact, intimate living spaces?

CO-SPACE

The Concept of Shared Economy and Community Living

Source: Spaces Crossway

Source: Coliving, logements - Habiter autrement

Source: The future of coworking spaces

The failure of high density cities to accomodate the growing demand of residential spaces, the surging scarcity of affordable and incremental solutions, transition of owning to sharing, rise of digital economy and technological innovations demand an alternative approach for spatial configurations and economical models. The shared economy model has permeated all facets of our day to day lives, which has created unpredicatble patterns as well as opportunities for all the individuals.

Not only co-working and co-living facilities, but mixed-use flexible spaces, and shared amenities are a big part of the shared economy model. A combination of private spaces with shared amenities like communal diners, fitness and recreational zones, event spaces, retail outlets and playscapes formulate thriving communities for people belonging to different backgrounds, age and living situaions. These flexible spaces need to be incremental or adaptable in nature which can cater to the ever changing needs of the society and prevent the buildings from becoming obsolete. The building system needs to be designed for disassembly and reuse.

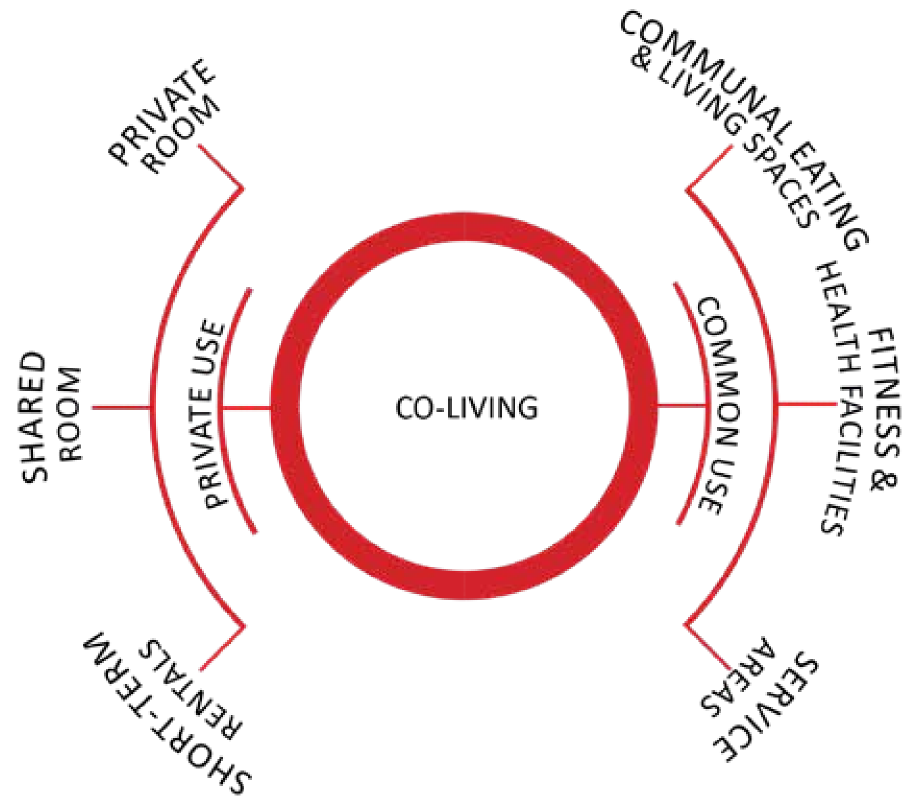
CO-LIVING
The Concept

Vindmøllebakken Co-Living Housing by Helen & Hard Architects
Source - Vindmøllebakken Housing / Helen & Hard

The 'co' in co-living is in general understood as 'collaborative', 'communal' or 'collective' (Vestbro & Horelli, 2012; Tummers, 2016). Collaboration implies there is a certain structure for (future) residents to work together in executing their project, from planning phase to operational phase. The communal aspect implies the emphasis on the fostering of a community and suggests a social connection between members. The collective element refers to the shared facilities and spaces that should be created by or for the residents (Vestbro, 2010).

Coliving is a modern form of communal living where the residents get a private living space in a furnished home/ building with shared common areas. Co-living offers real solutions to problems of lack of sufficient and affordable living spaces in a highly dense urban environment. Shared living spaces do not mean compromising privacy, comfort or belongings, contrarily it can offer wider choices and flexibility for a more effecient, healthy and sustainable living.

Common living celebrates the community aspect of the shared economy which makes housing more affordable, convenient and conducive to urban lifestyle.



Working Model of Co-Living Facilities

CO-LIVING

Understanding the Model and Key Considerations

The major merits of co-housing can be listed as follows:

- New social practices, technical processes and collective learning can reduce energy costs and improve housing performance.
- Because common household appliances and functions are shared, co-housing is a more affordable cost of living, in terms of food, utilities, goods and services.
- It increases the social and physical resilience of residents and wider communities through the provision of shared facilities.
- Enhanced sense of place, increased self-awareness and sharing community knowledge.
- Co-housing developments produce active and diverse communities that can enhance social interaction and combat loneliness, isolation and disconnection

Based on the norms of stay and the development process, co-living can be classified into different typologies. Primarily the duration of stay can identify the structure of the co-living system and the lifestyle associated with it. To categorise:

1. Short-Term Flexible Co-Living
2. Long-Term Permanent Co-Living

The collective spaces and facilities are influenced by the typology and the target demographic. Short-term flexible co-living shows significant potential in terms of dealing with the changing dynamics of family and individual living situations, constantly evolving lifestyles and financial flexibility. The subscription based short term rentals also make it easier to switch accommodations as one's living situation changes over time.

CO-WORKING
The Concept

WeWork Co-Working in Shanghai, China by Linehouse Architects
Source - WeWork Weihai Lu / Linehouse

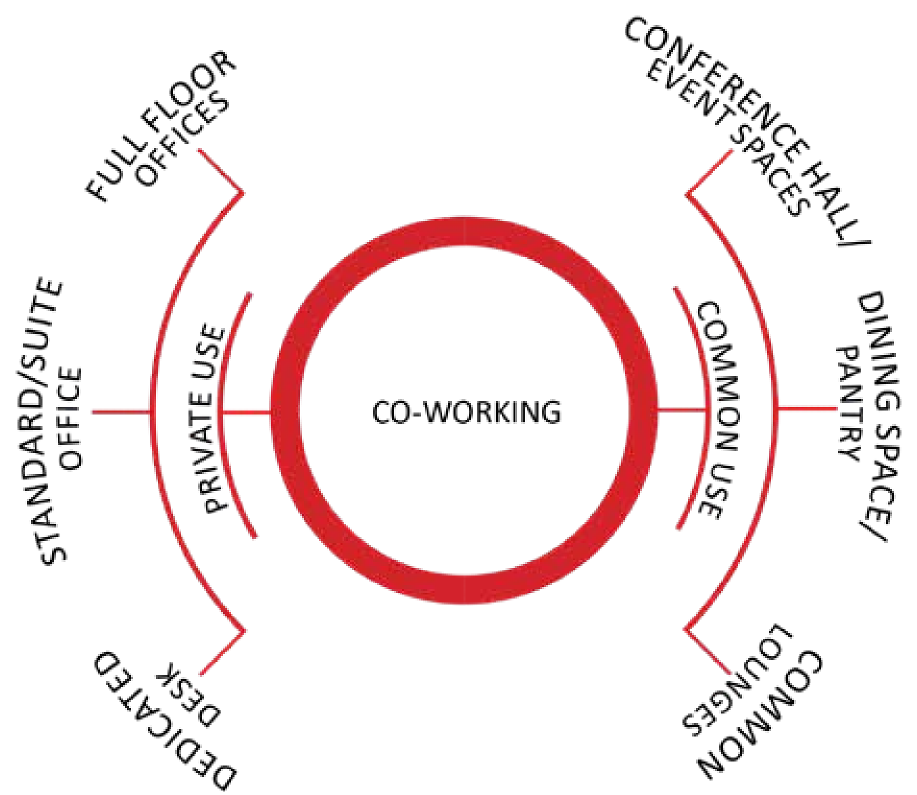
The phenomenon of co-working emerged as a result of development of new professions and changing economy requiring a fresh take on the physical and conceptual aspects of working spaces. Co-working spaces in essence are a set of innovation in terms of spatial organisation as well as human scale and dimensions. Co-working spaces are designated spaces that facilitate a flexible and shared work environment that can be subcribed on daily, weekly and monthly basis.

It is a work environment where diverse professionals, freelancers and companies can share a workspace. This kind of structure provides a flexible and affordable opportunity to working professionals. It also fosters a cultural model based on aspects like community, collaboration, diversity and sustainability.

As the digitalisation in all the professions rises, boom of start-ups and incubators envelop the growing economy, co-working space have rapidly gained momentum that cater to the dynamic present day situation. Moreover, in urban fabrics with high population density, co-working spaces in different parts of the city provide an accessible solution to digital nomads that are location-independent, young professionals, freelancers, remote workers and enterpreneurs.

CO-WORKING

Understading the Model and Key Considerations



Working Model of Co-Working Facilities

Private Use:

Dedicated desk - 1 user
Standard Office - 1 to 20 users
Office suite - 20 to 100 users
Full floor offices - 100+ users
Meeting room - Small / Large

Common Use:

Conference Hall
Pantry - Dining Space
Common lounges
Event spaces

What is Shared?

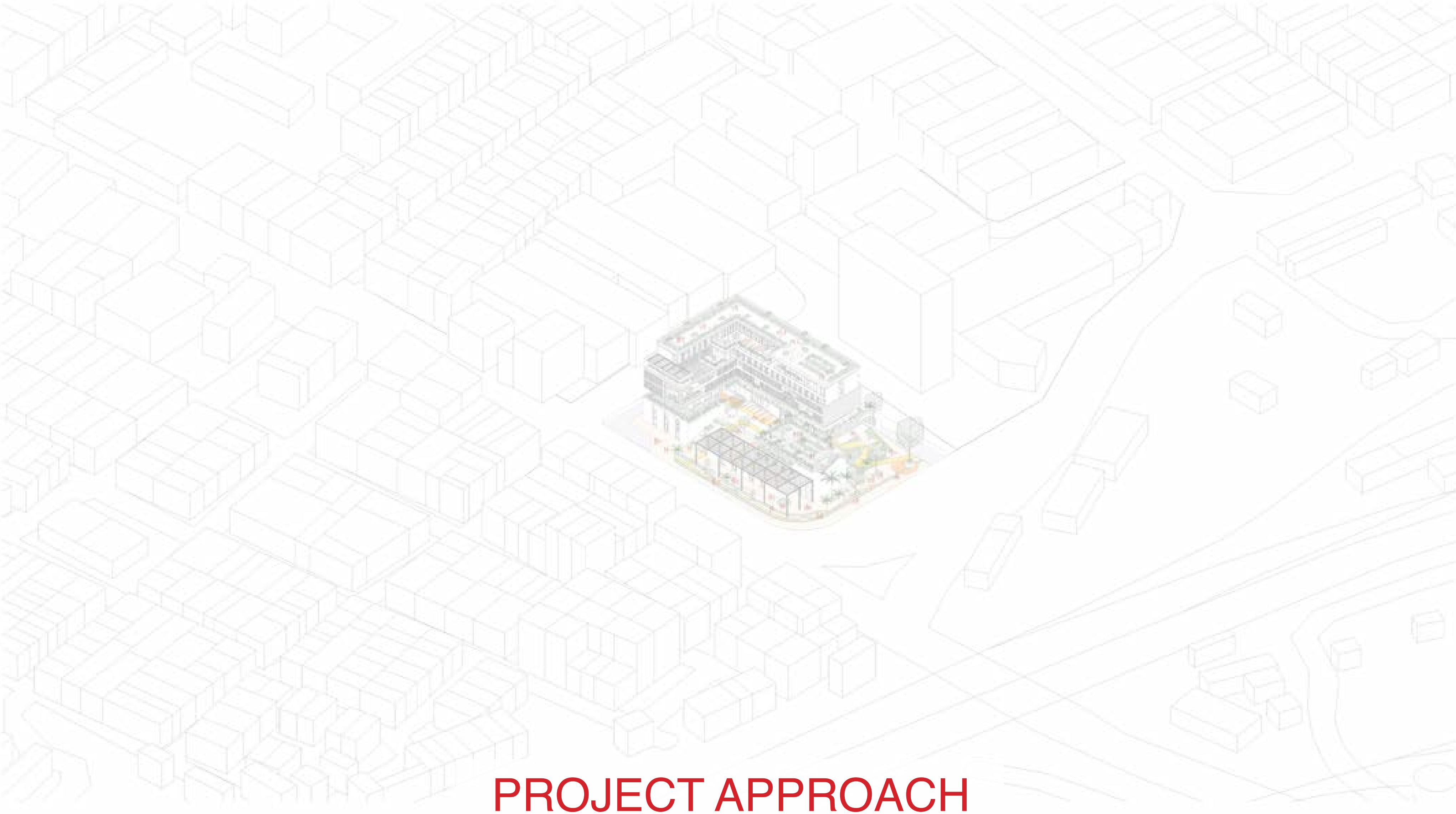
- Material/ Tangible: Users share places, facilities and equipments and othe material resources. Rooms, offices, kitchens, common amenities, digital infrastructure, computers, printers etc. are the primary resources that are shared in co-working.
- Social/ Intangible: Co-working provides networking opportunities to people from either intersecting or aligned fields of professions. An exchange of inter-disciplinary knowledge and ideas is also high.

Types of Co-Working:

Apart from the conventional co-working, some different typologies of co-working include specialised co-working, corporate co-working, open co-working, bartering co-works, incubators and informal co-working spaces.

Opertaional Models of Co-Working:

Co-working models are a combination of private and common spaces. Different configurations of subscriptions are available to the users which they can select according to their requirements.



PROJECT APPROACH

PRE-FAB FOR URBAN ADAPTATION

How can Pre-Fab Construction become a Solution for High-Density Compact Cities?

Several methods can be employed to provide a sustainable urban development for the future of dense and growing urban centres. With this research, the focus is on the usage of prefabricated construction techniques to provide sustainable, flexible and adaptable urban solutions as it is one of the most upcoming methods with immense potential for means of climate conscious and high performing buildings.

In densely packed urban centres, it is preferable to obtain solutions that cause **minimum disturbance and disruption** to the inhabitants, which require **shorter amount of time** to be executed and are environment friendly. **A high degree of pre-fabrication** can ensure high standards of quality as well as least intrusive construction methods. Pre-fabrication also provides scope of **recycling, reusing or even displacing** the building components with progression in the life cycle of the building, which proves to be of value in a high density fabric with constantly changing social and infrastructural needs.

Integrated planned models also enable the design of modular building blocks that can be universally adapted to different scenarios in different locations corresponding to the local needs. This **standardised approach** aids in making the construction cost more affordable, thus providing opportunities to develop multiple urban centres in the same city or even different cities simultaneously.

PRE-FAB FOR FLEXIBILITY

How can Pre-Fabricated architecture provide a smarter, sustainable and affordable solution for the built environment?

Part 1
RESEARCH
Pre Fabricated Modular Construction Technology

fig 1.1.1 Nakagin Tower - On site construction process
Source - Getty Images

fig 1.1.2 Metastadt, Wulfen, Germany
Source - Pinterest

fig 1.1.3 Habitat 67 - Module Placement phase
Source - Archdaily

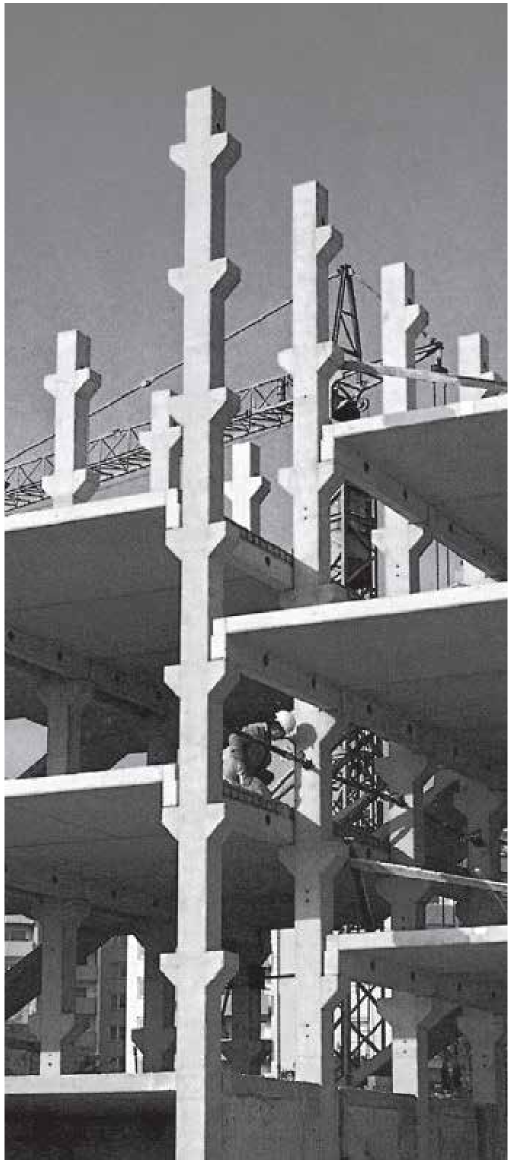


fig 1.1.4 Housing experiment Genter Straße, Munich
Source - Components and Systems

fig 1.1.5 - 1624, British use wooden panels for Fishing Fleet in Cape Ann

fig 1.1.6 - 1849, Sweden Kit Houses transported by railways

fig 1.1.7 - 1906, Aladdin Readi - Cut House

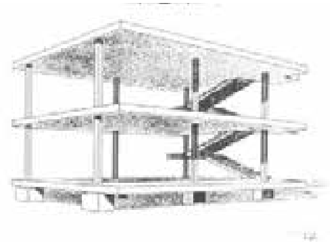


fig 1.1.8 - 1914, Domi-ino House by Le Corbusier

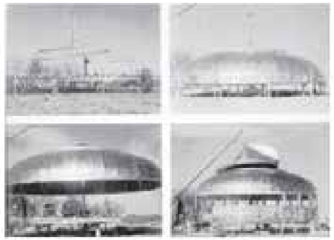


fig 1.1.9 - 1929, Buckminster Fuller - Wichita House

fig 1.1.10 - 1933, House of Tomorrow by George Fred Keck

fig 1.1.11 - 1931-1942 Copper House by Walter Gropius

fig 1.1.12 - 1933-1934, Keck Crystal House by George Keck

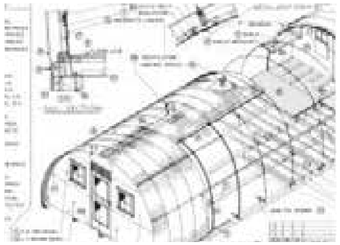


fig 1.1.13 - 1914, Quonset Hut by Peter Dejongh and Otto Brandenberger

fig 1.1.14 - 1945, Levittown Construction by Builder William Levitt

fig 1.1.15 - 1950, Mobilcore

fig 1.1.16 - 1954, Open Plan House by Harry Seidler in Australlia

Source - Scalable Modular Architecture

1.1 HISTORY OF PRE-FAB CONSTRUCTION

The conception of Prefabrication was around 1624 when the British started making prefabricated building parts for construction in their colonies around the world. In 1849 the Swedish introduced the renowned ‘notched building corner technique’ where log houses were built, packaged and transported by trains. Later in 1906 the concept of Kit architecture came about when Aladdin Readi-Cut Houses provided pre-cut pieces with assembling instructions without any requirement of brick or mortar.

In 1914 Dom-ino House by Le Corbusier created the first composable system of building units with open floor plan structure. In 1929 Buckminster Fuller introduced an early concept for the Dymaxion House which was affordable, easy to transport and more importantly earthquake and storm proof.

Later in 1932 Walter Gropius reshaped the Copper House design and provided a scheme of insulated portable walls with copper exterior. In 1945, William Levitt presented Levitton Construction that provided 15 houses in a week with all the elements of a house and also the furniture.

The ‘Mobilcore’ house in 1950 worked on the efficiency of complex components like kitchen and toilet and condensed them in a unique block which could be brought assembled on the site.

In 1954 Harry Seidler created a prototype of a house with prefabricated columns and beams which could provide maximum flexibility in the floor plan. Also, the house cold be elevated to form semi covered spaces or deal with extreme climatic conditions. Archigram Group in 1964 introduced the concept of walkable cities and Plug-in cities.

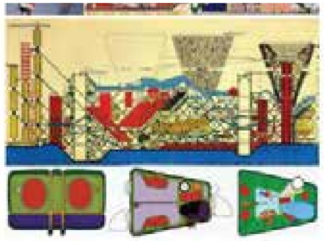


fig 1.1.17 - Archigram Plugin cities

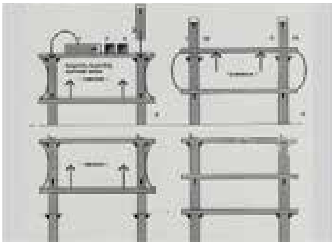


fig 1.1.18 - Dante Bini, Air Lift Up

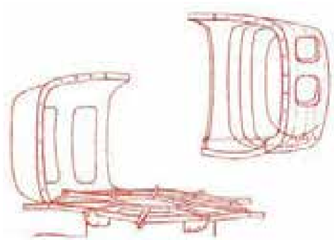


fig 1.1.19 - 1967-1970 Jean Benjamin Maneval, Pays de la Loire

fig 1.1.20 - Moshe Safdie's Habitat Montreal Expo

fig 1.1.21 - 1968-78 Futuro House, H. Leonard, Helsinki , Finland

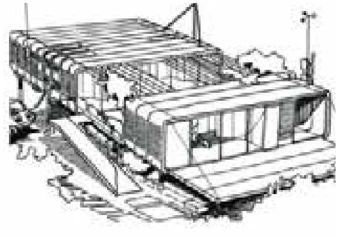


fig 1.1.22 - Richard Rogers proposes his zip up Enclosures

fig 1.1.23 - 1971 Paul Rudolph's Oriental Masonic Gardens, Connecticut

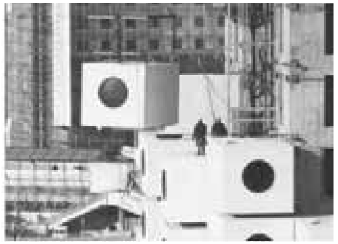


fig 1.1.24 - Kisho Kurokawa's Nakagin Capsule Tower, Tokyo

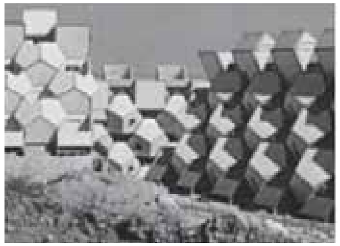


fig 1.1.25 - Zvi Hecker's Ramot Housing Complex, Jerusalem

fig 1.1.26 - 1996 Mass market retailer, Bo Klok house in Sweden

fig 1.1.27 - LOT-EK, Modular Dwelling Unit.

fig 1.1.28 - Steven Holl, New Mexico, Computer controlled cutting tech.

Source - Scalable Modular Architecture

Text in chapter 1.1 is retrieved from Scalable Modular Architecture, Workshop by JDP Architects

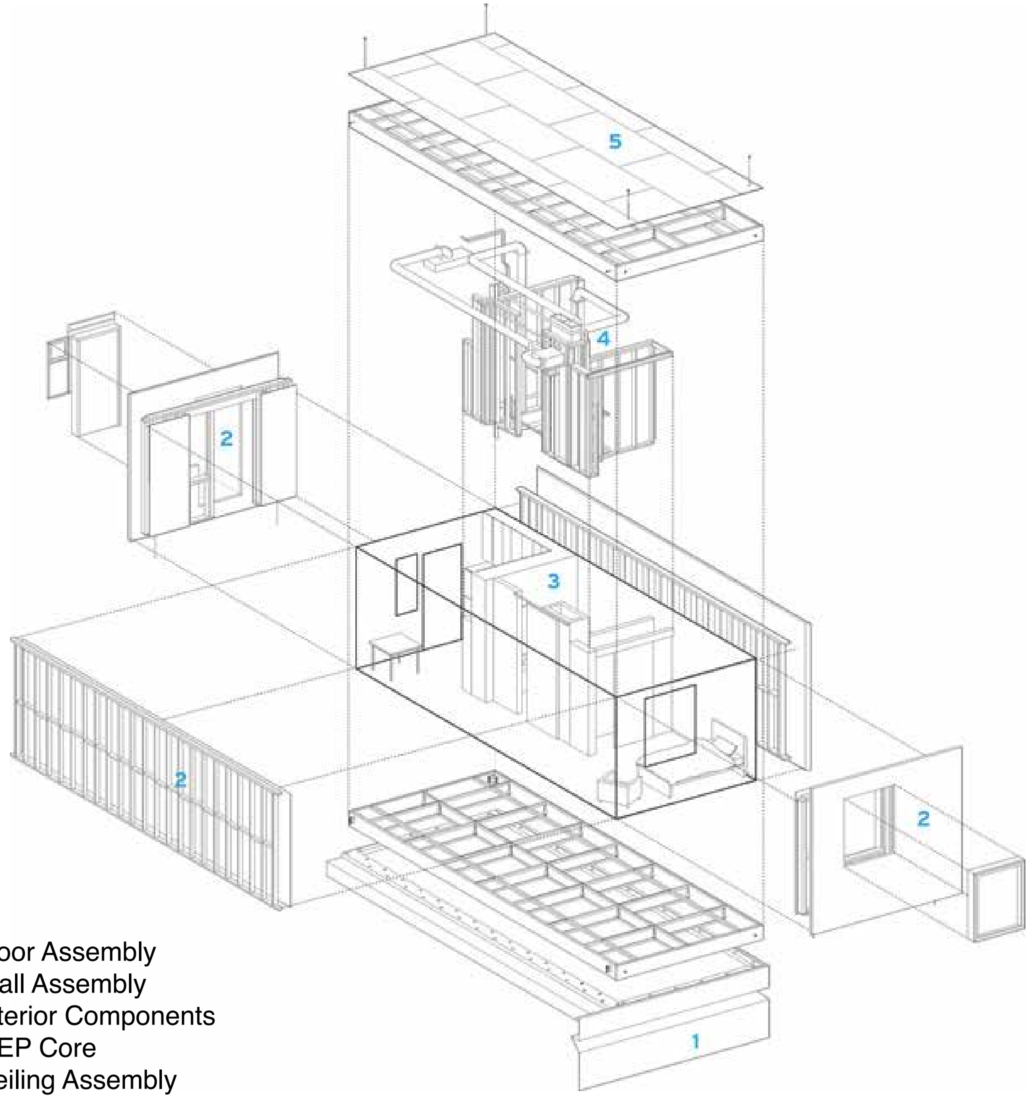
In 1967 Moshe Safdie introduced the iconic Habitat '67 at the Montreal Expo where 158 concrete modules (18 different designs) were stacked in a staggering manner. The Futuro House designed by H. Leonard Fruchter in 1968 was a self-sustaining unit based on circular economy. Richard Rogers proposed the Zip-Up Enclosures in 1968, as a series of standardised building elements where users can buy and expand the living modules. In 1971 Paul Rudolph designed Oriental Masonic Gardens where an overlapping system provides possibilities of different cluster formations.

The well renowned Nakagin Capsule Tower in Tokyo was designed by Kisho Kurokawa in 1972. It provided living unit capsules which could be changed over time giving a flexibility and adaptibilty to the living environment.

Zvi Hecker's Ramot Housing Complex in Jerusalem for colonies in Israel is a beehive configuration of 720 polyhydric modules. The idea to have multiple arrangements created varied images of the housing complex each unique to user needs and necessities.

In 1996, IKEA created a BO Klok house in Sweden as a designer product which could be ordered and customised like clothes and accesories. In 2003, LOT-EK architects completed the first prototype for a modular dwelling unit based on shipping container systems.

In 2005, Steven Holl explored the possibilities of modularity generated with computer technology. This opened doors to using designs with unique prefabrication. Today with evolving technology and machineries, prefabrication and robotics start to play a very important role in controlling quality, timeline, performance and budget of architectural projects.



1. Floor Assembly
2. Wall Assembly
3. Interior Components
4. MEP Core
5. Ceiling Assembly

fig 1.2.1 - Building System as an assembly of modular components.
Source - CE Centre - Modular Construction Paradigm Shift

1.2 FUNDAMENTAL OF PRE-FAB CONSTRUCTION

Pre-Fabricated construction techniques help visualize a building system into a set of elements which can be configured and spatially organised with similar dimensions to be manufactured on a large scale in industries.

The application of standardised elements is governed by a set of rules which are derived with respect to the whole building life cyle; from production to end of life disposal.

Industrial prefabrication of building systems can be categorised into the following:
1. Closed Systems
All elements are fabricated and manufactured by a single factory. It can be designed for an entire building or as partial systems, for load bearing structures, facades, fillers, etc. The range of application of closed systems is quite limited owing to the rigid detirmination of individual designs, unusual topography, unique project considerations, etc.

2. Modular Building Systems
These are closed systems whereby the elements are prefabricated by manufacturers independent of the whole building scheme. It can be built for entire ready built houses or a complex of units organised with a a set of geometric and construction rules.

3. Open Systems
It offers the alternative use of products flexibly from various manufacturers. When the building is designed with an open system, the architect determines the function of building components and the standardised elements from various companies are dimensionally coordinated and adapted.

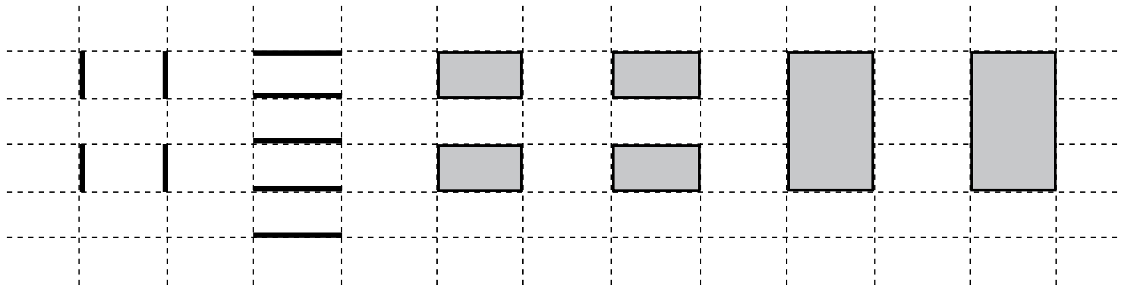


fig 1.2.2 - Modular systems - Elements, Room Modules, Building Modules.

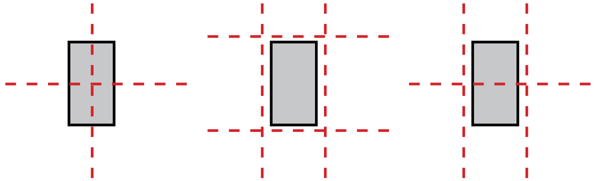


fig 1.2.3 - Examples for Grid Systems

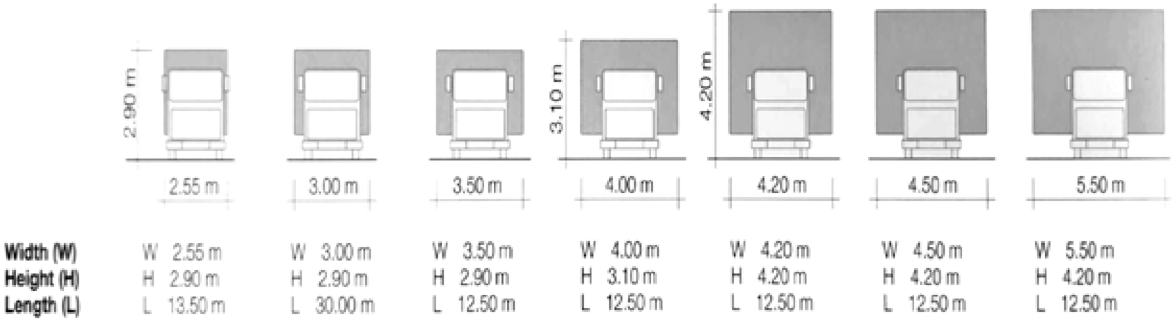


fig 1.2.4 Transport vehicle and size limitations.
Source - Building in Timber - Room Modules, München, 2019. p.58

fig 1.2.5 Process explaining transport to assembling on site.
Source - Sustainable Design and Manufacturing 2019

Once the construction system has been selected, the project can be designed with considerations based on the following aspects.

1. Module

The basic dimension of a geometric classification system is termed as a module; as are also elements that are positioned within a system based upon a classification principle, for example columns, wall panels and room units.

2. Grid

It is a geometrical system determining the length and size of building elements. The configuration of grid can be generated using several distinct references according to the final desired output; for example, Axial grid, Modular grid, Construction grid, Internal fit-out grid, Installation grid, etc.

3. Transport

The condition under which the building elements are to be transported is the most restrictive of all factors with regards to unit size. Transport becomes a critical factor contributing to the overall budget of the project, hence the distances for procurement from factories should be pre-planned.

The order of loading of elements onto the carriers is dictated by the sequence of assembling on site to maximise the efficiency of workflow.

4. Assembly

The erection of a building based on prefabricated elements requires assembly on site which includes hoisting, positioning, adjusting, connecting and waterproofing. Hence, the major part of site work is the assembly work.
Position, size and weight of the building elements are decisive for selection of hoisting equipment. The time of Assembling on site also depends upon how precise the building elements are manufactured according to site conditions.

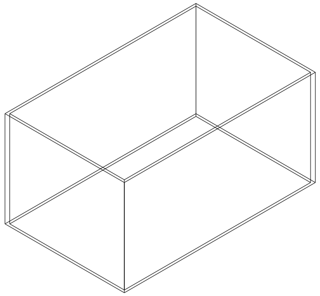
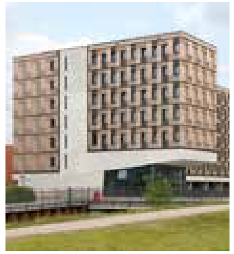
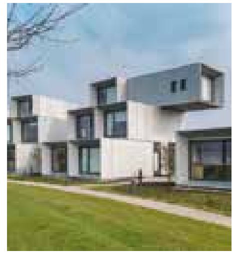
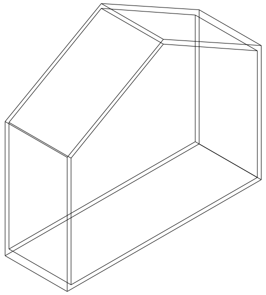
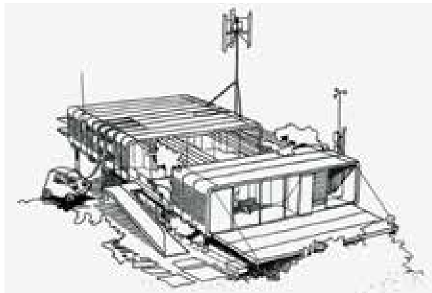
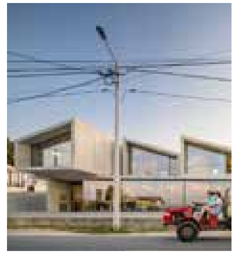
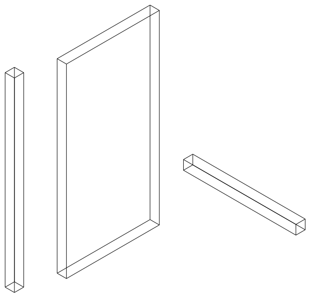
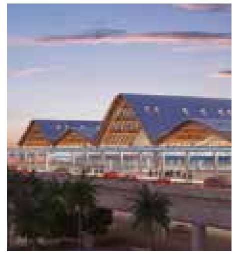
fig 1.2.6 - Assembly of prefab wall panels on site
Source - Think Wood - Brock Commons Tallwood House

5. Jointing
The intersections and junctions of the building play a major role in influencing the Architectural language and image of the project. The pattern of joints is devised by the dimensions of elements which in turn are fixed by production, design and transport conditions.
The joints are responsible for :
i) the dimensional accuracy between the building components and systems
ii) Moisture levels
iii) Thermal performance
iv) Accoustic efficiency

6. Tolerances
The differences in the dimensions of the actual sitework and design layouts must be considered during the planning process. These are affected due to the dimensions of the joints and elements used for the assembly of the prefab building system.

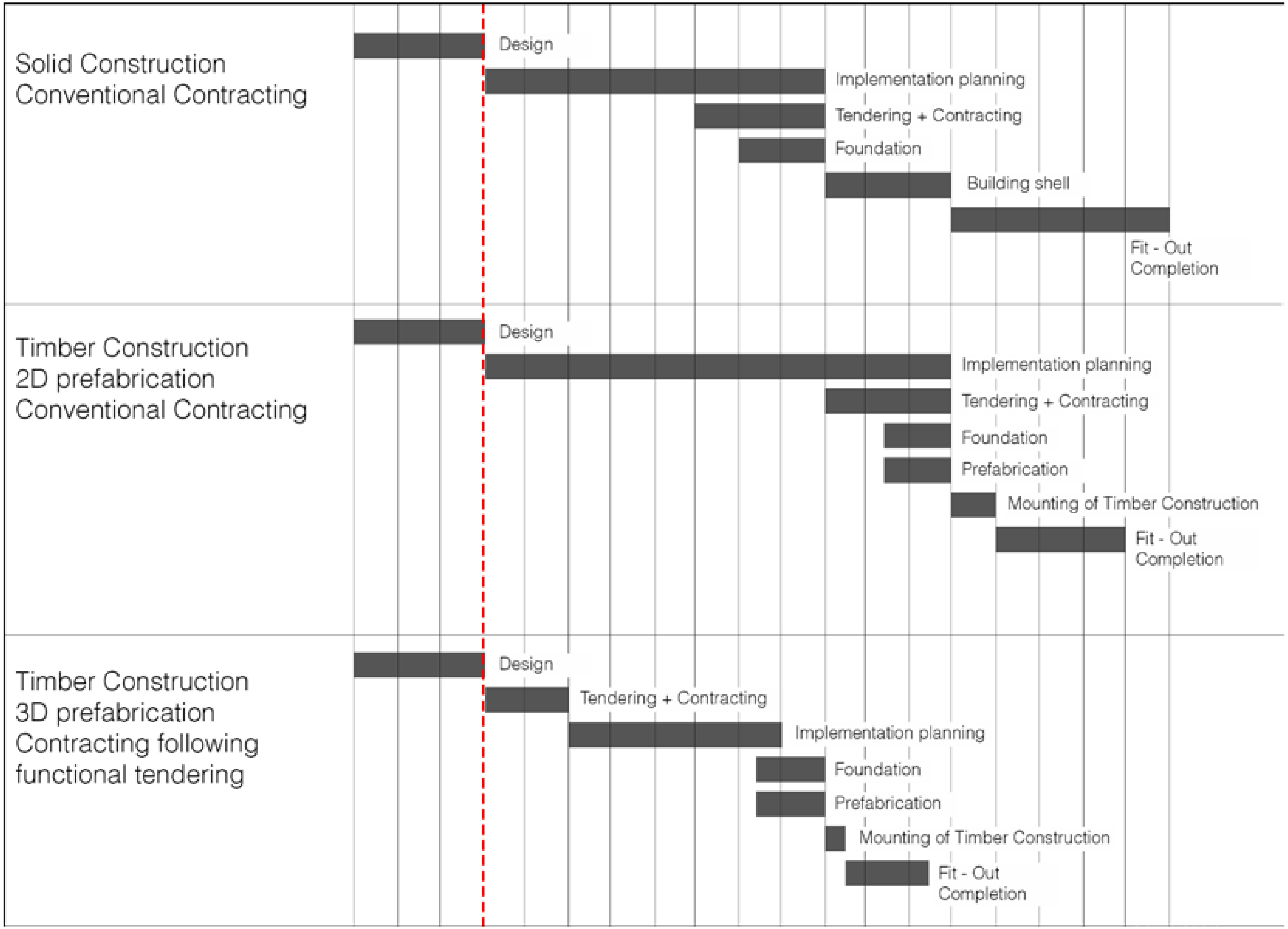
As there are wide range of possibilities in prefab systems, this study is focussed only on understanding the market, availability, working, budgets and various other concerns related to the following materials :
1. Timber
2. Steel

Text in chapter 1.2 is retrieved from
Components and Systems: Modular Construction - Design, Structure, New Technologies, München: Birkhäuser, 2013. p.42-47

CORE MODULE	FEATURES	PREDENCE	CONTEMPORARY EXAMPLES	
 Volumetric (Room Cell)	• As 3D modules (like boxes) • Simple connection to foundation • Size of the module is restricted by highway or shipping constraints	 Habitat'67 by Moshe Safdie	 Woodie Student Hostel, Hamburg	 Dyson Institute of Engineering, UK
 Sectional	• Sectional modules for ease in transportation • Potential for digital fabrication • Size is not restricted by transportational constraints	 Zip-Up Enclosure by Richard Rogers	 Prefabricated Pavilion Prototype, Madrid	 Vale de Cambra, Portugal
 Components	• Factory made components to reduce on-site labour • Allows flexible building shapes and forms • Includes panelized, pre-cut, kits of parts	 Copper House by Walter Gropius	 Dortheavej Residence, Copenhagen	 New Clark International Airport, Philipines

Information in chapter 1.3 is retrieved from
Huang, Joseph. (2007). A Choice Model of Mass Customized Modular Housing by Internet Aided Design.

2. Analyse and Understand Comparison
Conventional Construction vs Factory made Pre-Fabricated Construction



Project Timeline Comparison

Principles	Offsite	Onsite
Cost		
Financing	interest reduced on shortened schedule, even draws, and leasing options, alternative methods might be seen as risky for lenders	traditional construction loan / mortgage financing, lending freezes make construction actuation difficult
Administration	administrator overhead reductions	bureaucratic layers for decision making
Insurances	lower contingency costs	higher contingency costs
Transportation	two stage delivery shop and site	raw material delivery only
Change orders	extra cost and delay	accommodated changes
Overhead	larger shop overhead—people, equipment, space, utili- ties	overhead is absorbed into construction budget
Schedule	duration reductions recapture investment earlier	schedule overruns are common increasing overall budget
Material	less scaffolding, formwork, and shuttering	increased scaffolding, formwork and shuttering
Craning	costly heavy duty cranes for setting	no cranes for small projects, large stationary crane for larger
Initial cost	higher investment in product	lower initial cost for normative projects
Lifecycle cost	greater ROI over long term	greater maintenance requirement
Profit	subcontractor overhead costs project more, savings from scope, material may not be passed onto customer	overhead fees are more transparent to owner
Design fees	higher due to coordination requirement	standard fees
Lean	reduce time waste increase value	waste laden process
Productivity	full 8 hours of work, sophisticated machines, digital tools available	productivity increases difficult
Economy	when strong plenty of residential work, but less commer- cial, when weak, less residential and more commercial	residential and commercial ebb and flow with markets

Offsite construction requires higher initial costs (capital, machines) than a traditional on-site construction operation. Offsite construction can decrease on-site costs, majorly involving labor costs, site machinery and equipment costs, energy and water costs consumed during construction. Onsite labor costs are replaced by manufacturing costs (in the factory). However, when the production volume is increased, the difference between the onsite labor cost and the offsite manufacturing cost inreases manifold.

Principles	Offsite	Onsite
Schedule		
Duration	finish date met 50% reductions	schedule overruns are common
Scope coordination	extra coordination needed between site and plan	more time for coordination and opportunity to adjust dimensions
Schedule reliability	longer lead time, reduced erection time, reliable duration	shorter lead time, longer construction and less reliable
Permitting	streamlined in familiar jurisdictions opposite in unfamiliar	dependent on jurisdiction
Weather	sun always shines	delays due to weather are common
Work flow	concurrent scheduling	linear process
Subcontractors	fewer conflicts better sequencing	simultaneous trade crowding difficult
Supply chain management	coordinated and streamlined	uncoordinated and wasteful

Offsite construction is not affected by the fluctuating weather conditions or the conflicts and uncoordination between different agencies involved in the construction process. The initial lead time of offsite construction is more but as it is a concurrent construction method the project timeline becomes shorter and also the probability of exceeding the predetermined schedule reduces remarkably.

Principles	Offsite	Onsite
Labor		
Local labor	less local labor needed	local labor needed
Working conditions	improved working conditions and more stable job market	variable working conditions and more sporadic job market
Skill level	craft and technical skills needed	craft and problem skills are elevated
Subcontractors	fewer conflicts better sequencing	
Unskilled labor	supervision of labor, quality control process	unsupervised labor leads to portions of project being reconstructed
Labor comfort	ergonomics increased	physically difficult
Safety	reduced exposure to accident	accident prone job site
Health	better life style and mental health	more opportunity for variety in work
Skilled labor	less chance for skill development	more chances for skill development
Commute	factory near house—full 8 hour days and no out of town travel	out of town projects require commute times
Productivity	full 8 hours of work, sophisticated machines, digital tools available	less productive use of labor force
Union	declining due to immigrant population making less room for offsite	accommodates variety of labor types

Offsite construction provides a safer, more comfortable and conditioned environment for the workers. Moreover, offsite construction relies on more skilled labor force and machines for production so the quality and precision in work is higher than onsite construction.

Principles	Offsite	Onsite
Scope		
Supply Chain Management	long term supply chains for materials established	supplies restricted to project-based purchases
Coordination	extra coordination needed between site and plan	More time for coordination and opportunity to adjust dimensions
Flexibility	changes often cannot easily be made in field	Limited adjustment can be made easily in the field
Impact of changes	less accommodation	more accommodation
Maintenance	reduced maintenance and operations	higher maintenance and operations
Transportation	two stage delivery shop and site	raw material delivery only
Flexibility	changes not made in field	adjustments made in field
Design	requires higher level of detailing for assembly, only 50% with bridging documents	design intention communicated only
Production	predictable output, mockup and prototype required	difficult to anticipate, depends on skill level of con-struction crew
Regulatory	3rd party verifiers	local agency to inspect
Predictably	increase expected outcome	less predictable delivery
Staging	less material on site, but must be coordinated well	staging is logistically difficult
Accessibility	specialized companies, takes research and work	smaller construction companies

Principles	Offsite	Onsite
Quality		
Reliability	more reliable quality can be achieved in shorter amount of time	less reliable (depending on the site conditions and skill level of labor)
Coordination	integrated effort between factory and site	flexible coordination and adjustments
Design	integrated design and construction process	separation of design and construction
Production	predictable output, mockup and prototype required	difficult to anticipate, depends on skill level of construction crew
Regulatory	3rd party verifiers with industry knowledge	local jurisdiction with varied experience
Predictably	increase expected outcome	unpredictable quality
Innovation	R&D capacity and control	no research and development time or resources
Design flexibility	more restricted	more freedom
Equipment	easier access	equipment to and from site
Environment	lower waste, air and water pollution, dust and noise, and overall energy costs	difficult to manage waste and energy in construction
Handling	potential for damage during handling	smaller elements easier to handle
Joining	fewer joints, but difficult to detail	more joints, more potential for failure
Tolerances	great capacity, not forgiveness in module on site	forgiveness with details constructed on site
Fit	fewer points for water and air infiltration	more locations for infiltration
Quality of materials	quality control in SCM sourcing	contingent upon source
Warranty	opportunity for comprehensive warranty of products from one supplier	dedicated to each system supplier

With prefabrication method, the precision of the products increases which allows a greater control over the quality of the end product. Several checks and verifications are carried out for each component of the prefabricated modules so the lifespan and the safety of products is also higher. As everything is automated or machine made, the margin of error is lower and the raw materials used cannot be replaced with subpar quality raw materials.

Principles	Offsite	Onsite
Risk		
Cost	overall higher cost potential, more predictable	standard bidding process brings waste, cost is unpredict-able
Handling	transit damage potential, cumbersome large scale unit install	multiple trips, smaller pieces for easier per install handling
Public perception	negative	NA
Innovative	greater innovation possible	more difficult to achieve innovation complexity
Safety to labor force	safe indoor labor conditions	statistically more dangerous
Tolerances	discrepancy between onsite and offsite elements present problems, element tighter tolerances	tolerances can be accommodated easily in onsite instal-lation
Fit	if not fit, changing size of element is costly	onsite accommodation to fitting issues resolved without added cost
Quality	when increased, risk goes down	higher exposure to risk due to material and joint failure

Information in chapter 2 is retrieved from
Lean Wood - TU Munich - Book 4
(https://www.arc.ed.tum.de/holz/forschung/leanwood-1/about-leanwood/)

Depending on the scale of the project, the cost of offsite construction might be higher than it's traditional onsite counterpart which leads to a higher risk for the investors. However, in time sensitive projects, onsite constructions are more risky which can come to a halt owing to several unforeseeable factors while disrupting the predetermined schedule. Long term risk with regards to the users and habitants is lower in offsite constructions as the quality of construction and materials used is better.

Introduction to Research on Pre-Fab Building Systems Based on Timber and Steel

With evolution in technology in the construction sector, Pre-fabricated constructions have proved to be highly efficient, quick to build and cost effective for various projects around the world.

As the world of construction offers a wide range of materials, it becomes even more important to understand which materials could be easily adapted and configured into modular systems. Each material based on its local availability and cost has its own pros and cons.

But with the increasing need of flexible, adaptible and multi-functional spaces to tackle urban density, it becomes paramount for us to put forward a discussion on how material selection could have a major impact on sustainable, affordable ways to perceive a built environment.

This research focuses on understanding two specific materials; Timber and Steel, and how they can be efficiently integerated in modular building systems. Timber and Steel have been proven very easy to handle and precisely manufactured in offsite factory based constructions. The research covers a basic introduction on the materials, their properties, fabrication processes, principles in designing, etc and finally exploring their application in various case studies.

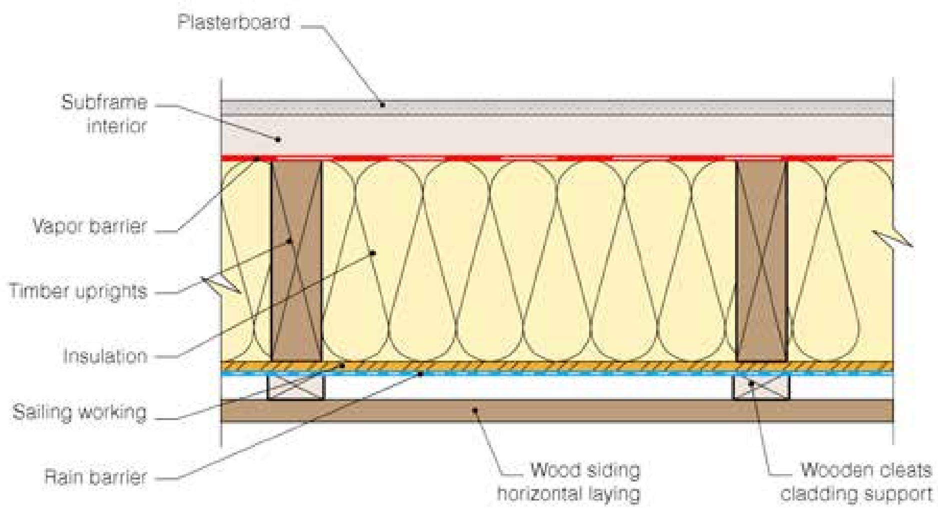


fig 3.1.1 Wall Cross section - Level of Prefabrication can be designed with various combinations.
Source - Catalogue Bois Construction

fig 3.1.2 Offsite module construction and assembly with interior fittings.
Source - APRAO - Modular Construction

3.1 INTRODUCTION

There are three main types of building systems that can be prefabricated using timber construction: Wooden Framework, Cross Laminated Timber (CLT) and 3D Modules [3.1.1].

WOODEN FRAMEWORK

The levels of prefabrication for wooden framework walls and decks can be defined as follows[3.1.2]:

Structure:

Studs, wall sheathings and lintels are assembled in a factory and can be lifted with or without a crane or lightweight hoist depending on size and weight.

Structure & Envelope:

Prefabrication includes the implementation of the insulation and vapor barrier in the factory.

Structure & Envelope with Exterior Wooden Cladding:

In addition to the structure, the thermal insulation and the vapor barrier; the exterior wooden cladding is added in the factory. The windows and doors can also be assembled in the wall at factory which improves the quality of final output and performance.

Volumetric Modules

The 2D panels (structure, envelope and cladding) are put together in the factory and transported to site with or without service equipments.

Text is retrieved from

3.1.1 - Lean Wood - TU Munich (Book 4- Part B) (https://www.arc.ed.tum.de/holz/forschung/leanwood-1/about-leanwood/)

3.1.2 - Catalogue Bois Construction. (https://catalogue-bois-construction.fr/)

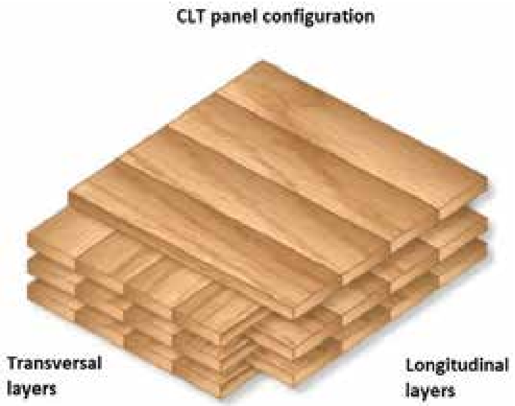


fig 3.1.3 - CLT Panel Composition
Source - WIGO Group CLT

fig 3.1.4 - CLT Panel Production
Source - WIGO Group CLT


fig 3.1.5 - CLT Panel Assembly On-Site
Source - Simpson Strong Tie

CROSS LAMINATED TIMBER

Kiln-dried, finger jointed spruce are cut into sheets of precise dimensions upto 10.5m x 2.95m. The sheets are stacked and glued in a machine press with microwave fix in the orthogonal panel layers. Panels with 3,4 or 5 layers are glued using melamine adhesives (selection of adhesive depends on local availability of material) to achieve a very high quality of adhesion, with no toxic emissions during the product life cycle [2.1.3].

Cross Laminated Timber Panels are majorly used for manufacturing structural elements, interior and exterior visual structures, etc.

They have an attractive finish for the interiors and need no coatings.

When used on an external facade, additional protection against the effects of weather must be applied once every 5 years for better performance.

CLT building materials have high fire resistance in comparison to steel or other construction materials. In case of fire, the outer layers of CLT elements burn first andd turn to char containing fire for 30-120 minutes.

Buildings with CLT can be designed and executed completely airtight for optimum fire resistance, energy efficiency and low thermal conductivity.

It offers an opportunity to reduce working and maintenance costs/ energy consumption by 60-70%.

Text is retrieved from
3.1.3 Introduction to CLT - WIGO Group (https://wigo.info/cross-laminated-timber)

3.2 PROPERTIES AND MATERIAL SPECIFICATIONS OF CLT

Use of CLT	Can be used in all load-bearing and visual structures of the house - base floor, intermediate floor, roof, exterior walls, interior walls, terraces and balconies
Surface quality	Industrial, non-visible, visible
Maximum length	10.50m
Maximum width	2.95m
Maximum thickness	60 - 260mm
Count of layers	3, 4, 5
Wood species	Spruce, Pine, Larch
Grade	C24, C30 (for structural calculations)
Moisture content	12% +/- 2%
Bonding adhesive	Prefere 4546 by Dynea, HB S029 Purbond by Loctite
Weight	500kg/m3 (for structural calculations)
Dimensional stability (panel size)	0.02% change for every 1% change in panel moisture content
Dimensional stability (panel thickness)	0.24% change for every 1% change in panel moisture content
Resistance to fire	Charring rate of 0.65 mm/min in accordance with EN 1995-1-2
Water vapor resistance μ	20 to 50 in accordance with EN 12524
Thermal conductivity λ	0.13 W/(mK) in accordance with EN 12524
Specific heat capacity	1600 J/(kgK) in accordance with EN 12524
Air tightness	Airtightness of a 3-layer CLT panel and of panel joints has been tested to EN 12114 where it was found that the volumetric rates of flow were outside the measurable range

fig 3.2.1 - Properties of CLT - Material Specifications by WIGO Group
Source - Technical Description of CLT by WIGO Group

3.3 ADVANTAGES OF CROSS LAMINATED TIMBER CONSTRUCTION

SUSTAINABILITY
CLT Panels are ecologically sustainable as the manufacturing process optimally uses the raw material significantly reducing the waste generated. A huge difference can be observed in the greenhouse gas emissions during its production. Hence, it offers a product with very less carbon footprint.

FLEXIBILITY
CLT panels can be manufactured for various purposes such as building roofs, walls or ceilings. It offers flexibility with variable thickness, easy management, material combinations and variable structural and thermal properties.

THERMAL INSULATION
CLT buildings offer a naturally high thermal insulation as they are made with excellent natural insulating wood. CLT building materials allow you to build a structure free of thermal bridges, radically minimizing heat loss and heating and cooling costs.

COSTS - BENEFITS
The extreme versatility, the lightness in the handling phase compared to traditional materials and the speed of realization allow to reduce the construction costs. It minimizes the wastage and offers better recyclability post life cycle.

SAFETY
Wood as a building material is naturally anti-seismic and fire resistant, which allows it to maintain structural integrity even during fires. Structurally, with much lower thicknesses than traditional materials, it has compressive and flexural strengths, far better in terms of static performance.

PRECISION
CLT panels are manufactured in controlled factory environments which help to ensure high level of accuracy, precision and desired conditioning of the components.

TRANSPORTABILITY
CLT panels and elements are comparitively light in weight which increases efficiency in transport and handling. The modular components can be designed and manufactured according to sizes of vehicles available for transport.

PRE-ASSEMBLY - PRODUCTION PHASE
One of the biggest advantages of CLT building materials is the ability to fully assemble and manufacture large modules in a factory environment. Depending on the level of prefabrication required in the project, CLT can be used to manufacture a wall, roof, stair, floor panels or even complete modules that can be delivered to the construction site. Compact, easy to transport and highly efficient handling makes delivery to large distances possible.

ASSEMBLY - CONSTRUCTION PHASE
The CLT panels are ready to install on site, which prevents any damage due to climate conditions and saves time for curing. Comparitively lightweight panels are easy to handle and assemble on site. Reduces construction timeline and overall project costs making the process more profitable for investors.

Text in chapter 3.3 is retrieved from CLT Advantages listed WIGO Group. (http://www.wigo-house.it/costruire-in-clt/)

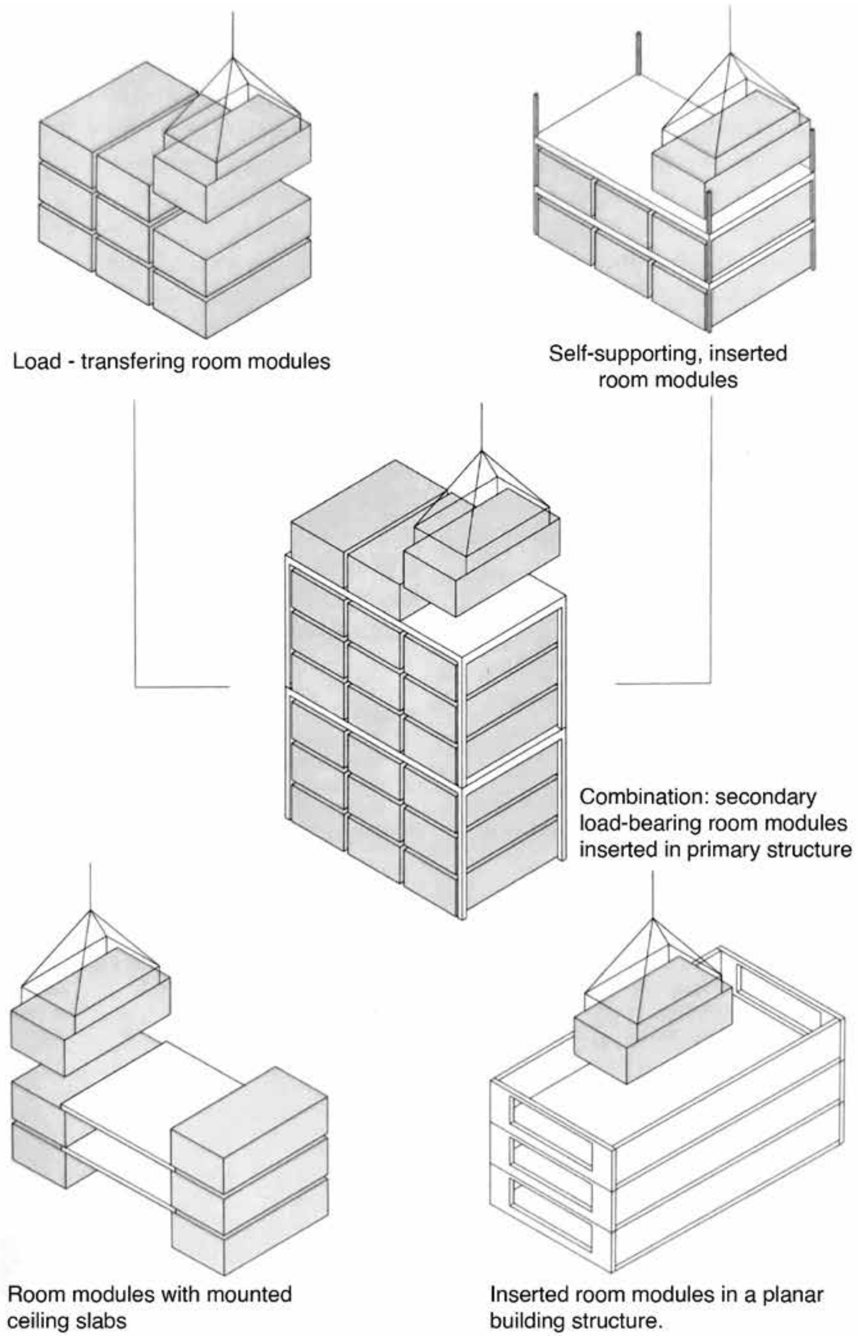


fig 3.4.1 Possible building system solutions with room module configuration.
Source - Huß, Wolfgang, Kaufmann, Matthias and Merz, Konrad. Building in Timber - Room Modules, München: DETAIL, 2019. , p. 16

3.4 DESIGNING BUILDING SYSTEMS WITH ROOM MODULES

The prefabrication process of design shapes in room module construction is significantly higher as compared to any other method. The decision to use room modules should be taken at the very begining of the design conceptualization. The strong spatial guidelines offer endless posssibilities of combinations of open and closed modules with respect to the desired function of the built environment.

HIERARCHY OF SUPPORT STRUCTURES

The factory built constructions of room modules are sufficiently sturdy to transfer their own weight and withstand the conditions of transport. When placed in a building system of several floors, there are various methods to design the structural system.

1. Load Bearing system of room modules
2. Frame structure and inserted room modules
3. Combination : secondary load bearing room modules inserted in a primary structure.
4. Combination of load bearing primary structure and dependant service structures.
5. Inserted room modules in a planar building structure.

The prefab sanitary modules installed post assembly are common examples of inserted module system. Lift shafts and service cores can also be constructed at a later stage adapting the inserted module system to avoid any damage to core during placement of modules on site.

Text in chapter 3.4 is retrieved from
Huß, Wolfgang, Kaufmann, Matthias and Merz, Konrad. Building in Timber - Room Modules, München: DETAIL, 2019. p. 16

3.5 PROCESS OF MANUFACTURING MODULES

CLT building materials provide more strength and durability than other forms of hardwood. It consists of 3,5 or 7 layers of kiln dried timber placed perpendicularly to one another and glued in a press. Hence, The mechanical strength can be controlled according to desired outputs providing a precise sturdy structural system.

The CLT panels are cut to right shape and size based on 3D technical drawings in a machine inside a factory controlled environment. This increases precision of all architectural elements minimizing defects.

fig 3.5.1 Timber construction and manufacturing hall at Erne. - Manufacture of timber frame elements as shell structure by means of a rail system and indoor crane.

fig 3.5.2 Timber construction and manufacturing hall at Erne.
- Multifunctional bridge.

fig 3.5.3 Manufacture of complex room modules as timber frame structures using a gantry robot. Research project by Erne in collaboration with ETH Zurich.

Source - Huß, Wolfgang, Kaufmann, Matthias and Merz, Konrad. Building in Timber - Room Modules, München: DETAIL, 2019. , p. 54-55

fig 3.5.4 Manufacturing Hall at Kaufamann Zimmerei und Tischlerei in Dornbin(AT), Architect Johannes Kaufmann Architektur, Room module shell structures made of CLT.

fig 3.5.5 Basic installation of MEP, HVAC systems.

fig 3.5.6 Electrical piping and insulation.

fig 3.5.7 Window mounting.

fig 3.5.8 Drywall construction

fig 3.5.9 Paintwork

fig 3.5.10 Floor Structure

fig 3.5.11 Tiling Work

fig 3.5.12 Floor covering work.

Once the units are assembled, the fit-outs are carried out in the following steps :

- Sanitary installation : installing pipes, conduits in flooring, walls and ceilings.

- Electrical installation : installation of cable routes.

- Mounting windows : the time of window mounting is flexible depending on the connection details.

- Drywall construction : wall structure, wall and ceiling cladding, shafts and internal walls.

- Paintwork : paintwork with coating and drying phases with interior fit-out.

- Floor structure : dry screed optimizes workability. However, if wet screeds are used, the construction should be configured according to drying periods.

- Tiling work : construction of wall surfaces in kitchens and bathrooms.

- Floor covering work

- Final installation work : mounting sockets, switches, sanitary objects and fittings.

- Furniture : mounting of fixed components

- Facade work : depends on degree of prefabrication, insulation, cladding and other details.

- Ensuring transportability : adding rain protection, lifting aids and storage before the transport.

fig 3.5.13 Transport preparation

fig 3.5.14 Hotel Nordlingen 2018 Ar. Johannes Kaufmann
Loading of room modules onto the articulated truck in manufacturing hall.

fig 3.5.15 Hotel Nordlingen 2018 .Mounting of room modules.

fig 3.5.5- 3.5.15 Source - Huß, Wolfgang, Kaufmann, Matthias and Merz, Konrad. Building in Timber - Room Modules, München: DETAIL, 2019. , p. 56-61
Text in chapter 3.5 is retrieved from
Building in Timber - Room Modules, München: DETAIL, 2019. p. 57

fig 4.1.1 Manufacturing process of Wall Panel at factory

fig 4.1.2 On Site construction and Assembly of Prefab Steel Components

Source - Infinity Structures - Metal stud wall panels

4.1 INTRODUCTION

“...the time is probably near when a new system of architectural laws will be developed, adapted entirely to metallic construction.” - John Ruskin, (1819- 1900)

The concept of serial production was greatly adapted in the architectural industry since the innovation of steel as a building material. The possibility to fabricate and execute projects with the highest precision level in a short time brought a revolution in the field of factory built construction elements. Steel as a material has brought out big innovations and opened up a whole new realm of possibilities with economical solutions.

Steel systems for Prefab Offsite constructions offer a wide range of products and services from smallest service pods to units and also the building system as a whole. Hence, it becomes essential to understand the propeties of the material to optimise their design systems for every site condition.

Text in chapter 4.1 retrieved from
Staib, Gerald, Dörrhöfer, A. & Rosenthal, Markus. Components and Systems: Modular Construction - Design, Structure, New Technologies, München: Birkhäuser, 2013. p.50

semi-finished project neutral	**mechanical refinement**	**coating**	**jointing**	**building element/group project specific**
sections	drilling	galvanising	screwing	**wall elements** wall frames/elements sandwich elements
			pinning	
	sawing	plastic coating	clamping	**slab elements** slab/roof elements
tubes				
	cutting	membrane coating	rivetting	**frame elements** columns and beams sections, trusses, frames and castellated beams
			welding	
sheets	stamping	painting	adhesive fixing	

fig 4.2.1 Manufacturing process of elements at factory

prototype (rough form)	**hot processed**	**cold processed**	**product**
	continuous hot-rolling		**sections, tubes, sheets** rough surface low dimensional precision
non-continuous block casting		continuous cold-rolling	**sections, tubes, sheets** smooth surface high dimensional precision
continuous extruding	continuous hot-rolling	continuous rolling	**sections, tubes, sheets** smooth surface medium dimensional precision
		non-continuous edging deep drawing	**formed sheets, sections** smooth surface medium dimensional precision
	non-continuous extruding		**sections, tubes** smooth surface high dimensional precision
continuous casting			**cast elements** cast steel, cast iron medium dimensional precision

fig 4.2.2 Manufacturing techniques to achieve desired properties at factory

Source -
Staib, Gerald, Dörrhöfer, A. & Rosenthal, Markus. Components and Systems: Modular Construction - Design, Structure, New Technologies, München: Birkhäuser, 2013. p.56

4.2 PROPERTIES OF STEEL

Owing to the simensional accuracy of its production, Steel building elements are highly appropriate for the assembly of modular building systems. Steel is an elastic material with great abilities to withstand tensile and compressive forces with a high yield point.

Properties of structural steel include:
i) Tensile properties
ii) Shear properties
iii) Hardness
iv) Creep
v) Relaxation
vi) Fatigue

- The mechanical properties of steel are based on a combination of chemical composition, heat treatment and manufacturing processes.
- Iron is the main constituent while the properties such as ductility, strength, weldability can be managed by addition of alloys like manganese, niobium and vanadium.
for e.g. Decrease in sulphur content - Increase in Ductility, Increase in nickle content - increases toughness.

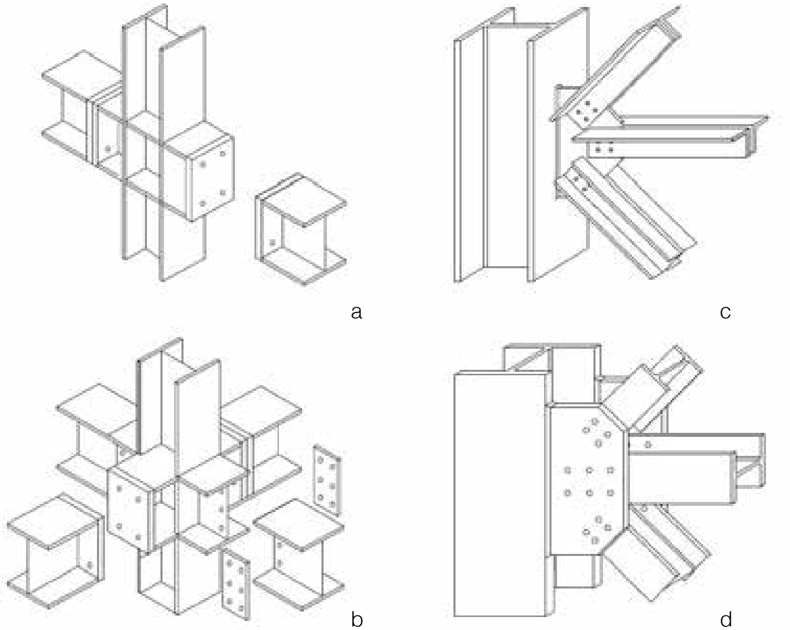
- Mechanical strength also depends upon the process of manufacturing. Following are different categories used to obtain distinct steel elements :

i) As-rolled steel
ii) Normalized steel
iii) Normalized-rolled steel
iv) Thermomechanically rolled (TMR) steel
v) Quenched and tempered (Q&T) steel.

Text in chapter 4.2 retrieved from Steel Construction Info
(www.steelconstruction.info/Steel_material_properties)

description	smallest dimension (h x w)			largest dimension (h x w)		
wide flange beams						
HEA light	HEA 100	(96 × 100 mm)	16,7 kg/m	HEA 1000	(990 × 300 mm)	272,0 kg/m
HEB standard	HEB 100	(100 × 100 mm)	20,4 kg/m	HEB 1000	(1000 × 300 mm)	314,0 kg/m
HEM heavy	HEM 100	(120 × 106 mm)	41,8 kg/m	HEM 1000	(1008 × 302 mm)	349,0 kg/m
standard sections						
INP	INP 80	(80 × 42 mm)	5,9 kg/m	INP 550	(550 × 200 mm)	166,0 kg/m
UNP	UNP 65	(65 × 42 mm)	7,1 kg/m	UNP 400	(400 × 110 mm)	71,8 kg/m
parallel flange sections						
IPE	IPE 80	(80 × 46 mm)	6,0 kg/m	IPE 600	(600 × 220 mm)	122,0 kg/m
IPET	IPET 80	(40 × 46 mm)	3,0 kg/m	IPET 600	(300 × 220 mm)	61,2 kg/m
UPE	UPE 80	(80 × 50 mm)	37,9 kg/m	UPE 400	(400 × 115 mm)	72,2 kg/m
hollow sections						
cold/hot square	RRW 40 × 40	(40 × 40 mm)	3,4 kg/m	RRW 400 × 400	(400 × 400 mm)	191,0 kg/m
cold/hot rectangular	RRW 50 × 30	(50 × 30 mm)	3,6 kg/m	RRW 400 × 4200	(400 × 200 mm)	141,0 kg/m
cold/hot round	ROR 21,3	(Ø 21,3 mm)	0,9 kg/m	ROR 813	(Ø 813 mm)	159,0 kg/m
bars						
round	RND 10	(Ø 10 mm)	0,6 kg/m	RND 500	(Ø 500 mm)	1540,0 kg/m
square	VKT 10	(6 × 6 mm)	0,3 kg/m	RKT 200	(200 × 200 mm)	314,0 kg/m

fig 4.3.1 Dimensions and weight of steel sections



Bolted connections between columns and beams

a) Rigid connection with welded stiffeners and flush end plate
b) Prefabricated rigid three dimensional connection

Connection of lightweight and heavyweight diagonal bracing in frame structures

c) with a single gusset plate
d) with two gusset plates

fig 4.3.2 Bolted connections and diagonal braced frame structures.

Source - Staib, Gerald, Dörrhöfer, A. & Rosenthal, Markus. Components and Systems: Modular Construction - Design, Structure, New Technologies, München: Birkhäuser, 2013. p.58

3.3 CONNECTION TECHNIQUES AND ELEMENTS

- Fixed Connections

i) Rivets
It has a hiigh aesthetic quality and is majorly used in construction/ preservation of historical buildings.
Requires high level of labour and highly expensive.

ii) Welding
Structural Elements like trusses can be welded using gas or electric arc-welding.

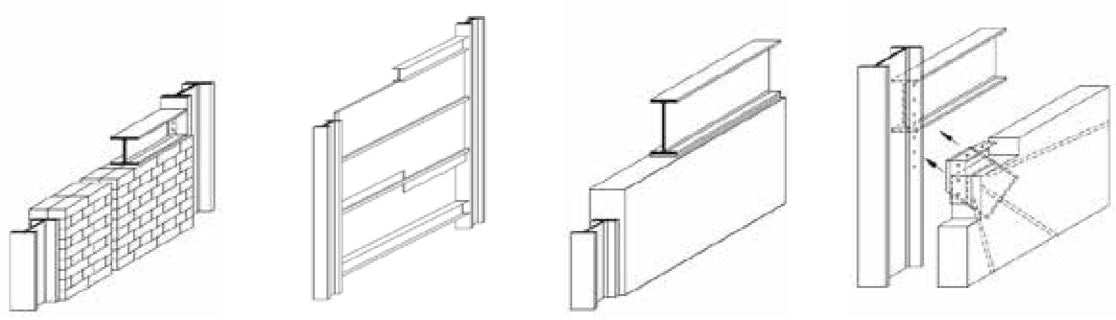
- Demountable Connections

i) Screws
It is the most advantageous way of constructing with steel elements as it provides high level of reusability and sustainability. Makes construction work easy, flexible and highly time efficient.

BRACING ELEMENTS AND SYSTEMS

The design of corners and junctions become a critical part to tackle structure failures.

i) Framework Corners and Diagonal Connections
The beams and columns are provided more strength at the flange level with extra ribbed elements in the area of load transmission.
These highly rigid screwed connections absorb bending moments and shear forces.
The diagonal connections are braced with column-beam structure using screwed/ welded connections with junction plates.



a b c d

fig 4.3.3 Types of shear walls

Shear walls
a) Masonry panels for low horizontal loads
b) Sheet metal walls braced to prevent buckling
c) Precast concrete panel
d) Precast concrete panel with gusset plate

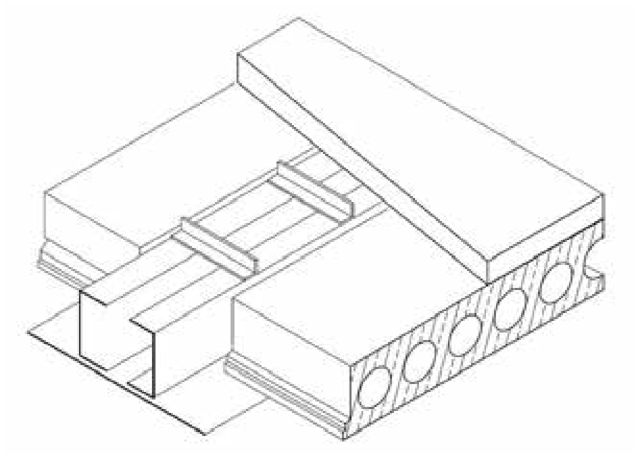


fig 4.3.4 Slender floor slab system (Slim-Floor-Slab)

ii) Shear walls

Shear walls of steel sheeting are designed to support large horizontal loads.
These can be replaced with masonary infill or prefabricated concrete panels depending upon the amount of load to be supported.

iii) Intermediate Floor Slabs

Prefabricated concrete slabs or sectional steel sheets resting on solid web beams, castelated beams or trusses, are used during steel construction.
Economical solutions can be designed by using combinations of corrugated steel sheeting or a slim floor slab.
These are composite elements with prefab hollow systems sealed with concrete.

iv) Structural Cores

When the bracing elements of a steel skeleton structure is a concrete core, the steel beams and floor slabs are fixed to the wall of core in the following 3 ways:
- Steel connection plates are concreted into the walls of concrete core. (Web junctions are screwed)
- Steel connection plate is set into the concrete wall and anchored. (Web junctions can be welded)
- The concrete wall is cast with recessed profiles to support the steel elements. (Web junctions can be screwed)

Text in chapter 4.3 retrieved from - Staib, Gerald, Dörrhöfer, A. & Rosenthal, Markus. Components and Systems: Modular Construction - Design, Structure, New Technologies, München: Birkhäuser, 2013. p.58 - 59

4.4 CONSTRUCTION PRINCIPLES

The structural system of the building with a steel skeleton can be designed in mainly four distinct ways according to the required design and performance.

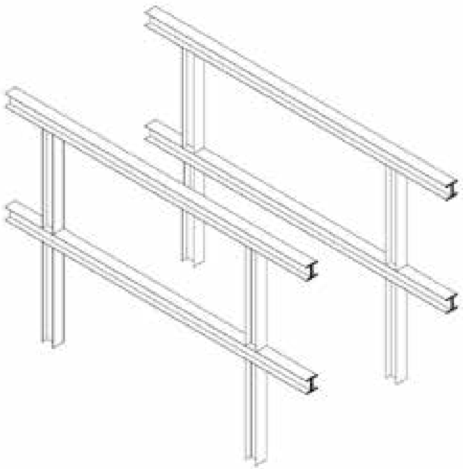
i) Frames with Continuous Beams

ii) Frames with Continuous Columns

iii) Non-directional Skeletons

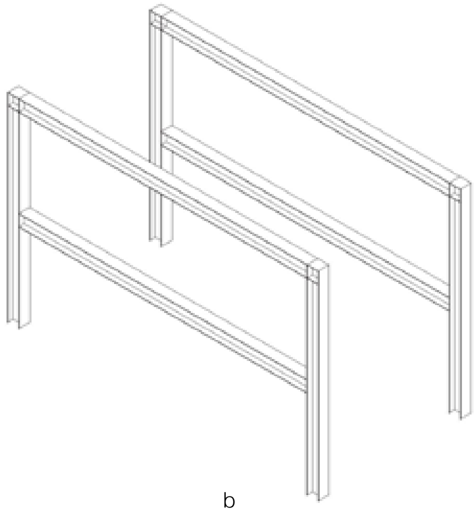
iv) Space Frames

Prefabricated steel constructions of room modules can be configured into an existing frame system or as load-bearing systems with built-in steel skeleton to support the loads.



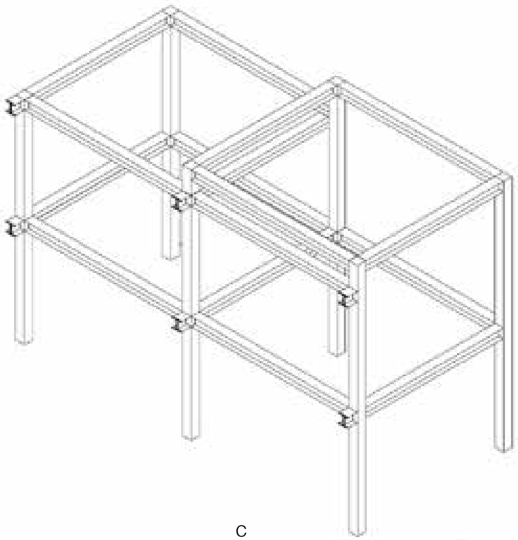
a

fig 4.4.1 Frames with Continuous Beams



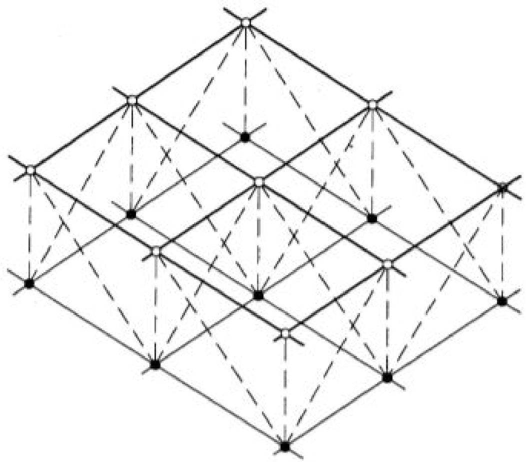
b

fig 4.4.2 Frames with Continuous Columns



c

fig 4.4.3 Non-directional Skeletons



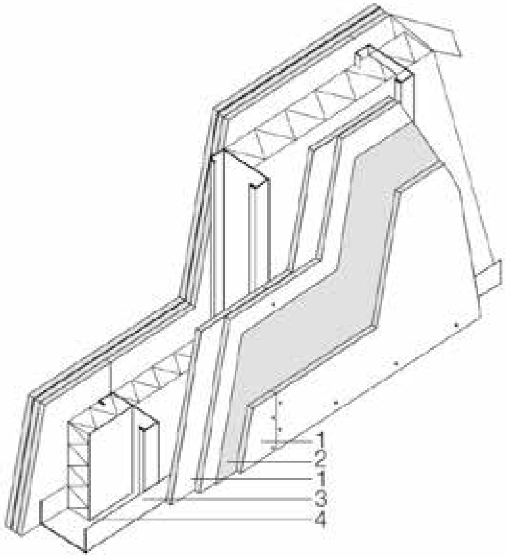
d

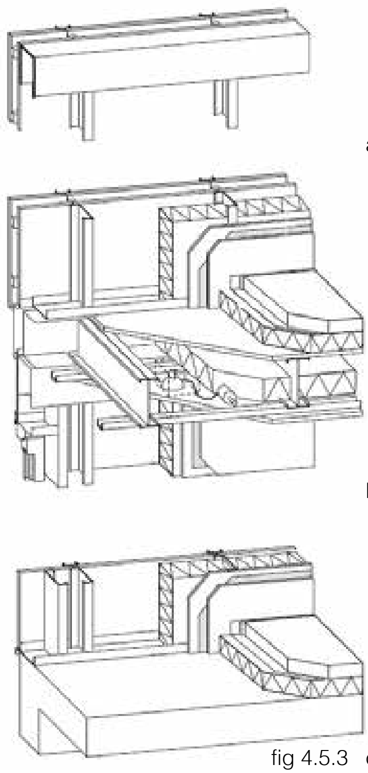
fig 4.4.4 Space Frames

Typologies of Steel Construction

Figures and Text in chapter 4.4 are retrieved from - Staib, Gerald, Dörrhöfer, A. & Rosenthal, Markus. Components and Systems: Modular Construction - Design, Structure, New Technologies, München: Birkhäuser, 2013. p.60

fig 4.5.1 Manufacture of a steel frame in a factory

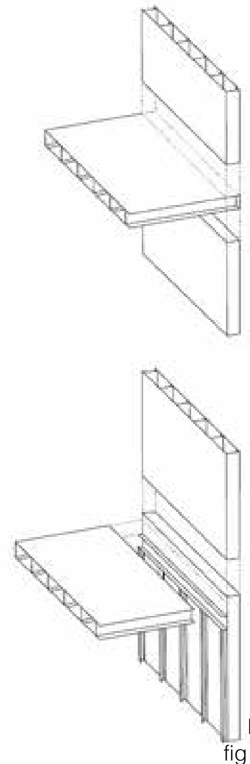




a

b

fig 4.5.3 c



a

b

fig 4.5.4

fig 4.5.2 Steel frame wall construction
1 12.5 mm plasterboard cladding
2 0.38 mm metal panel
3 C-section (416 mm centre distance)
4 insulating fibreboard

fig 4.5.3 Isometric representation of
a) steel-frame construction
b) intermediate floor connection
c) footing connection

fig 4.5.4 Construction principles of steel-frame construction
a) Platform building method
b) Balloon frame building method

4.5 BUILDING WITH STEEL PANELS

The steel frames, cross ribs and panels are manufactured and assembled in factory depending upon the level of pre-fabrication.

i) Steel framework construction

- The load bearing panel elements are constructed with cold rolled steel sections as rough building elements for walls, slabs and roofs.
- Low weight and high load bearing capacity is generated by arranging vertical studs at 40-80 cm, connected with profiles at top and bottom.
- Connections are welded or screwed.
- A stable wall is composed with double sided cladding of panels.
- Accoustic and thermal insulation can be added according to requirements. Thermal bridges due to metal studs can be sealed with additional insulation layer.
- Planning and construction grids are based on axial grid principle.

ii) Platform Construction Systems:

- Buildings are erected storey by storey.
- The floor slabs rest on high wall units.

iii) Balloon Frame Construction Systems:

- The external walls stretch ove the entire height of buildings.
- The floor slabs are not connected to wall construction but to console elements that are welded to stud sections.

fig 4.5.5 House, steel frame construction (Cocoon Transformer), Zagreb 2006

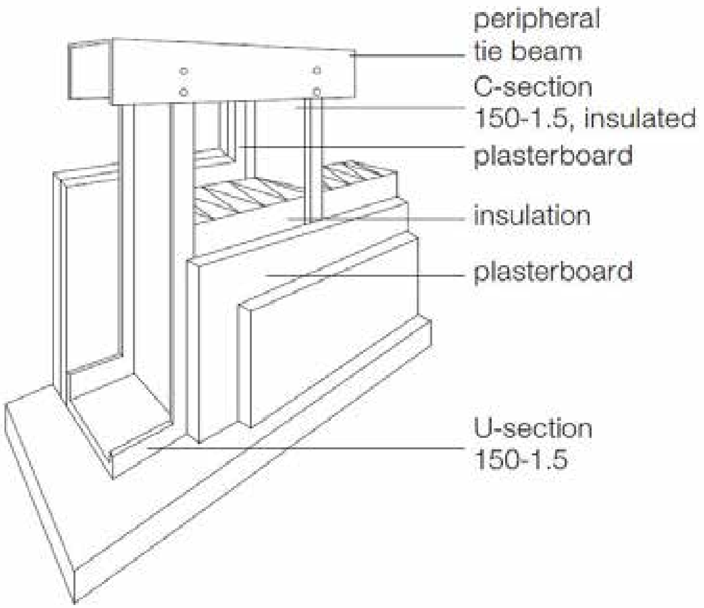


fig 4.5.6 Construction of a cocoon wall

Building with steel panels reduces the total weight of upto 30% compared to timber framework construction and upto 66% when compared with conventional solid wall construction.

Large panels can be manufactured as wall units with maximum widhts upto 12.5 m and slab elements with span dimensions of up to 14 m.

iv) Cocoon Transformer:
This approach is mostly suitable for new buildings, extensions and addition of one or more storeys.
The wall units are manufactured, completed with finishings in the plant and are ready for assembly at site.
Appropriate for wide wall spans and slab constructions.
They can be extended and added to in both vertical and horizontal directions as desired.

For example, with this system, the loadbearing structure of a single-family house can be erected within 3-4 days:

- Application:
external and internal walls, intermediate floor slabs, fireproof walls.

- Usage:
office and administration buildings, housing, social facilities, small industrial facilities.

Figures and Text in chapter 4.5 are retrieved from - Staib, Gerald, Dörrhöfer, A. & Rosenthal, Markus. Components and Systems: Modular Construction - Design, Structure, New Technologies, München: Birkhäuser, 2013. p.111-113

fig 4.5.7 Manufacture of trapezoidal steel sheeting

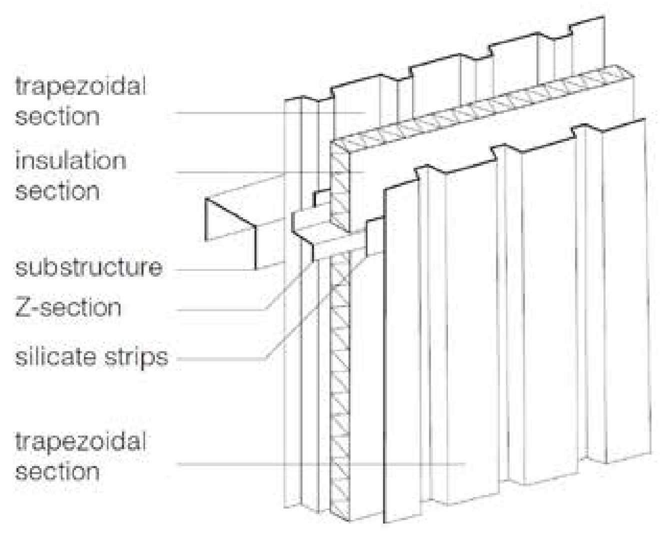


fig 4.5.9 Trapezoidal sheet steel wall

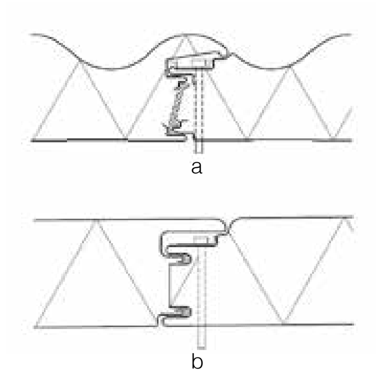


fig 4.5.8 Concealed jointing for sandwich elements
a) Sandwich element with corrugated cover plate
b) Sandwich element with flat cover platesteel sheeting

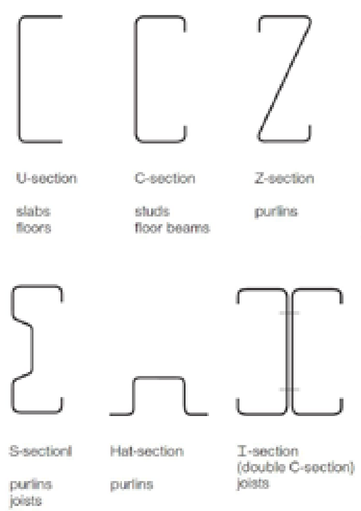


fig 4.5.10 Lightweight cold-rolled steel sections

CONSTRUCTION MATERIALS AND ELEMENTS

i) Sectional Sheet Panels
- Wall panels of sectional sheeting for partitions and enclosure do not bear load.
- Double-layered, thermally insulated, trapezoidal or corrugated metal wall panels are used in housing industry.
- Highly processed external layer is connected with internal layer by spacers, keeping them thermally separated. Humidity from inside the building is transffered to outside with a air separation layer behind outer surface.

ii) Sandwich Elements
- These can be used as self supporting units both for facade and roofs.
- The strength can be increased by rolling and folding processes, suitably with aluminium, steel and stainless steel.
- Sandwich roof panels- 1000 mm wide, 70 -110 mm depth. Facade elements - 600- 1200 mm, 40 to 200 mm depths. Both panels can be fabricated in lengths of up to 20 m.

iii) Lightweight Stell Sections
- Lightweight steel sections are produced of hot-dipped galvanised steel sheeting with thicknesses of 1 to 2.5 mm.
- The C, U and Z sections are available in lengths upto 12m.

iv) Steel Sheeting
- Steel sheeting is rolled in fabrication plants in widths of 2000 mm.
- Cold-rolled sheeting can be up to 100 mm thick, and hot-rolled sheeting up to 3 mm thick, prior to being further processed as trapezoidal or corrugated sectional sheeting.
- The stability of non-sectional sheeting can be improved by adding engineered elements such as the forming of ridges or ribbing.

4.6 ADVANTAGES OF STEEL PREFAB CONSTRUCTION

VALUE FOR MONEY

- Short Construction timeline
- Earlier possession of the building for use or rent (30% to 60% faster).
- Lower financing costs
- Better site utilisation

COST SAVINGS THROUGHOUT THE WHOLE PROJECT

- Smaller footprint of the building.
- Steel construction maximizes floor area.
- Excellent strength to weight ratio lowers total foundation costs.
- Weather resistance can be controlled as required.
- Services can be easily integrated.

FLEXIBILITY

In Design
- Innovative rolled and prefabricated steel section shapes can offer attractive profiles for fabrication.
- Economic methods for manufacturing shapes and curves.
- Standardised techniques can be adapted for floor systems and connections.
- Offers opportunities to design large openings for doors and windows.

During Construction
- Integration of curtain walls and glass panel systems is easily possible to execute.
- Modular elements such as bathroom pods, kitchen pods, dry casing, MEP/ HVAC services can be efficiently connected to structure.
- Easy dismantling saves a lot of capital during on site changes in construction.

In Use
- Supports adaptive re-use or change in functions/ layout over time.
- Strengthening individual elements is very easy to maintain the life of building.
- New connections can be easily introduced in the structure.

SPEED

- Mass manufacturing of steel elements reduces not only the cost but also the speed of assembling modules offsite.
- High dimensional accuracy in less time.
- Quick foundation constructions.
- Assembling work is a lot faster as compared to other materials on/off site.

EASE OF REPAIR:

- In general, it is easier and quicker to repair steel structures if there are any damages.

4.7 CHALLENGES OF STEEL PREFAB CONSTRUCTION

ACCURATE PLANNING & SCHEDULING:

- Accurate planning with detailed scope and design details required before the start of the project
- If there are minor discrepancies in following schedule, the timeline of the whole project can be disturbed remarkably.

TRANSPORTATION CHALLENGES:

- A large number of transportation vehicles are required to deliver the prefab components or modules.
- Oversized components require complex transportation arrangements and may cause delay or added costs.
- Transportation limitations might disrupt the timeline and cost effectiveness of a project.

GENERAL COST:

- Steel structures can be costlier than concrete or timber structures.
- Offsite construction can only be more cost efficient than on-site construction if the quantities of prefab components and modules is large.

SKILLED WORKERS & ON-SITE HANDLING:

- Prefab construction demands machine-oriented expertise, both on-site and in the manufacturing units.
- Larger prefab components need heavy-duty cranes & machinery and also requires accuracy & precision of handling and positioning on site.

FIREPROOFING & MAINTENANCE OF STEEL:

- Strength of steel reduces drastically with the exposure of high heat so adeqaute fireproofing is required for a safe use of steel structure.
- Usage of weathering and corrosion resistant steel is required if the structure is to have extensive exposure to natural elements like saline air and water.

fig 3.8.1 Four Sided Module with Staggered end
Source - ED014, Light steel framing and modular construction series by R M Lawson

fig 3.8.2 Long Four-Sided Module with Integrated Corridor
Source - ED014, Light steel framing and modular construction series by R M Lawson

4.8 TYPOLOGIES & APPLICATION OF PREFABRICATED STEEL MODULES

FOUR SIDED MODULE

Four-sided modules are made with four closed sides to create cellular-like spaces and are designed to transfer loads through their longitudinal walls. Typically, the maximum height of buildings constructed in modular construction using four sides is six to ten floors, depending on their location and exposure to wind loading. However, you can achieve a taller building by combining the module with a concrete or steel core.

Modules are manufactured from a series of panels that are attached together, starting with the floor cassette. The four walls and the ceiling panel are then attached to the floor cassette. The vertical load-carrying walls of the upper module are designed to rest on the horizontal load-carrying walls of the module below.

Their external width is limited by the transportation requirements for shipping to approximately 4 m (3 to 3.6 m is the typical internal module width for most applications). The length of the light steel modules is usually 6 to 15 m. The walls are made of deep C sections of 65 to 100 mm.

Source - ED014, Light steel framing and modular construction series by R M Lawson

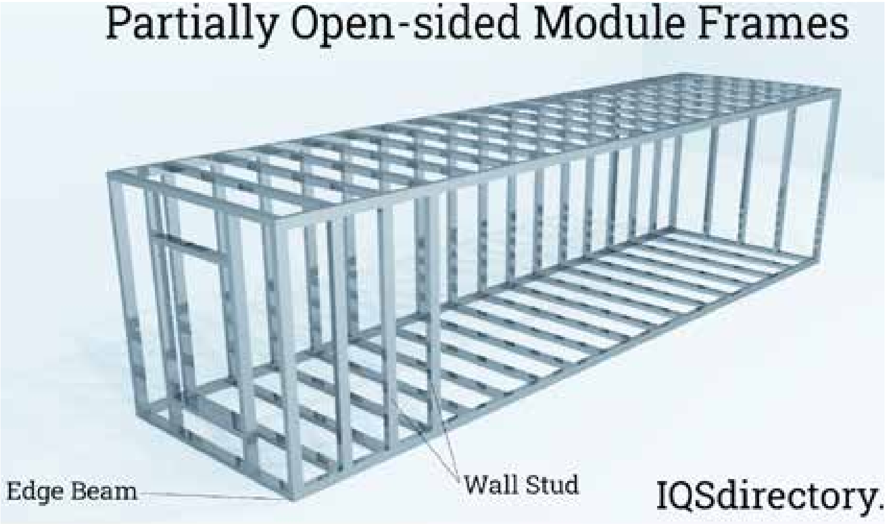


fig 3.8.3 Partially Open Sided Module Frames
Source - Prefabricated Buildings by Industrial Quick Search

PARTIALLY OPEN-SIDED MODULE

Modules can be planned with partially open sides by using of corner and intermediate posts and by using a stiff edge beam in the floor cassette. Additional intermediate posts are usually small, square hollow sections that fit within the wall. Two units can be put together to create a larger spaces.

The compression resistance of the corner or internal post is important in the structural design. Typically, six to ten floors can be achieved with modular construction, as for four-sided construction. A long module can also have an integrated corridor. This installation approach can help to avoid weather tightness issues during installation and finishing work.

The modules are similar to those with four sides, except that they use steel members that are either 70x70 or 100x100 in size as additional posts. The stability and transfer of horizontal forces is provided by additional bracing located in the walls of the modules.

Source - ED014, Light steel framing and modular construction series by R M Lawson

fig 3.8.4 Open-sided module

Source - Multi-storey Modular Cold-Formed Steel Building in Hong Kong: Challenges & Opportunities by Andy Prabowo

fig 3.8.5 Steel Open Sided Module

Source - Steel-Framed Modular Construction For High-Rise

OPEN-SIDED (CORNER SUPPORTED) MODULE

Modules can be designed to have open sides on one or both long sides, depending on how the loads are transferred to the corner posts. This is accomplished by bending the longitudinal edges of the beams. The framework of the module often uses square hollow sections (SHS) columns and parallel flange channel (PFC) edge bears that are bolted together.

Modules can be placed side-by-side to create larger open plan spaces, as required in hospitals and schools. The stability of a building usually depends on a separate bracing system in the separating walls. For this reason, fully open sided modules are not often used for buildings more than three floors high.

Open sided modules consist of a main steel frame with longitudinal edge beams supporting the floor beams. The edge beams are typically 300 to 450 mm deep, depending on the span, which is typically 5 to 8 m. Some systems use heavy cold formed profiles while others use hot rolled steel profiles such as PFC. The combined depth of the edge beams, ceiling and floor can be 600 to 800 mm The open-sided modules provide design flexibility. Their width is typically around 3 to 3.6 meters, and rooms of 6 to 12 meter width can be created by combining modules.

The corner posts provide compression resistance and are usually 70x70 to 100 × 100 SHS. The edge beams may be connected to these posts by fin plates, which provide a nominal bending resistance. The corner posts are resistant to compression, suitable for use in buildings up to 10 stories high.

Source - ED014, Light steel framing and modular construction series by R M Lawson

fig 3.8.6 Installation of modules behind external steel framework at MoHo Manchester
Source - ED014, Light steel framing and modular construction series by R M Lawson

MODULES SUPPORTED BY A PRIMARY STRUCTURE

Modular units may be designed to be supported by a primary structure at a podium level. This allows for a more consistent appearance and reduces the need for additional support features. The supporting columns are spaced at a multiple of the width of the modules (normally 6 to 8 meters). The beams are designed to support the combined weight of the modules above. The steel framework provides open plan space at ground floor and below ground levels.

An external steel structure may be used to stabilise a building, as well. The modules are placed internally within the braced steel "exo-skeleton". This construction style is suitable for mixed-use developments, such as commercial and residential areas. Modules can be positioned away from the façade line. A mixed development with commercial space on the ground floor.

Modules can be designed to be supported by either steel or composite beams. Columns generally align with other columns in between every two or three modules. The depth of the podium type structure is typically 800 to 1000 mm, and spans of 10 to 18 m can be created below the podium.

Source - ED014, Light steel framing and modular construction series by R M Lawson

BATHROOM PODS

A bathroom pod is a factory-built restroom unit that is manufactured and delivered with pre-installed mechanical, electrical, plumbing, and HVAC. These are most commonly adapted in hotels, multi-family apartment buildings, senior housing, and student housing projects.

Advantages

- 80 % reduction of defects.
- Same cost, higher quality, very less time.
- High skilled work, more sustainable.
- Easy repair, replace, maintain.

Process

The integeration of bathroom pods require a high level of coordination with onsite works to ensure that the works are carried out in correct sequence and in parallel.
- With the final design specs, the machine files are delivered to create the metal framing which is ready to use.
- These prefab steel frames are assembled.
- The pods are then fitted with the internal drywall, tiling, and waterproof lining in controlled environments.
- The walls are joined with floor and ceiling to complete the room structure.
- All the joints between walls, floor and ceilings are sealed.
- The bathroom fixtures and fittings like cabinets, toilets, sinks, lights, mirrors, etc are installed.
- MEP services are installed.
- Quality checks are carried out following which they are packed ready to transport.
- The pods are placed on site using cranes and are connected to power and water services similar to plugging in a major appliance.

https://www.wallsupusa.com/products/pods/bathroom-pods/
https://bmarkostructures.com/bathroom-pods/

https://www.bathsystem.com/en/products/prefabricated-kitchen-pods/
https://bmarkostructures.com/kitchen-pods/

KITCHEN PODS

A kitchen pod is a factory-made kitchen unit that comes pre-installed with mechanical, electrical, plumbing (MEP) systems, kitchen appliances, and elements.

Once it is made in the factory, it is plastic wrapped, placed on a flatbed trailer, and shipped to the final construction site. Once on site, the pod needs to be placed inside its final unit and simply connect the MEP system from the prefab kitchen pod into the main connections from the building.

Prefabricated kitchen pods provide significant advantages when matched up to traditional kitchen construction. A prefab kitchenette pod incorporates roughly 10 trades into one prefabricated end-product. Once installed, you build around the kitchen pod, speeding up your build, and saving valuable resources, and of course money.

5. Case Studies and Analysis

PROJECTS

5.1 Modular Schools - Zurich
5.2 Place Ladywell - Coliving & Coworking spaces - London
5.3 6 Orsman Workspace - London
5.4 Citizen M Tower - Affordable Luxury Hotel - London
5.5 Urban Village Project

STRUCTURE OF STUDY

- Project Image
- Site Context and Introduction
- Project Statistics
- Architectural Drawings
- Use of Spaces
- Assembly Detail & Material Specifications
- Construction Images
- Detail Observation
- Construction Process

5.1 MODULAR SCHOOLS IN ZURICH

fig 5.1.1 Typical Front Facade of a Modular School in Zurich. Source - Atlas of Places

SITE CONTEXT & INTRODUCTION

INTRODUCTION :

Blumer Lehmann has been building temporary school buildings in timber modular construction for the City of Zurich for 20 years. In Zurich, our pavilions are generally used for 10-15 years on the same site before being redeployed at another location.

More than 1,000 modules have been deployed at around 60 sites in the metropolitan area of Zurich with a further planning of extending the number until 2025.

LOCATION : Zurich, Switzerland.

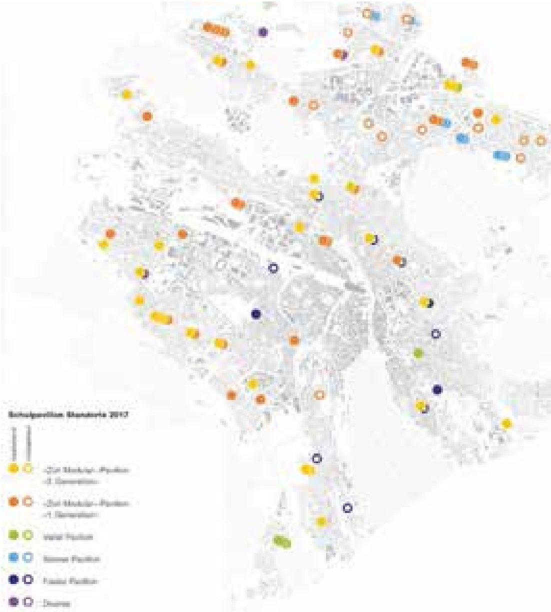


fig 5.1.2 Modular school delivered to more than 60 locations around Zurich

fig 5.1.3 Understanding the immediate site context.

Source - Blummer Lehmann Group

PROJECT DATA

Architects: Bauart Architekten
Use: Public School
Construction: Timber
Construction Company: Blumer Lehmann AG, Gossau
System: Sectional Volumetric Profiles
Completion:
1st generation (1998-2011) 29 pavilions + 5 extensions
2nd generation (from 2012) 28 pavilions

MODULES

30 3 Modules/ Classroom
Modules

27
Unit area (m^2)

3m x 9m
Module Size

10
Modules per floor

CONSTRUCTION DATA

03
Stories

270 Per Floor
Typical Floor Area (m^2)

18 6 days/ floor
Days for Construction in Factory

30 complete fittings in 4 weeks
Days to Assemble on site

Yes
Flexible/ Movable Interior Partitions

Medium
Degree of Prefabrication

ARCHITECTURAL DRAWINGS

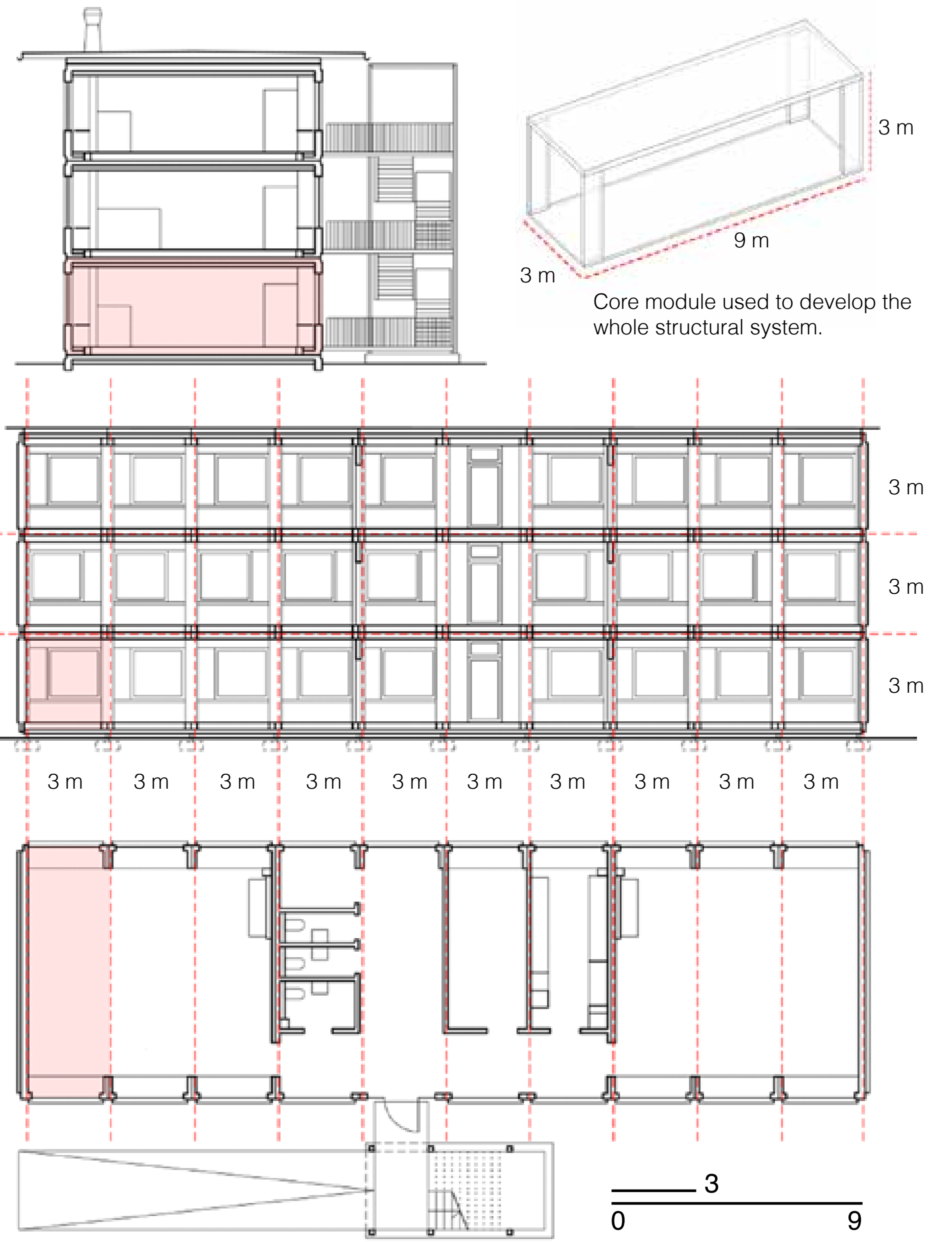


fig 5.1.4 Project drawings to explain the spatial organisation.

Source - BAUART - Zurich Modular (bauart.ch/news/zueri-modular-en-us/)

The Zuri-Modular system offering temporary spaces for schools, nursery schools and day-care centres was created in 2012 with increased area requirements and energy standards.

Each floor provides two classrooms of 68 m^2 each, one group meeting room of 33 m^2, toilet and restrooms of 10 m^2 and a technical room with an area of 5 m^2.

Core structure of design consists of two classrooms per floor which are connected via cloakroom, toilets and group room.

Lit from both sides which makes the modular approach independent of local conditions.

Load bearing walls have timber frame structure cladded with plasterboard.

Ceilings have perforated accoustic panels. With double box ceiling, floating screed is not required. Hence, only floor consisting of classrooms was applied on site.

High degree of prefabrication increases reusability. The building can be easily dismantled and moved.

Text in chapter 5.1 retrieved from
Staib, Gerald, Dörrhöfer, A. & Rosenthal, Markus. Components and Systems: Modular Construction - Design, Structure, New Technologies. München: Birkhäuser, 2013. p.58-59

USE OF SPACES

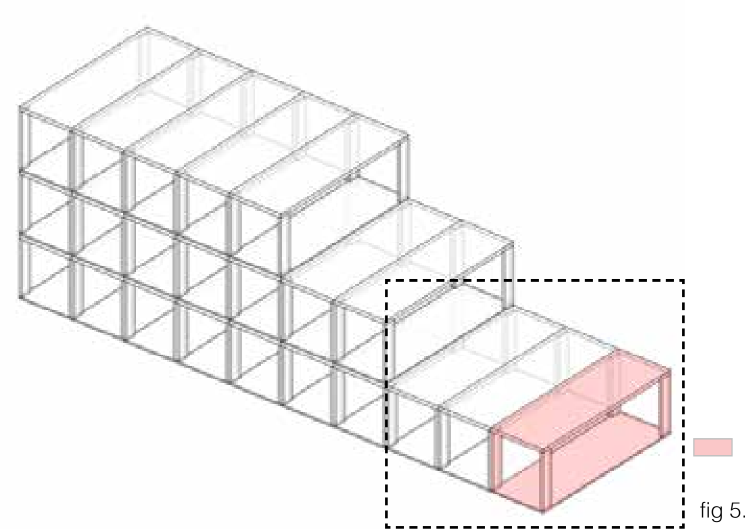


fig 5.1.5 Module Configuration

The configuration of stacked modules.
3 Modules comprise of 1 class room module on each side with the central 3 used for a kitchenette and restroom amenities.

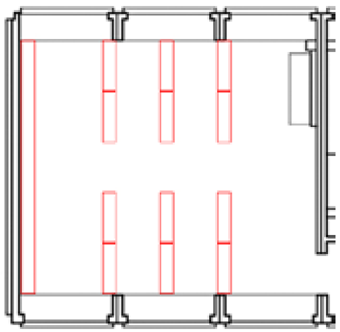


fig 5.1.6 Conventional Classroom

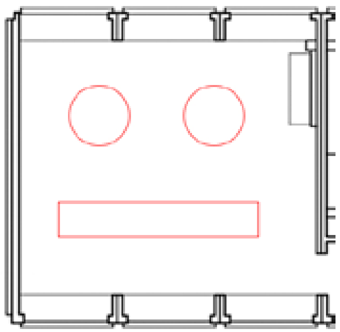


fig 5.1.7 Art Classroom

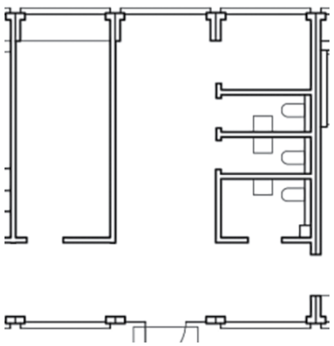


fig 5.1.8 Service Areas

The Floor plan is devised with prefabricated cross-sections of room cell offering maximum flexible furniture layout solutions. Partitions can be attached/removed during the lifecycle. This creates great opportunities to adapt the same built environment into various co-working/ learning facilities.

fig 5.1.9 Open floor plan allows multiple classroom configurations.

fig 5.1.10/11 The interior spaces are well lit with natural sunlight from both the sides.

Source - Blummer Lehmann Group

ASSEMBLY DETAIL

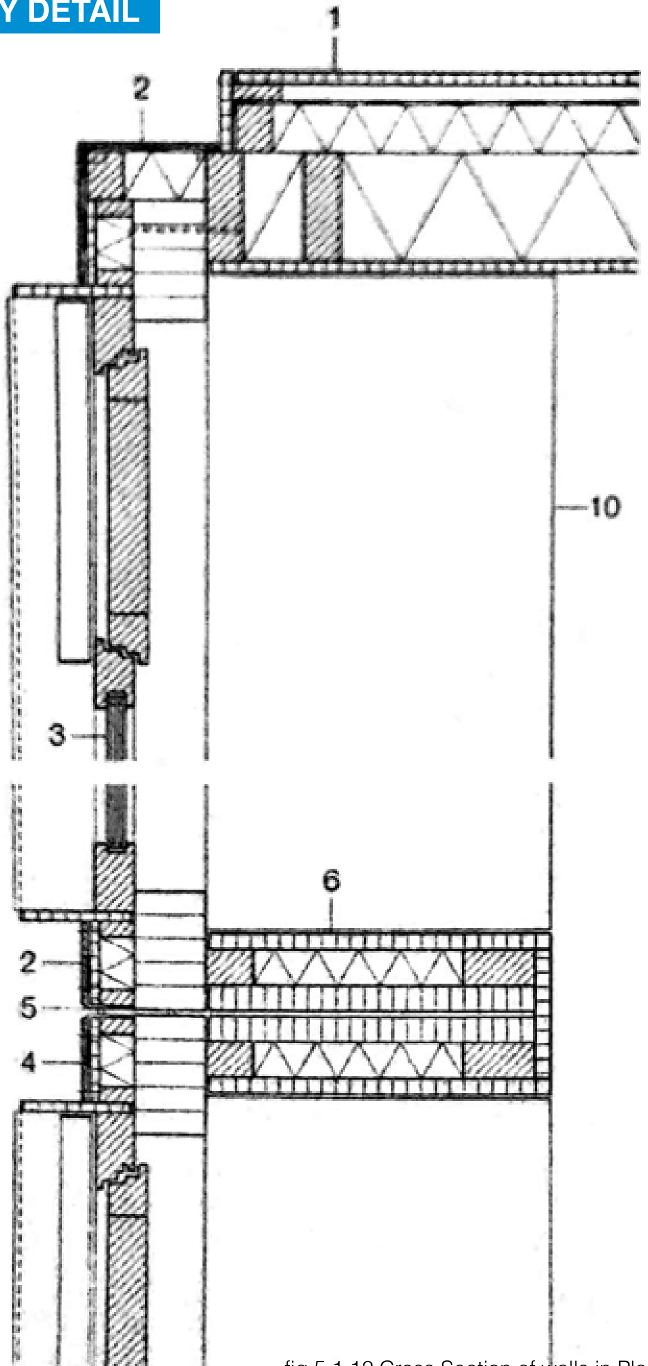


fig 5.1.12 Cross Section of walls in Plan

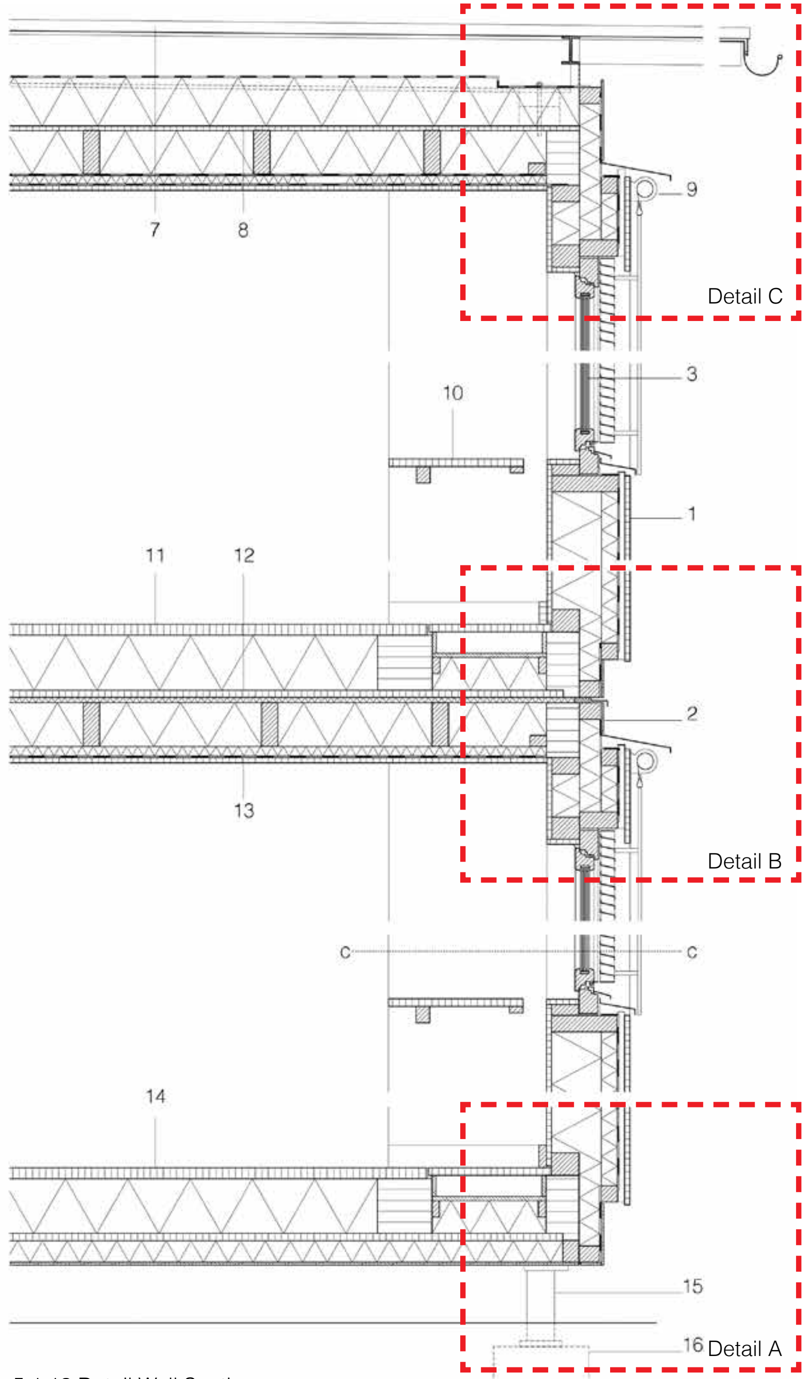


fig 5.1.13 Detail Wall Section

ASSEMBLY DETAIL AND MATERIAL SPECIFICATIONS

1 Modular wall structure, timber-frame construction:
Three-layer slab, larch, untreated, 19 mm
Battens, 30/70 mm, rear ventilation
Windproof membrane
Solid construction timber, 60/80,
thermal insulation in between
Solid construction timber, 60/180,
thermal insulation in between with vapour barrier
Three-layer slab, spruce, varnished, 19 mm

2 Facade panel, mineral wool, pressed, 8 mm

3 Wooden window with insulating glazing

4 Wood fibreboard, 16 mm

5 EPDM profile

6 Acoustic three-layer slab, spruce,
varnished, 16 mm
Solid construction timber, 60 mm,
thermal insulation in between,
sheep's wool Three-layer slab, 42 mm
Module joint Three-layer slab, 42 mm
Solid construction timber, 60 mm, s
heep's wool in between Acoustic three-layer slab,
spruce, varnished, 16 mm

7 Roof structure:
Trapezoidal sheet, 1.5 mm
Substructure, steel profiles,
rear ventilation, 80-400 mm
Windproof membrane
Thermal insulation, mineral wool, 180 mm

Source - Huß, Wolfgang, Kaufmann, Matthias and Merz, Konrad. Building in Timber - Room Modules, München: DETAIL, 2019. pp. 97-99.

8 Modular ceiling, timber-frame construction:
Wood fibreboard, 16 mm
Edge beam, glued-laminated timber,
200/200 mm, tier of beams of solid construction timber, 60/160 mm, in between, with thermal insulation,
mineral wool, 160 mm
Film Slatted frame, 40 mm, thermal insulation in between, sheep's wool
Acoustic fleece
Three-layer slab, spruce, 19 mm, with acoustic perforation

9 Sun protection blind, textile

10 Windowsill, three-layer slab, painted, 27 mm

11 Floor structure of upper floor:
Linoleum, 2.5 mm
Timber-frame construction element:
Three-layer slab, spruce, 40 mm
Beam, glued-laminated timber, 200 mm,
thermal insulation in between, mineral wool,
Three-layer slab, spruce, 27 mm

12 Compressed tape, 20 mm

13 Modular ceiling, timber-frame construction:
Three-layer slab, spruce, 19 mm, with acoustic perforation
Acoustic fleece
Battens, 40/60 mm, thermal insulation in between, sheep's wool Edge beam, glued-laminated timber, 200 mm

14 Floor structure of ground floor
(Module/Substructure) Linoleum, 2.5 mm
Three-layer slab, spruce, 40 mm
Beam, glued-laminated timber, 200 mm,
thermal insulation in between, mineral wool Cement-bonded chipboard, 12 mm

15 Support, column, steel profile, 200 mm

16 Individual foundation, reinforced concrete

CONSTRUCTION IMAGES

fig 5.1.14 Placing Units on foundation

fig 5.1.15 Aligning the module to be placed

fig fig 5.1.16 Aligning the module to be placed

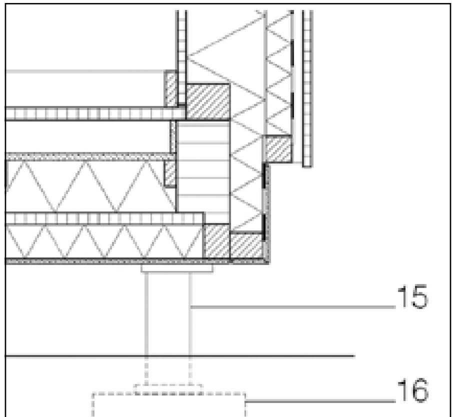
fig 5.1.17 Aligning the module to be placed

The pictures explain the methodology adapted to assemble the prefab modules (with windows/ fixtures) on site.

Source - Blummer Lehmann Group

DETAIL OBSERVATIONS

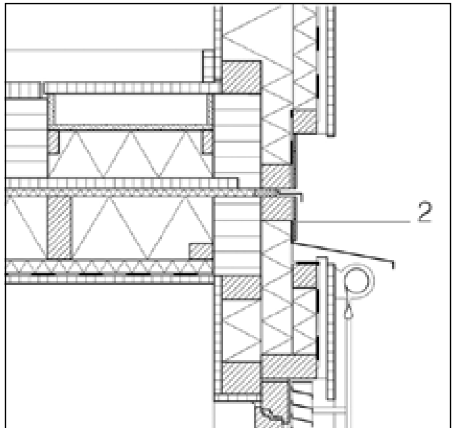
Elevated Foundation prevents the direct contact of timber with humidity of ground. As the module is not cast-in concrete foundation, the joinery is easy to dismantle and move the modules when needed.



Detail A

fig 5.1.18 Aligning the module to be placed

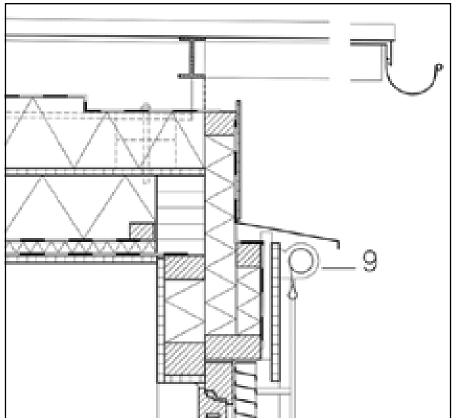
The recessed profile of structure highlights the use of modular approach.
The modules are stacked on site using a crane as shown in fig



Detail B

fig 5.1.19 Aligning the module to be placed

The service pipelines are integerated with the structural and facade aesthetics.
This makes the installation and maintenance of services very easy and efficient during the entire life cycle of project.



Detail C

fig 5.1.20 Exposed Services

fig 5.1.21 Exposed Services

5.2 PLACE LADYWELL CO LIVING / WORKING, LONDON

fig 5.2.1 Place Ladywell Co-living/ Co-working space, London

Source - Place Ladywell (https://www.placeladywell.co.uk/)

SITE CONTEXT & INTRODUCTION

INTRODUCTION :

Rogers Stirk Harbour + Partners' partnership with Lewisham Council to make a deployable residential development employing a volumetric construction method on the location of the previous Ladywell Leisure Centre, which was demolished in 2014, responds to the high demand for housing within the Borough by offering a brief term solution. The finished structure is additionally fully demountable meaning it may be used over variety of years and in several locations across the borough.

LOCATION : London, England.

261 Lewisham High St, London SE13 6AY, United Kingdom

fig 5.2.2 Understanding the immediate site context.

Source - Roger Strik Harbour + Partners

PROJECT DATA

Architects: Rogers Stirk Harbour + Partners
Use: Co living - Co working space
Construction: Timber
Construction Company: SIG Build
System: Room Cell
Cost : £4,980,000 (£1200/m²)
Completion: 2016

MODULES

64 **Modules**	Small unit - 27 Big unit - 47.25 **Unit area (m²)**
4.5m x 6m 4.5m x 10.5m **Module Size**	16 **Modules per floor**

CONSTRUCTION DATA

03 **Stories**	Residential- 700 Commercial- 940 **Typical Floor Area (m²)**
06 **Months for Construction in Factory**	30 16 units / week **Days to Assemble on site**
Partial **Flexible/ Movable Interior Partitions**	High **Degree of Prefabrication**

ARCHITECTURAL DRAWINGS

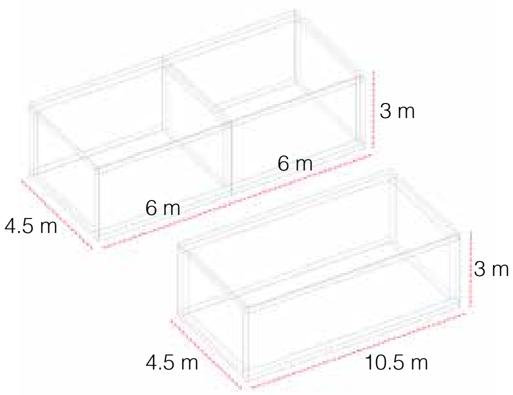


fig 5.2.3 Dimensions of Modules

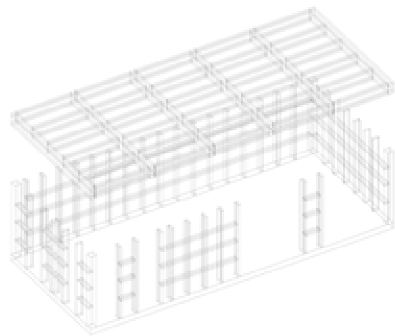


fig 5.2.4 Structural system of typical modules

fig 5.2.5 Project Drawings

Typical Residential Floor Plan

6

0 18

Place Ladywell was designed as a Co-working and Co-living space for the community that consisted of 24 flats for locals and 8 non residential units on the ground floor for local start ups and creatives and a community cafeteria.

Using a ground breaking construction method, the project was built very quickly in just over 6 months with very less expenses than using traditional methods. All units have a superior 10 percent edge over the current space standards.

The project is designed for a vision with use at Lewisham for 4 years after which it shall be deconstructed, moved and reconstructed to a new site. But with an overwhelming response from community, the spaces have now transformed into co-working hubs and have become an integral part of the fabric.

The SIG Build manufactured the modules using a volumetric concept which provided high quality, energy efficiency and in a very short time compared to traditional methods.

The units are manufactured using a timber frame construction and installed with complete fittings in bathroom, kitchen, flooring and all finishes at the factory. Improved quality control, speedy construction and minimal waste and nuissance on site were the key elements achieved.

Text and Plan Drawings in chapter 5.2 retrieved from - Roger Strik Harbour + Partners

USE OF SPACES

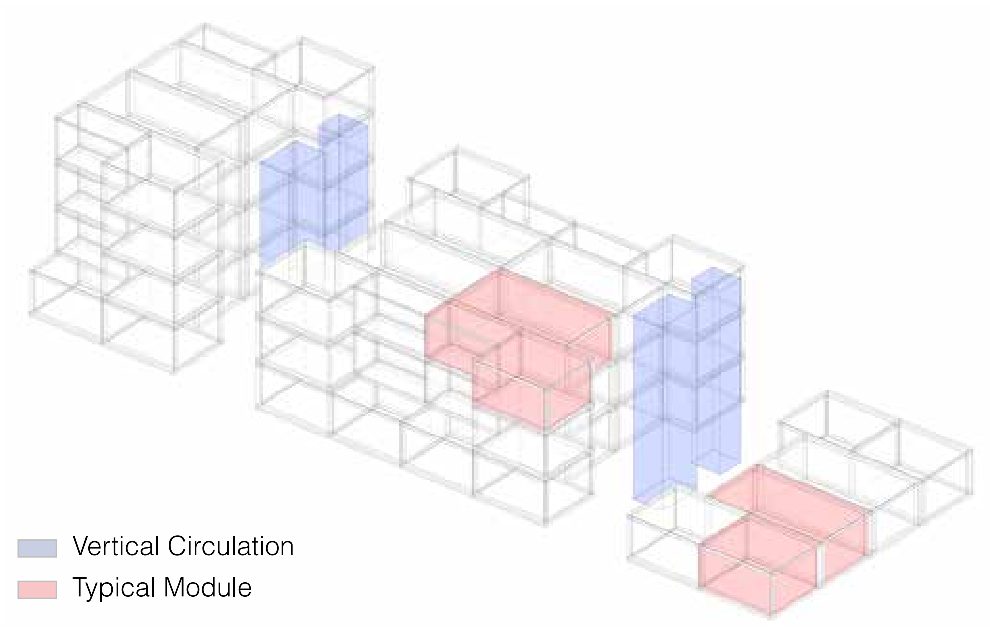


fig 5.2.6 The configuration of stacked modules.

fig 5.2.7 Co-Living use

fig 5.2.8 Co-working use

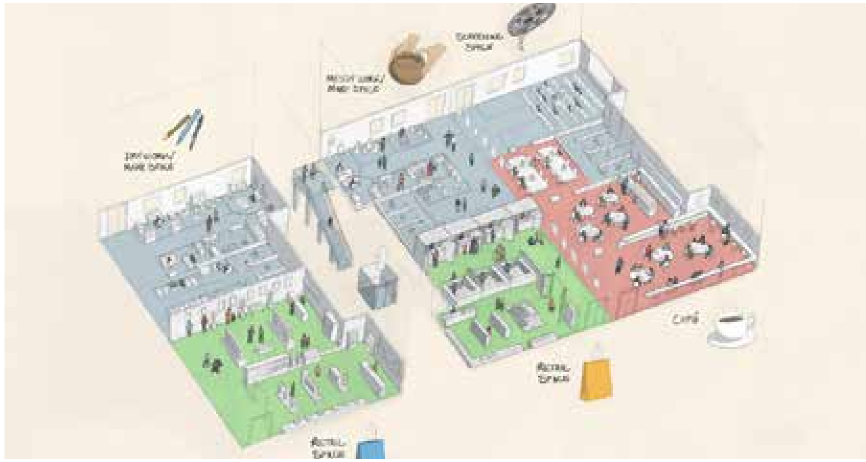


fig 5.2.9 Ground Floor with Co-working, Commercial facilities

fig 5.2.10 Interior of modules with flexibility to adapt to new functions.

fig 5.2.9 source: Blogsport-Brockley Central

fig 5.2.10 Interior images source: Studio Tilt - Place Ladywell

CONSTRUCTION IMAGES

fig 5.2.11 Transport to site

fig 5.2.12 Transport to site

fig 5.2.13 Lifting the module to place on precise location

fig 5.2.14 Transport to site

The pictures explain the methodology adapted to assemble the prefab modules (with windows/ fixtures) on site.

fig 5.2.11-12 source - Roger Strik Harbour + Partners

fig 5.2.13-14 source oucre - Trust for London

DETAIL OBSERVATIONS

Timber frames placed at regular intervals for walls and floor are packed with insulation and cladded with different interior and exterior panels.

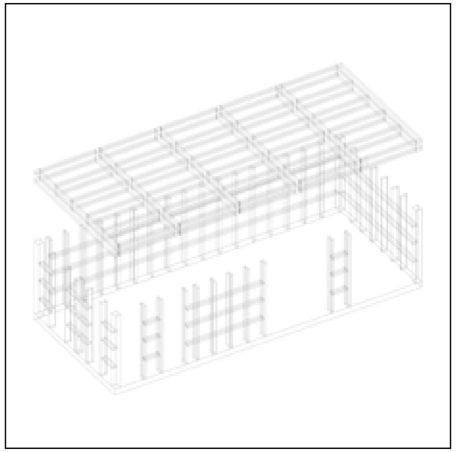


fig 5.2.15 Frame Construction

The service cores including staircase and lifts are constructed on site using precast ready to place concrete blocks.
The concrete blocks are prefit with a possibility to dismantle after use.

fig 5.2.16 Prefab RCC Circulation Core

The part that overlaps between the modules is observed to be exposed.
The floor plan has a double wall at the overlapping junctions between modules.

fig 5.2.17 Connection between modules


fig 5.2.18 SIG Build Factory


fig 5.2.19 Preparing the timber frames for walls


fig 5.2.20 Timber frame slabs assembled and lifted


fig 5.2.21 Adding insulation and fittings to the module


fig 5.2.22 Interior panelling and cabels put in place


fig 5.2.23 Modules packed with waterproof membrane


fig 5.2.24 Complete assembled modules


fig 5.2.25 Module lifted with crane


fig 5.2.26 Packed module ready for transport

fig 5.2.27 Precast Concrete blocks stacked for stairwells

fig 5.2.28 Panelling to be added in corridor spaces

fig 5.2.29 Modules assembled to location with crane

fig 5.2.30 New modules ready on site to be assembled

fig 5.2.31 Exterior facade cladding and sealing junctions

fig 5.2.32 Assembled blocks ready for facade treatment

fig 5.2.33 Picture to show phase nearing completion

CONSTRUCTION PROCESS

Understanding the whole process from step 1 at the factory to the ultimate assembly and finishing on site, this project has helped us realise how modular approach to visualising the future can play a vital role in engaging with the needs of the community. The project being designed particularly for the community also opens up the possibilities of multiplying and deploying similar models of development at other available sites in the country and also the whole world.

Source - Roger Strik Harbour + Partners

5.3 6 ORSMAN ROAD WORKSPACE, LONDON

fig 5.3.1 Front and rear Facade of 6 Orsman Workspace in London

Source: Waugh Thistleton Architects

SITE CONTEXT & INTRODUCTION

INTRODUCTION :

The sustainably centered edifice includes 34,000 sq. ft. across 5 floors and has been designed to strengthen productivity. The building champions the utilization of property materials associate degreed has been designed exploitation an innovative hybrid structure that mixes cross-laminated timber (CLT) and steel, meaning that the whole building will ultimately be demounted and repurposed.

LOCATION : London, England.

6 Orsman Rd, London N1 5RA, United Kingdom

fig 5.3.2 Understanding the immediate site context.

Source: Waugh Thistleton Architects

PROJECT DATA

Architects: Waugh Thistleton Architects
Use: Office Building
Construction: Hybrid - Steel + Timber
System: Steel Columns and Beams with CLT Slabs
Total built area: 3158 sqm
Period of construction: 13 weeks

MODULES

-	Typical Small grid - 18 Big grid - 27
Modules	**Grid Module area (m²)**
3m x 6m 3m x 9m	23
Structural Grid Size	**Modules per floor**

CONSTRUCTION DATA

05	630
Stories	**Typical Floor Area (m²)**
-	91 10-14 days / floor
Months for Construction in Factory	**Days to Assemble on site**
Yes	Low
Flexible/ Movable Interior Partitions	**Degree of Prefabrication**

ARCHITECTURAL DRAWINGS

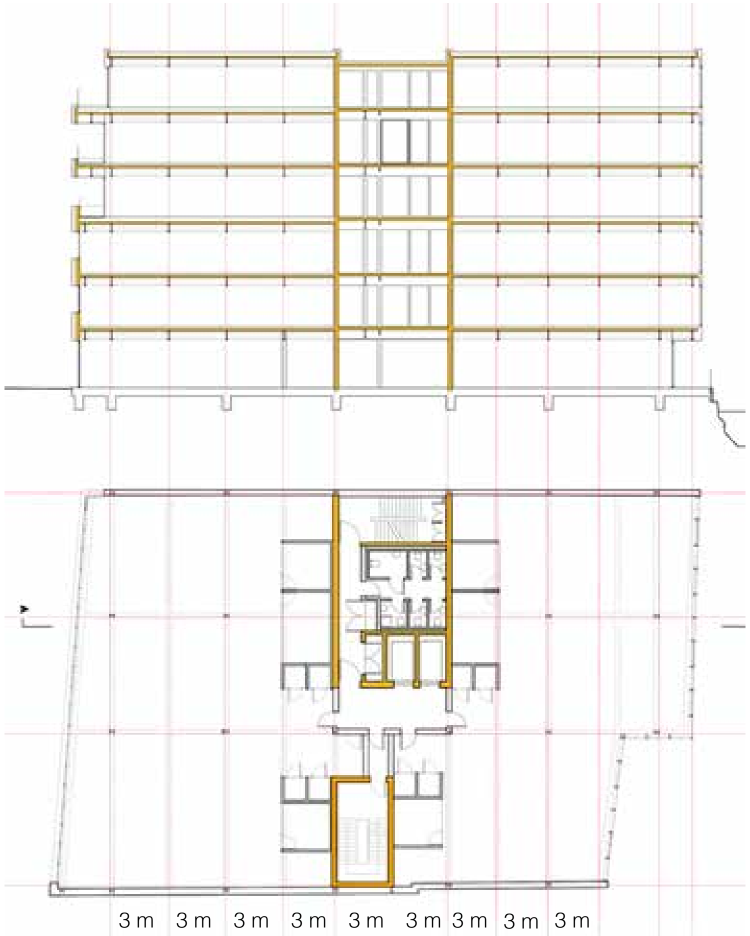


fig 5.3.3 Typical Floor Plan and Section to explain the volumes of workspaces in the project.

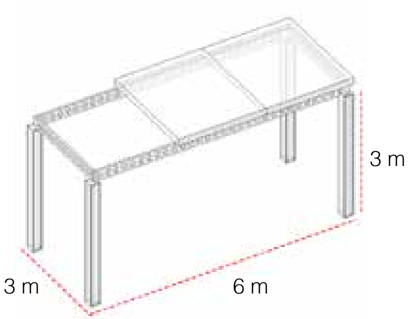


fig 5.3.4 Standard frame grid module

Storey is British Land's resolution to versatile non-public workspace; versatile in terms of lease length, size of the workplace, layout, and design, and a group of encompassing services. Orsman Road has been designed to cater for businesses with 20+ workers that gives a unambiguously property and re-configurable workplace model, enabling workspaces to easily adapt to ever-changing workplace needs.

CLT is additionally exposed internally at 6 Orsman Road, minimising the number of finishes used on the structure, and thus the offcuts from the building are repurposed to make piece of furniture at intervals the shared areas of the building.

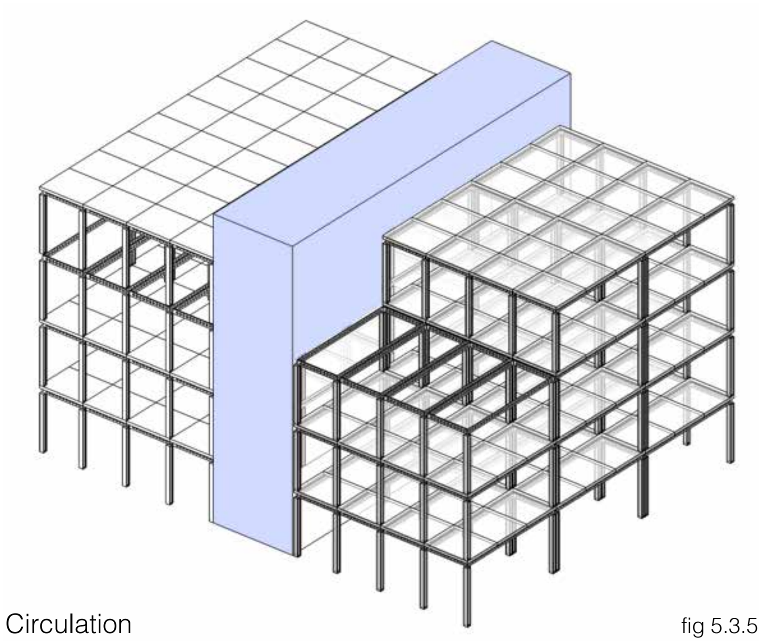
Designed to strengthen productivity and welfare. Everything at six Orsman Road, from the exposed timber to the bank setting, has been designed to make customers feel calm, focused, and impressed.

The timber surfaces and panels among the building have a special acoustic profit, riveting sound then rising comfort. Different areas among the building are created for noisier and lots of cooperative work, just like the lounge and also the restaurant , guaranteeing activities at completely different noise levels happen in several areas.

Studies by the planet Health Organisation have found that the employment of biophilic design can increase office productivity by 8% and wellbeing by 13%, and firms with timber interiors report higher staff retention, and fewer employee sick days.

Fig 5.3.3 and Text retrieved from - Source - Archdaily 6 Orsman Workspace

USE OF SPACES



Vertical Circulation

fig 5.3.5

Arrangement of Hybrid structural system with a Vertical Circulation Load bearing Core at the centre.

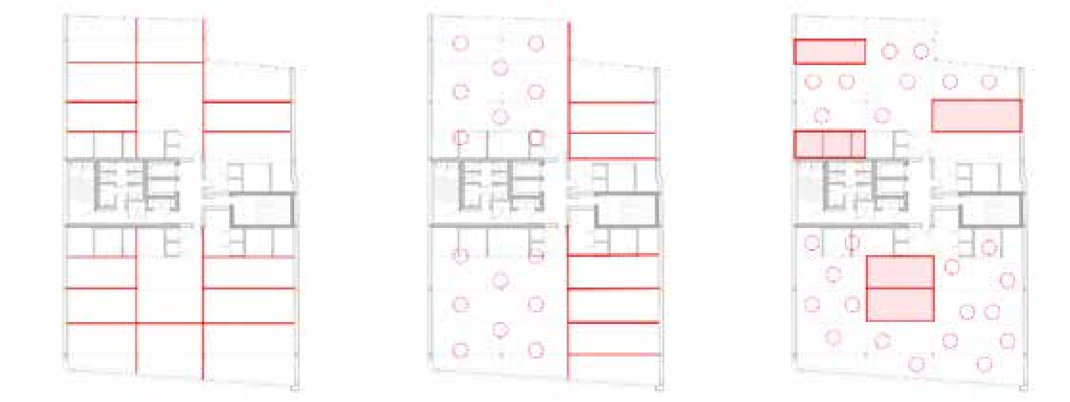


fig 5.3.6 Multiple arrangements for workspaces on an open floor plan.

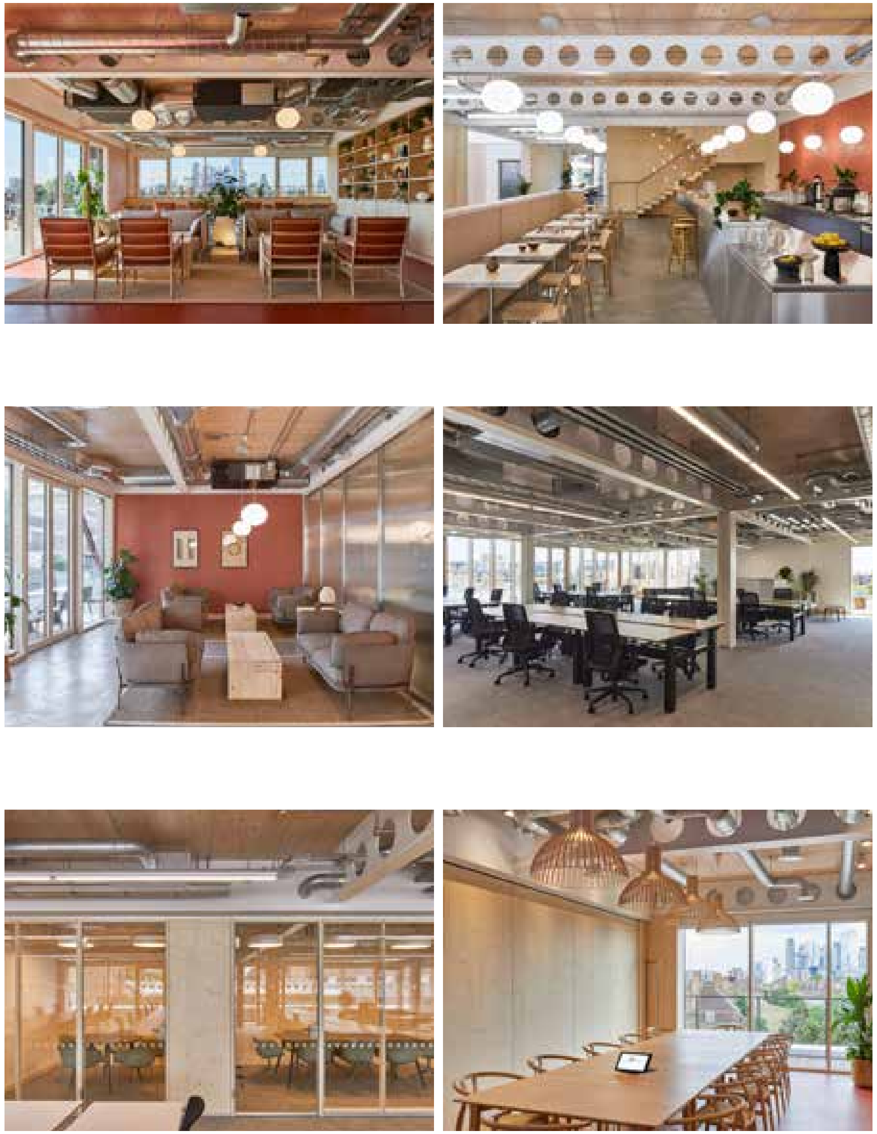


fig 5.3.7 Possible variations to offer utility for more functions.

Fig 5.3.7 Interior Images - Source - Archdaily 6 Orsman Workspace

ASSEMBLY DETAIL

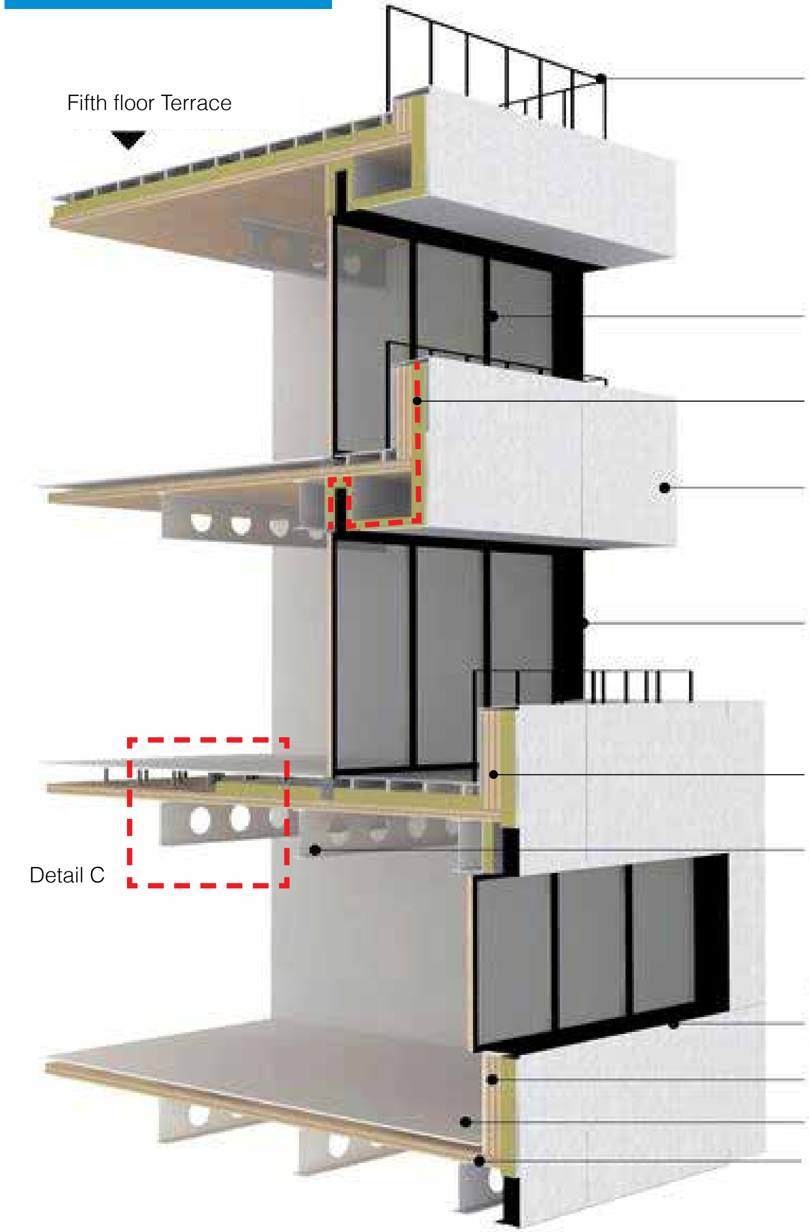
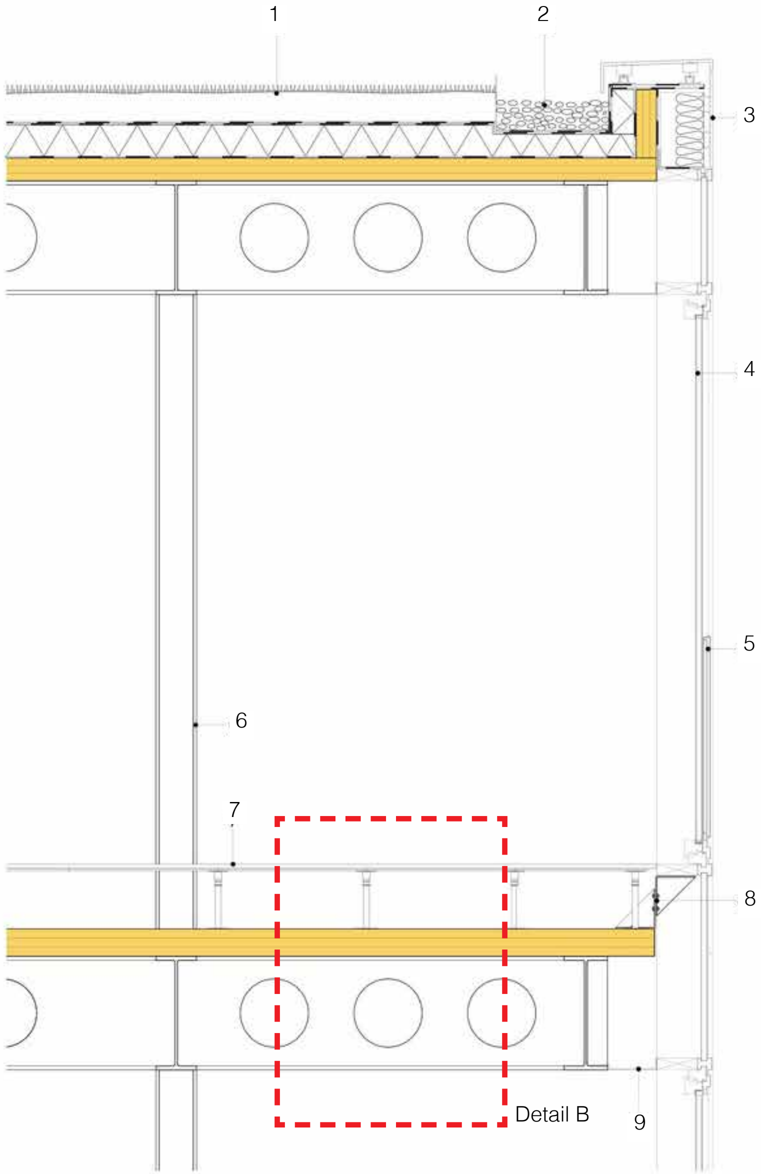


fig 5.3.8 3D Part Section Highlighting Assembly and Connections
Source: Waugh Thistleton Architects



- Raised Floor system and Circular cut outs in beams help flexible arrangement of services over life cycle.
- Flooring system can be changed over years without damaging the structural elements.

fig 5.3.9 Deatil Part Section
Fig 5.3.9/10 - Source - Archdaily 6 Orsman Workspace

The superstructure consists of steel I-section columns and cellular beams. The fixed service core and floor slabs are made up of prefabricated exposed CLT panels. Clay plaster and linoleum have been applied in some areas. The simple finishes complement the CLT structure repurposed as furniture.

ASSEMBLY DETAIL AND MATERIAL SPECIFICATIONS

1. Vegetation blanket with 14 different species of wildflowers
100 mm intensive biodiverse substrate
Waterproofing membranes
140mm PIR insulation board
Vapour control Layer
100mm 3ply Cross Laminated Timber (CLT) slab
Steel cellular beam

2. Pebbles

3. Fibre-C rainscreen cladding system

4. Composite curtain wall system

5. Framless glass balustrade

6. I Steel column

7. Raised access floor system
120 mm 3 ply CLT slab
Steel cellular system

8. Fixing bracket

9. White anodised aluminium plate

Source - Archdaily 6 Orsman Workspace

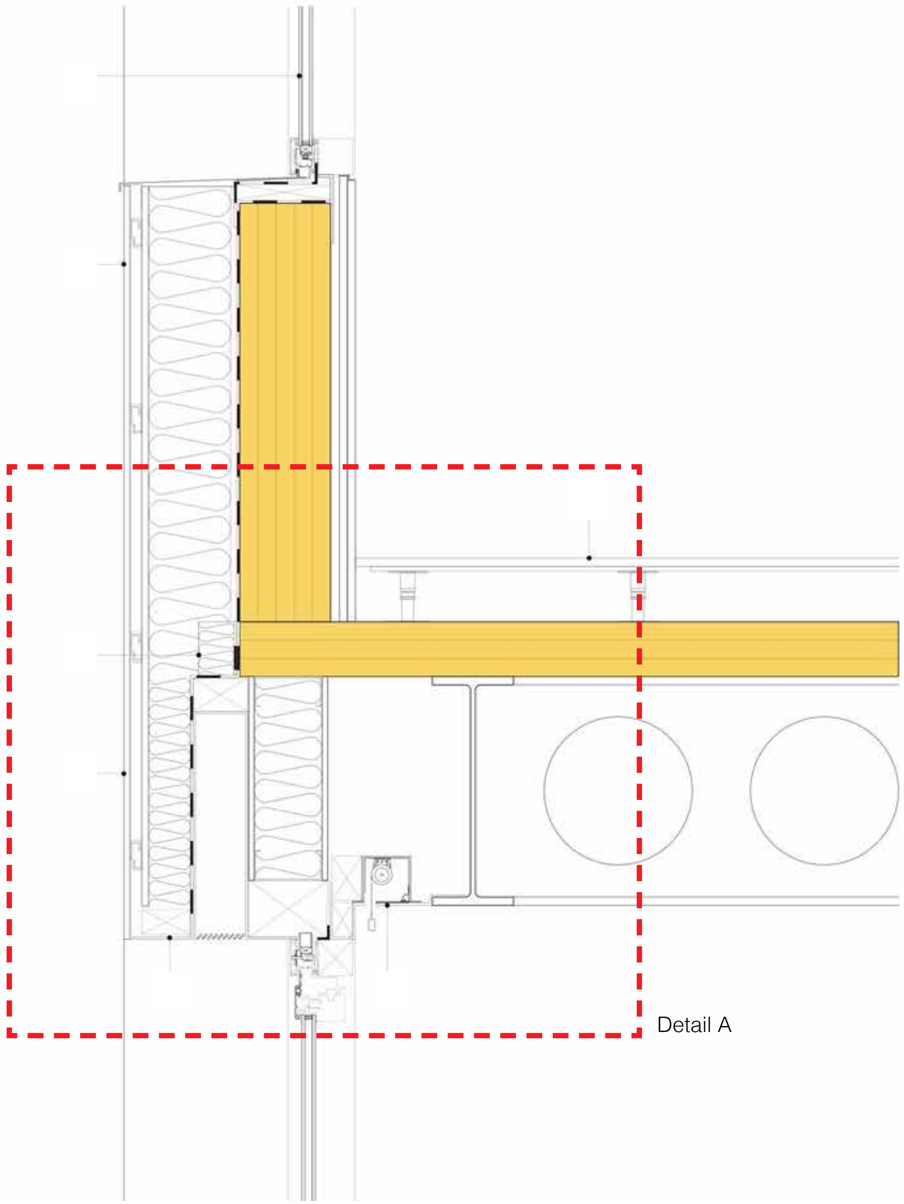


fig 5.3.10 Detail Section Wall-Slab Junction

CONSTRUCTION IMAGES

fig 5.3.11 Construction in progress

fig 5.3.11 Source - Flickr

fig 5.3.12 Source: Waugh Thistleton Architects

fig 5.3.12 Construction in progress

fig 5.3.13 Load Bearing CLT panels for Vertical circulation core

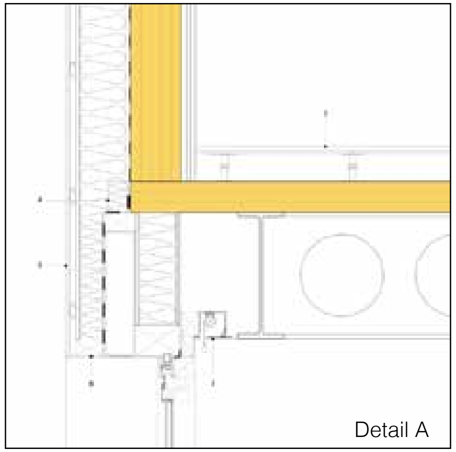
fig 5.3.11 Source - Engenuiti

fig 5.3.14 Interior Floor Space

The pictures explain the methodology adapted to assemble the prefab components into a frame structure on site.

DETAIL OBSERVATIONS

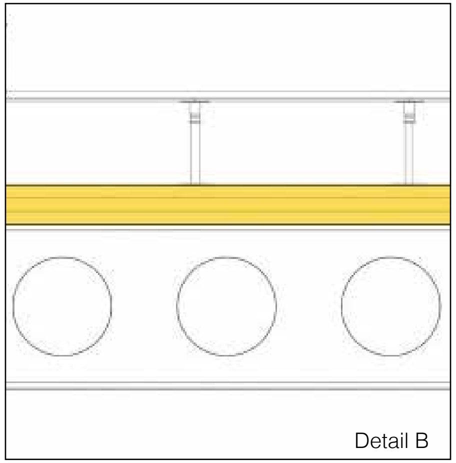
The structural elements are designed at an offset on the interior side to prevent thermal bridges and also optimize the efficiency of the water-proofing membrane.



Detail A

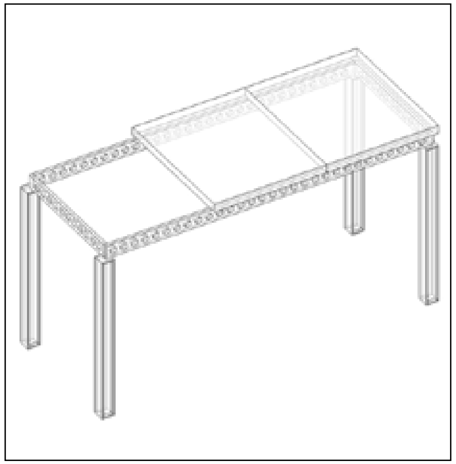
fig 5.3.15 Recessed Beam- Parapet/ Wall Detail

The steel beams are casted with circular cut-outs to reduce the selfweight and also provide flexibility to arrange service lines for multiple configurations in future.

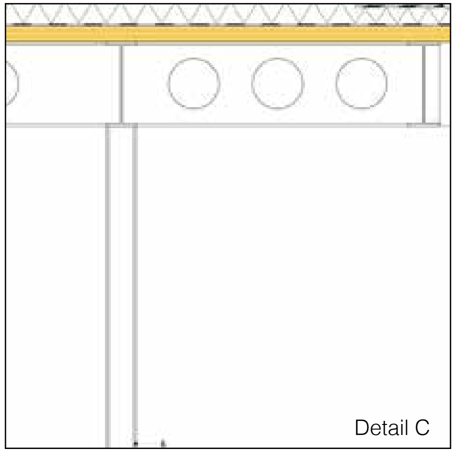


Detail B

fig 5.3.16 Exposed Service - Beam Detail



The vertical service cores are load bearing with 5-layer CLT panels and the usable floor area is designed for open floor plans with steel frame structure and CLT slabs.



Detail C

Source - Archdaily 6 Orsman Workspace

fig 5.3.17 Column-Beam Joint

fig 5.3.18 CLT Central Core

5.4 CITIZEN M AFFORDABLE LUXURY HOTEL, LONDON

fig 5.4.1 Citizen M Tower, London - Facade and site context

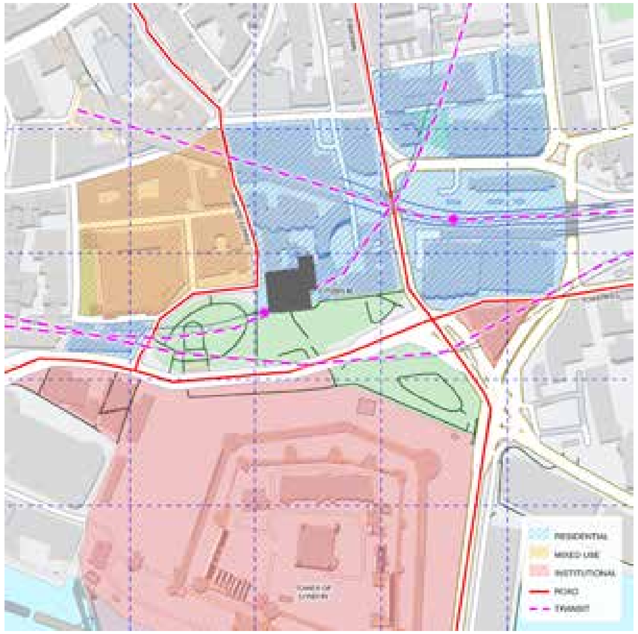
Source: Sheppard Robson Architects

SITE CONTEXT & INTRODUCTION

INTRODUCTION :

Citizen M at Tower Hill are going to offer mobile citizens of the globe affordable luxury within the heart of the town.
The concept of the hotel is to chop out all hidden costs and take away all unnecessary items, so as to produce its guests a luxury sorrow a budget price. The hotel exists of 370 rooms of 14 sq m, all prefabricated produced during a factory and straightforward to move. The planning is focussed on citizenM's belief that an excellent bed and an easy and clean bathroom is all we'd like during a city or business trip.

LOCATION : London, England.



20 Lavington St, London SE1 0NZ, United Kingdom

fig 5.4.2 Understanding the immediate site context.

fig 5.4.3 Citizen M Hotels around the world with modular room and prefab construction technology.

Information retrieved from Source - Archello

PROJECT DATA

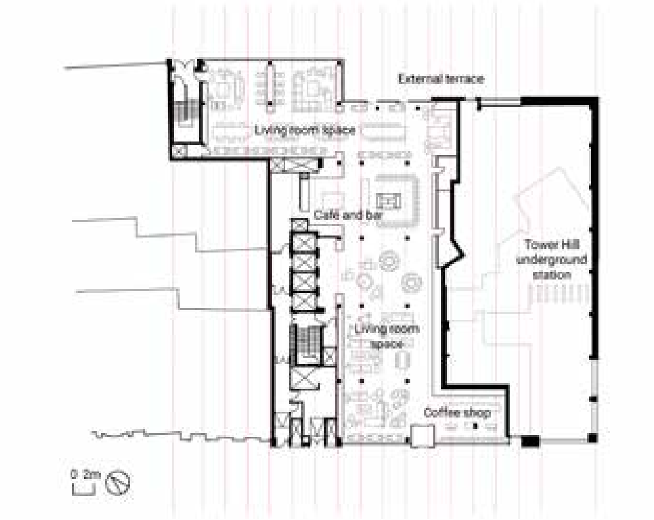
Architects: Sheppard Robson
Use: Hotel
Construction Primary Material: Steel
Construction Company: Ramboll UK Limited
System: Room Cell
Completion: 2016
Project manager: Turner & Townsend
Main contractor: Balfour Beatty

MODULES

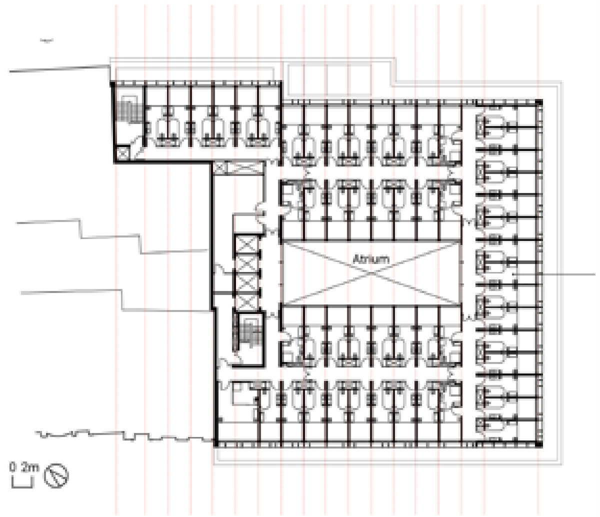
370 **Modules**	14 **Unit area (m^2)**
2.2m x 6.3m **Module Size**	55 **Modules per floor**

CONSTRUCTION DATA

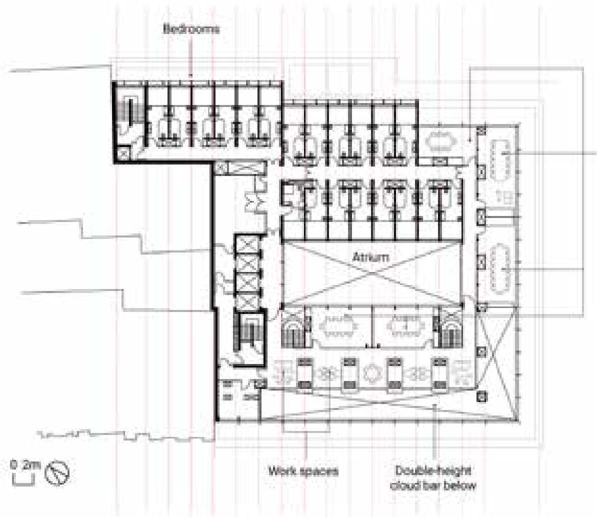
09 **Stories**	1200 **Typical Floor Area (m^2)**
- **Months for Construction in Factory**	100 8 units / night **Days to Assemble on site**
No **Flexible/ Movable Interior Partitions**	Very High **Degree of Prefabrication**



Ground Floor Plan



Typical Floor Plan



Eighth Floor Plan

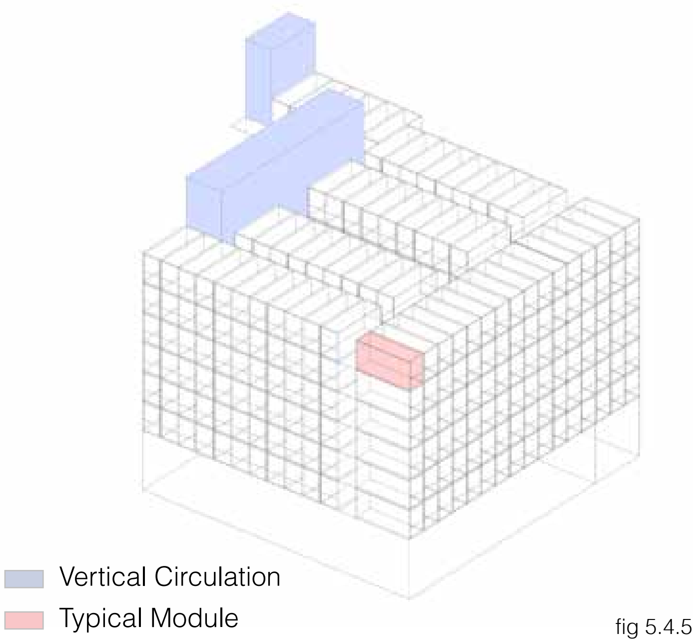


fig 5.4.5
The configuration of stacked modules with vertical circulation cores.

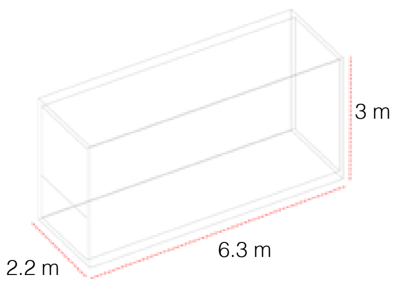


fig 5.4.6
Standardised Room Module

The facade of the building is characterized by the utilization of Portland Stone, a fabric that's in-keeping with the adjacent Trinity square. The frame is animated by vertical concrete fins that area unit intersected by horizontal Al projections, the lightness of that act as a counterpoint to the lustiness of the stone.

The integrative variety of the building includes a coherent relationship with the Georgian terraces adjacent, in this it's shaped of 4 horizontal parts: a definite base that grounds the building; a bigger middle and smaller higher section; and a recessed prime.

With interiors by Concrete, the bedrooms area unit organized around a central curtilage. This ready-made technique of construction means the bedrooms enjoy increased internal control, that has resulted in precise particularisation and wonderful internal finishes – a vital characteristic of high-quality building rooms.

Plan Drawings and Text retrieved from Source - Archello

USE OF SPACES

fig 5.4.7 Design Configuration

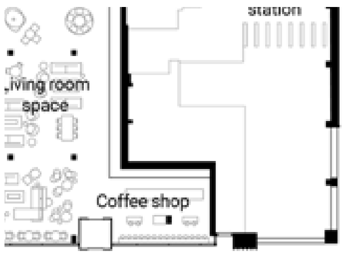
fig 5.4.8

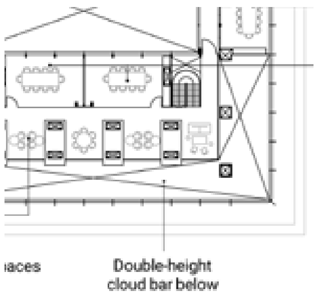
fig 5.4.9

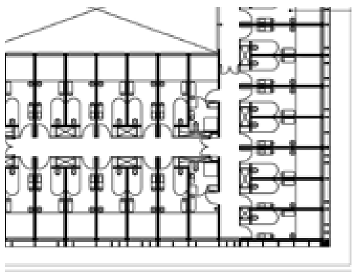
Interior Space of typical module room

fig 5.4.10

fig 5.4.11







New modules ready on site to be assembled New modules ready on site to be assem New modules ready on site to be assembled

fig 5.4.12

fig 5.4.13

Interior Spaces of common areas in the Hotel

fig 5.4.8- 13 Interior Images - Source: Archello - Citizen M Tower London

ASSEMBLY DETAIL

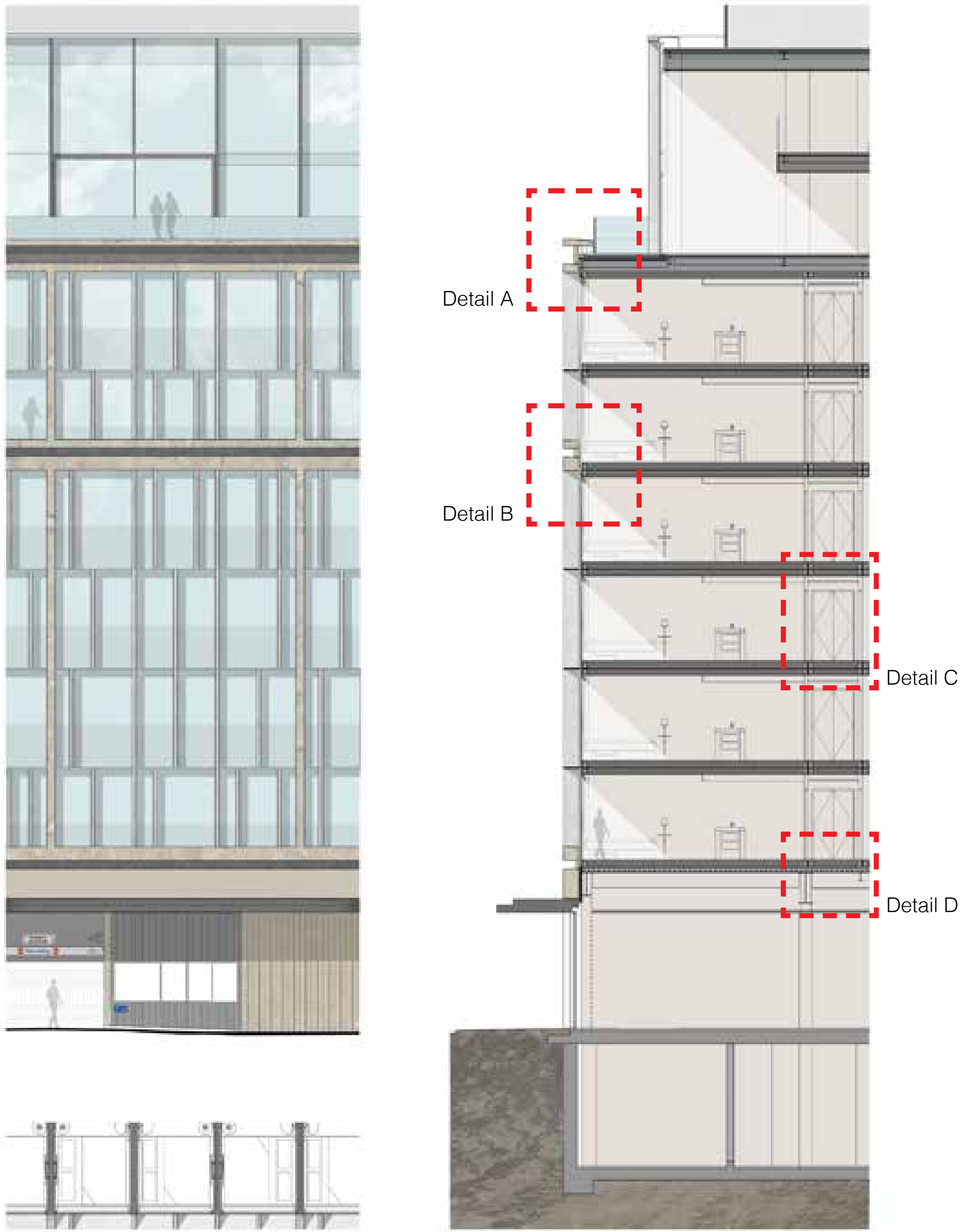


fig 5.4.14 Project drawings

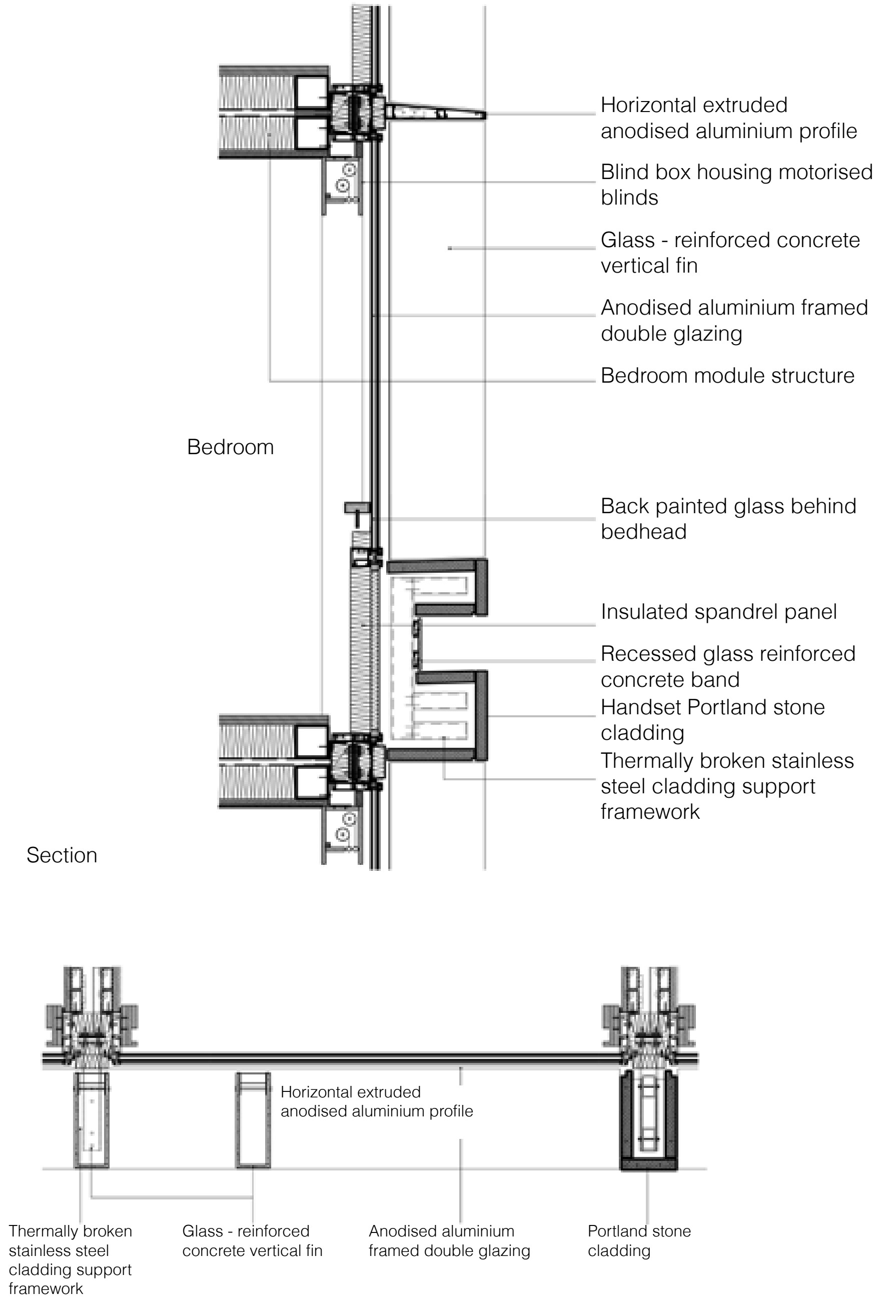


fig 5.4.15 Window Junction Details

fig 5.4.14- 15 - Source - Architecture Journal

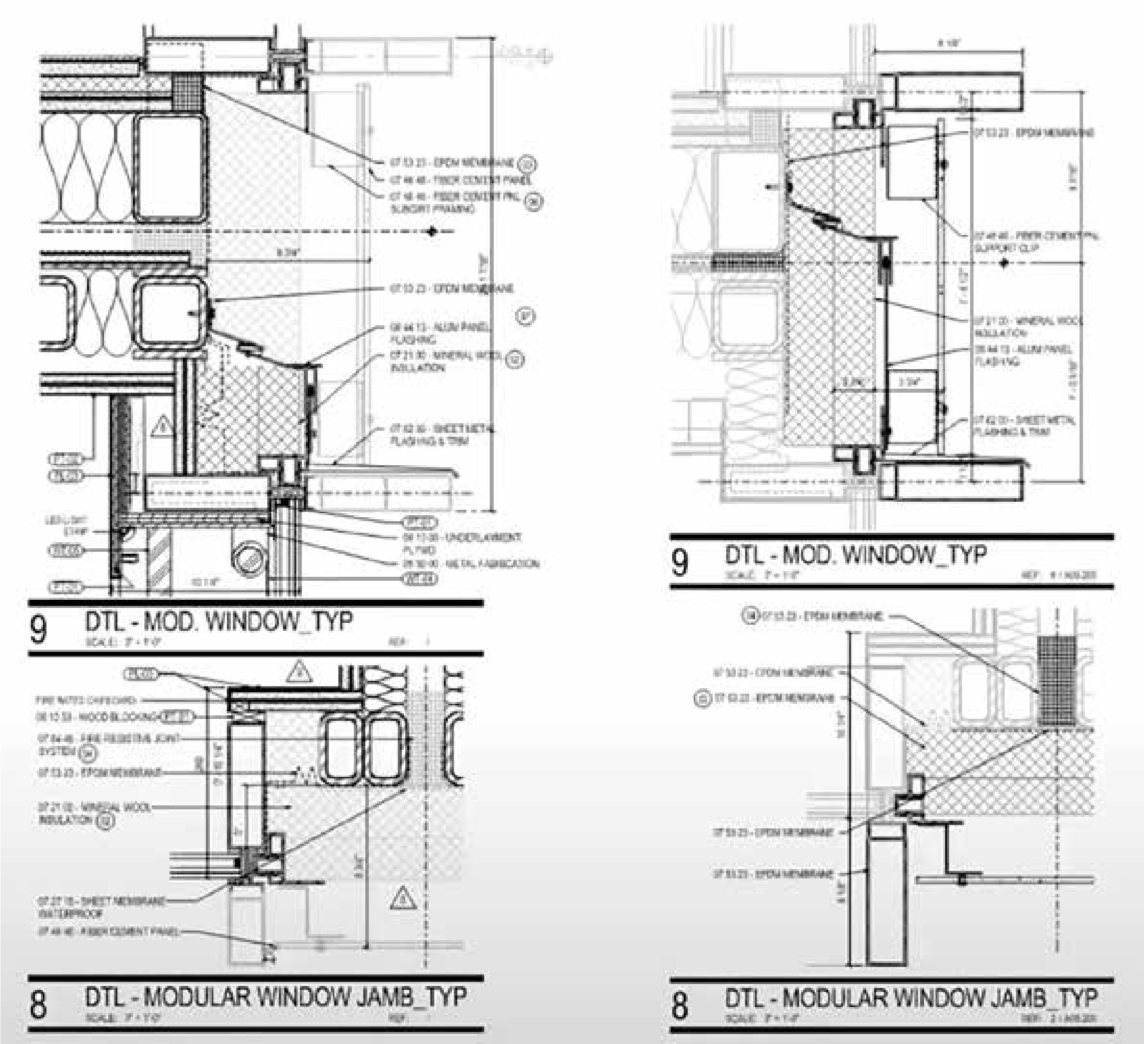


fig 5.4.16 Construction Drawings with clear distinction between Modular and On-site construction.
fig 5.4.16 Source - Mortenson - ModX

A very important learning from the above detail drawing is to understand how very complex detail drawings can be made easy for the contractors by highlighting the difference through distinct lineweights between the ready to place modular unit and the part to be constructed on site.

LIST OF COMPANIES FOR DIFFERENT ELEMENTS

Bedroom modules- Polcom

Ironmongery- Yannedis
Sanitaryware- Duravit
Shopfitting- Roord
Curtain walling Architectural- Aluminium

Structural steel- Hillcrest

Concrete- Moortown

Portland stone Albion Stone and Stone Systems

Precast cladding- Techrete

Structural steel- Hillcrest

Lifts Kone, Lodige

Roofing- Bauder

Sprinkler system- Marioff
Linear drains- Wade

Floor tiles- Kronos Ceramiche

Acoustic ceiling- Ecophon
Wall tiles- Royal Mosa
Carpet- Desso

Screeds- Flowcrete

Drylining, ceilings- British Gypsum
Insulation- Kingspan and Bauder

External access systems- Eurosafe Solutions
Sliding partitions- London Wall Design

External paving- Kilsaren
External bamboo decking- Mosso
Rubber flooring- Nora

CONSTRUCTION IMAGES


fig 5.4.17 Ground Floor Podium Structure construction on site.


fig 5.4.18 Water Proof Membrane wrapped modules.


fig 5.4.19 Service Pipelines integerated with structure.

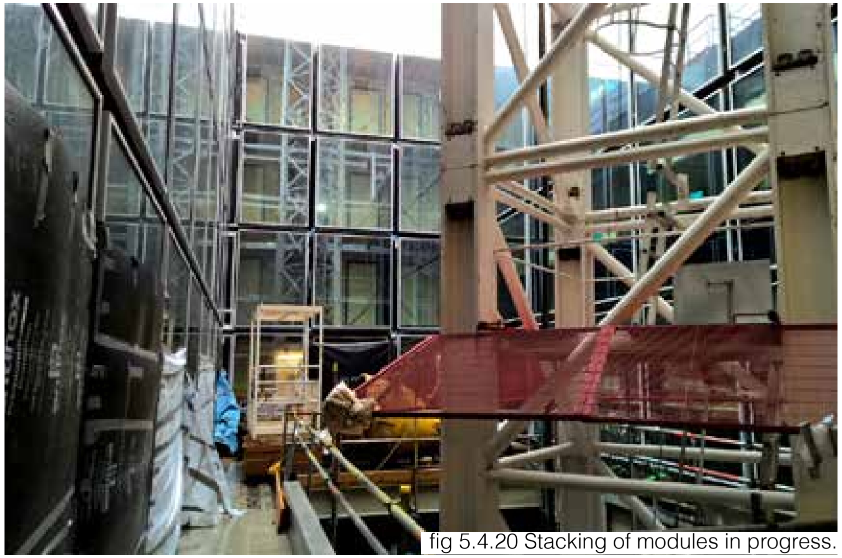


fig 5.4.20 Stacking of modules in progress.

The pictures explain the methodology adapted to assemble the prefab modules (with windows/ fixtures) on site.

fig 5.4.17- 20 - Source - Ramboll Group

DETAIL OBSERVATIONS

A temporary cross bracing is added to the design to provide stiffness to the module during transport to prevent any cracks to interior fittings.
After the module is placed on site, the same is to be removed to optimize flexibility to withstand structural loads

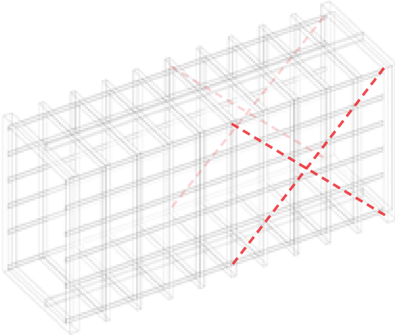
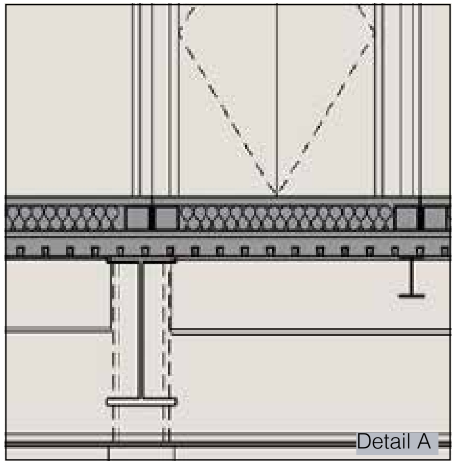
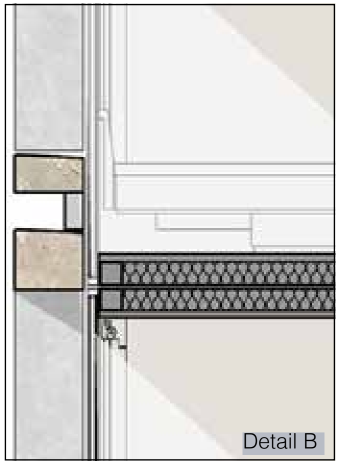


fig 5.4.21 Module Structural Skeleton

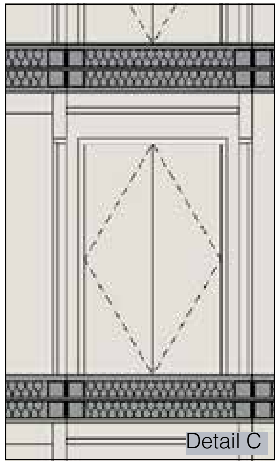
Detail A - Junction between the Prefab steel living modules and the concrete podium slab.
Detail B - Junction between the Prefab steel living modules and the additional external facade.
Detail C - Junction between the Prefab steel living modules and the additional corridor steel module.
Detail D - Junction between the Prefab steel living modules and the additional layers of Terrace.



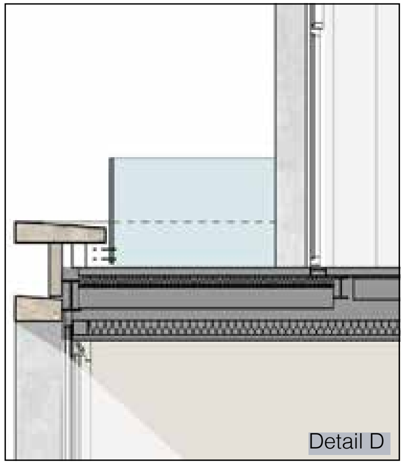
Detail A



Detail B



Detail C



Detail D

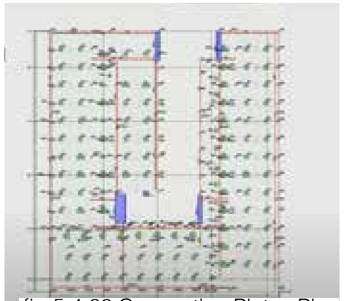


fig 5.4.22 Connection Plates Plan

The connection plates used between the stacked modules also creates inefficient water, fire and thermal proofing.

Source : Mod X podcast with Citizen M - Mortenson

Source - Architecture Journal

Evolution in design system

fig 5.4.23 Container modules

This observation led to a change in design of the modules from a steel frame structure to a container panel based construction.

Cage -
Stiff or flexible?

- Stiff for transport.
- Stiff for install.
- Flexible in place.


fig 5.4.24

Cage -
Stiff or flexible?

design for
- Gravity
- Uplift
- Lateral

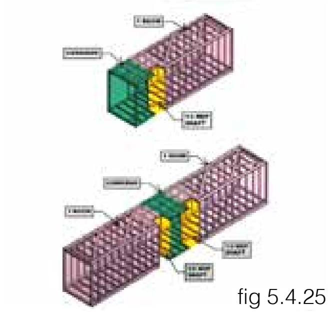


fig 5.4.25

~~Fit-out~~ vs Fit-in

- The cage pre fit with insulation and service pipes in factory.


fig 5.4.26

~~Fit-out~~ vs Fit-in

- Plumbing and Mep services installed in the factory.


fig 5.4.27

~~Fit-out~~ vs Fit-in

- Process to complete module, ready to install and use.


fig 5.4.28

More than the sum of its parts

design for
- Speed
- Quality
- Labor availability


fig 5.4.29

Golden Ticket

- Plumbing pressure test
- sprinkler pipe testing
- Electrical

Mortenson
- General QC
- Final sign off


fig 5.4.30

Loading the modules

- The modules are lifted from the anchor points at the ends.


fig 5.4.31

Assembly

- The modules are quickly stacked at an average speed of 8 units per night.


fig 5.4.32

Rigging

- Modules are rigged with steel chains and lifted and aligned to place.


fig 5.4.33

Connection plates

-The plates are prefit into modules to help provide connection with other units in place.


fig 5.4.34

Connection plates

- A plan is worked out and pre-planned to reduce the number of connection plates required.

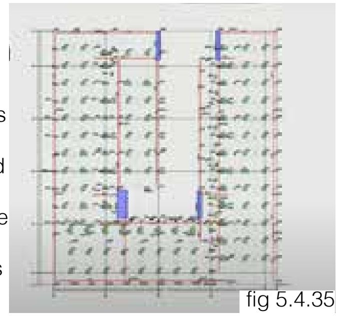


fig 5.4.35

Fire/ Waterproof Seal

- factory precision
- construction tolerance
- fire rating
- seal for weather protection


fig 5.4.36

Project nearing completion in Seattle


fig 5.4.37

CONSTRUCTION PROCESS

The Images taken from a podcast by the manufacturing company helped us understand not just the process of construction for the project in Seattle (similar model to London) but also how they identified certain problems and resolved using improved techniques for future designs in the manufacturing pipeline.

fig 5.4.24-37 Source : Mod X podcast with Citizen M - Mortenson

Citizen M group have been front-runners in proving how modular design approach can be used in a creative and profitable way when explored in mass volumes.

Chicago

Kuala Lumpu

New York

Miami

London

Washington

Rotterdam

Seattle

Amsterdam

Source - Citizen M Group

5.5 THE URBAN VILLAGE PROJECT


fig 5.5.1


fig 5.5.2


fig 5.5.3

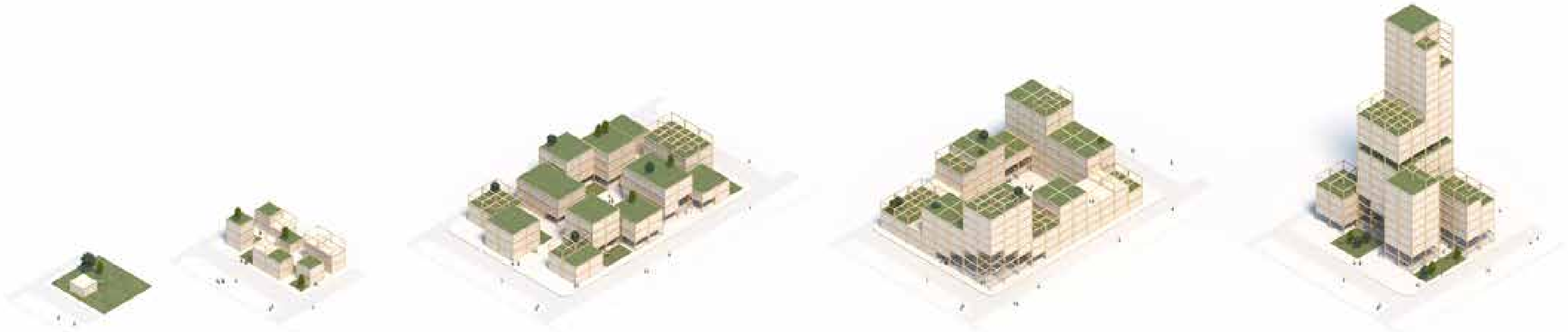


fig 5.5.4 Multiple possible prefab configurations adaptable to unique requirements.

fig 5.5.1- 4 Source - Effekt Architects

SITE CONTEXT & INTRODUCTION

INTRODUCTION :

A new way of Living Together

The project aims to provide cheaper home solutions to the market, an affordable, more sustainable way to imagine future.

LOCATION : Can be proposed anywhere in the world.

fig 5.5.5 Effekt proposes a model for developing projects anywhere across the world adaptive to the climate and site constraints.

fig 5.5.5 Source - Adobe Stock

PROJECT DATA

Architects: EFFEKT
Use: Mixed Use and Housing
Construction: Timber
System: Frame Structure with Flat - Pack components assembly
Project Status: Proposed - Conceptual

Liveability

Flexible adaptible provisions to suit to the users unique needs form a closely knit community cultivating a sense of belonging. Cross generational shared living communities could easily find suitable sizes and be a part of a vibrant social lifestyle.

The project offers offering multiple apartment types instead of standard, family homes—so whether you're single, a family of four, a retired couple or a group of students, you have options.

Shared facilities and services.

Communal dinners, shared daycare, urban gardening, fitness, groceries, and shared transportation.

fig 5.5.6 Ground Floor Configuration of a proposed Urban Village Housing Cluster.

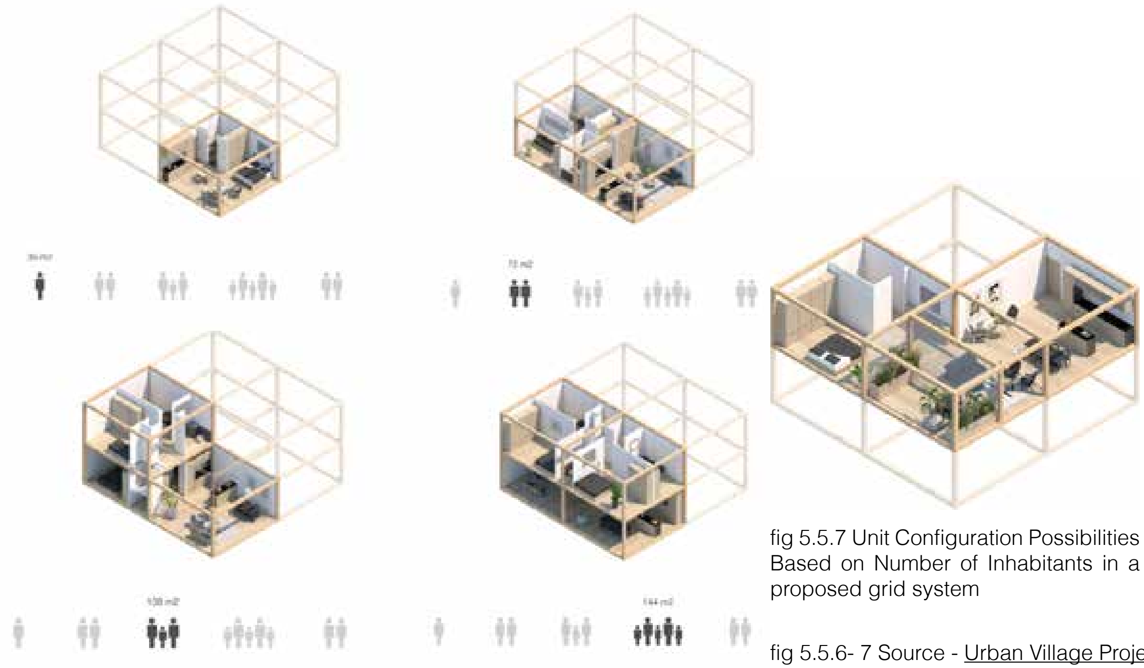


fig 5.5.7 Unit Configuration Possibilities Based on Number of Inhabitants in a proposed grid system

fig 5.5.6- 7 Source - Urban Village Project

Sustainability

Sustainability should be a natural way of living life.
The project offers a careful integration of features like water harvesting, renewable energy, local food production and local composting and waste treatment plants.

Shared services and resources reduce the living costs and improve the lifecycle energies of the entire ecosystem.

Homes made out of cross-laminated timber come with huge environmental benifits and outperforms steel and concrete on multiple levels.

A modular building technology, where all building components and materials can be disassembled and replaced, reused and recycled over the lifespan of the building.

The homes can be customised according to unique user demands from a catalogue of flat pack designed by the architects which includes wall finishes, furniture layouts, window/ door sizes, modular kitchens, etc.

Text retrieved from Source - Space 10 - Research and Design Lab

USE OF SPACES

fig 5.5.8 Flexibility in using the grid modular development for different functions - Communal spaces, Living Spaces, Services, Utilities and Green Spaces.

fig 5.5.8 Source - Urban Village Project

Affordability

Standardised moduar building technology with prefabricated and mass produced flat pack materials for lower construction costs.

The developers have made several investment models and a monthly rate for all the essentials like rent, electricity, water, heating, maintenance and shared facilities.

Flexible, add-on subscriptions would offer improved deals on daily needs like food, media, insurance, transport and recreation.

The option to shop for 'shares' of real estate—to access possession more and more and make the most later because the property worth will increase. this may get obviate pricy down payments direct aboard interest rates that limit 1st time consumers from coming into the housing market. Over time, the property would be in hand by the community, and residents would be able to make the most on the profits.

Why do we need this?

Cities all round the world face complicated problems like fast urbanisation, ageing populations, global climate change and a scarcity of natural resources. At an equivalent time, we tend to square measure within the middle of a worldwide housing crisis. we tend to merely aren't building enough reasonable homes to stay up with the demand.

Our cities are getting more and more unaffordable, unsustainable and socially unequal. and also the state of affairs is simply become a lot of challenging: one.5 million folks square measure moving to a town each week—meaning that in barely a touch over a decade, 1.6 billion folks square measure projected to lack access to reasonable, adequate and secure housing.

So, we've a haul. On high of this, we tend to face another challenge: individuals reside nearer and area unit a lot of connected than ever before, however we tend to still feel more and more lonely, anxious and stressed in our cities.

It's within the intersection of those pressing challenges wherever we tend to believe The Urban Village Project may provide an answer. we all know that around 40% of the areas which will have to be compelled to be urban in 2030 don't nonetheless exist; as discouraging because the task is, we've a blank canvas to explore however we wish the long run of our cities to seem like and performance.

Text retrieved from Source - Space 10 - Research and Design Lab


fig 5.5.9 Configuration in an Urban Context.


fig 5.5.10 Market and Cafeteria Spaces along the Road Edge.


fig 5.5.11 Integeration of Green and Community spaces with Built Environment.


fig 5.5.12 Communal Working Spaces and Library.

Fig 5.5.9- 12 Source - Space 10 - Research and Design Lab

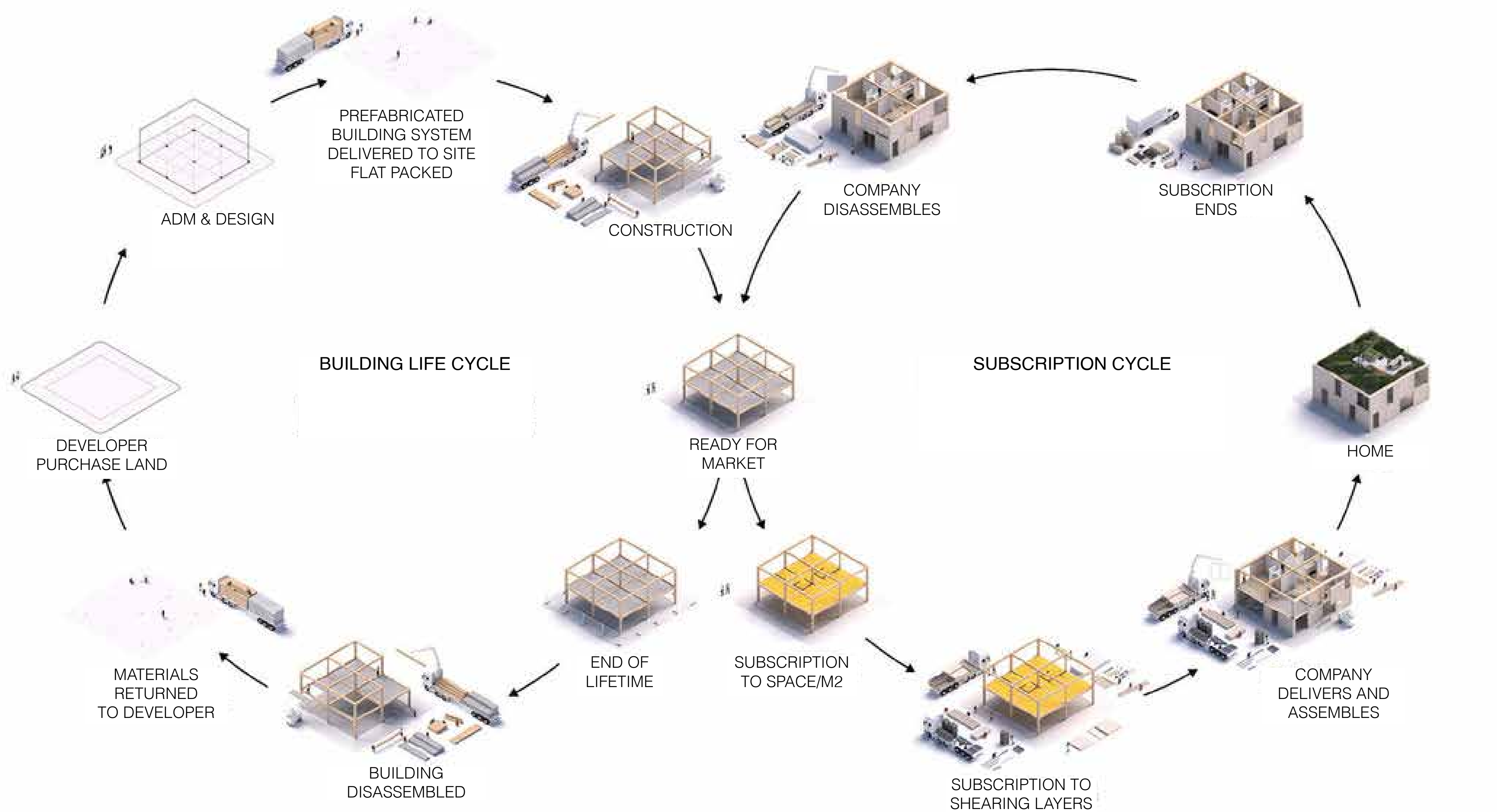


fig 5.5.13 Construction Process and Economic Subscription Cycle.

fig 5.5.13 Source - Urban Village Project

LIFESPAN OF BUILDING COMPONENTS

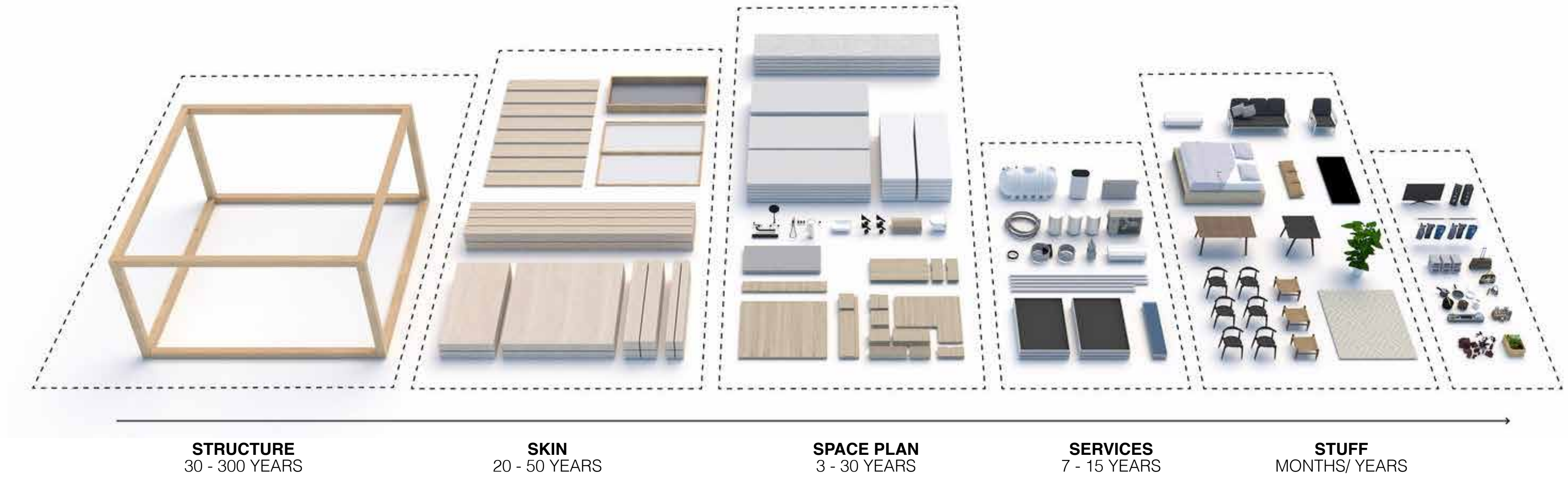


fig 5.5.14 Catalogue of elements available for customisation with prefab module .

fig 5.5.14 Source - Urban Village Project

Modular Schools In Zurich

Architects: Bauart Architekten
Use: Public School
Construction: Timber
Construction Company: Blumer Lehmann AG, Gossau
System: Sectional Volumetric Profiles
Completion:
1st generation (1998-2011) 29 pavilions + 5 extensions
2nd generation (from 2012) 28 pavilions

MODULES

30 (3 Modules/ Classroom) **Modules**	27 **Unit area (m²)**
3m x 9m **Module Size**	10 **Modules per floor**

CONSTRUCTION DATA

03 **Stories**	270 (Per Floor) **Typical Floor Area (m²)**
18 (6 days/ floor) **Days for Construction in Factory**	30 (complete fittings in 4 weeks) **Days to Assemble on site**
Yes **Flexible/ Movable Interior Partitions**	Medium **Degree of Prefabrication**

Lady Well Co living

Architects: Rogers Stirk Harbour + Partners
Use: Co living - Co working space
Construction: Timber
Construction Company: SIG Build
System: Room Cell
Cost : £4,980,000 (£1200/m²)
Completion: 2016

MODULES

64 **Modules**	Small unit - 27 Big unit - 47.25 **Unit area (m²)**
4.5m x 6m 4.5m x 10.5m **Module Size**	16 **Modules per floor**

CONSTRUCTION DATA

03 **Stories**	Residential- 700 Commercial- 940 **Typical Floor Area (m²)**
06 **Months for Construction in Factory**	30 (16 units / week) **Days to Assemble on site**
Partial **Flexible/ Movable Interior Partitions**	High **Degree of Prefabrication**

6 Orsman Workspace

Architects: Waugh Thistleton Architects
Use: Office Building
Construction: Hybrid - Steel + Timber
System: Steel Columns and Beams with CLT Slabs
Total built area: 3158 sqm
Period of construction: 13 weeks

MODULES

-	Typical Small grid - 18 Big grid - 27
Modules	**Grid Module area (m^2)**
3m x 6m 3m x 9m	23
Structural Grid Size	**Modules per floor**

CONSTRUCTION DATA

05	630
Stories	**Typical Floor Area (m^2)**
-	91 — 10-14 days / floor
Months for Construction in Factory	**Days to Assemble on site**
Yes	Low
Flexible/ Movable Interior Partitions	**Degree of Prefabrication**

Ctizen M Tower

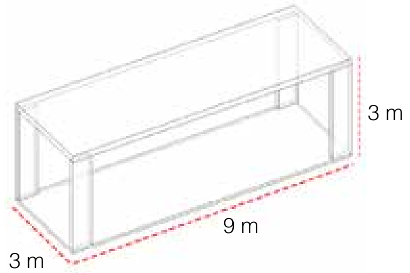
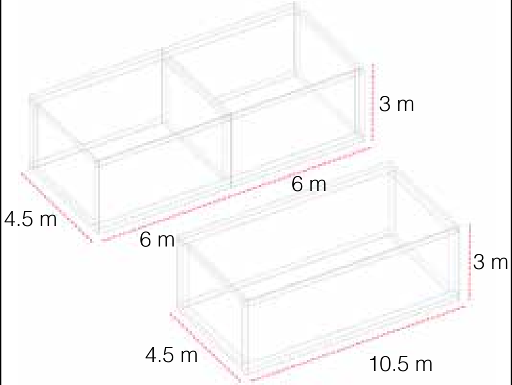
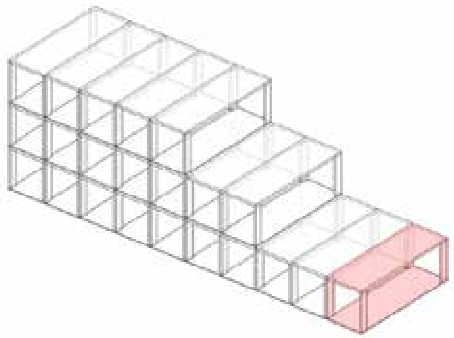
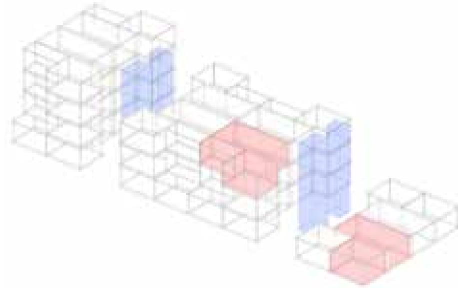
Architects: Sheppard Robson
Use: Hotel
Construction Primary Material: Steel
Construction Company: Ramboll UK Limited
System: Room Cell
Completion: 2016
Project manager: Turner & Townsend
Main contractor: Balfour Beatty

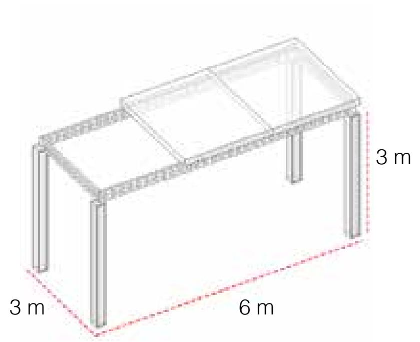
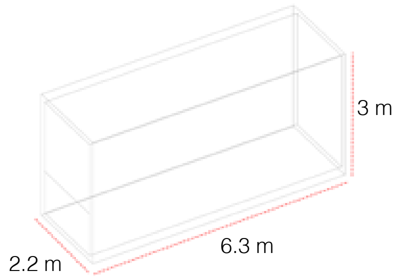
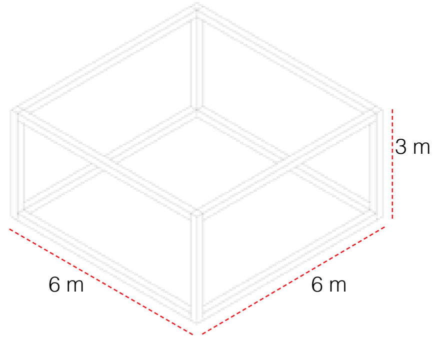
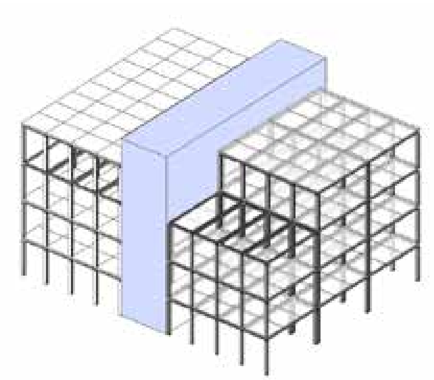
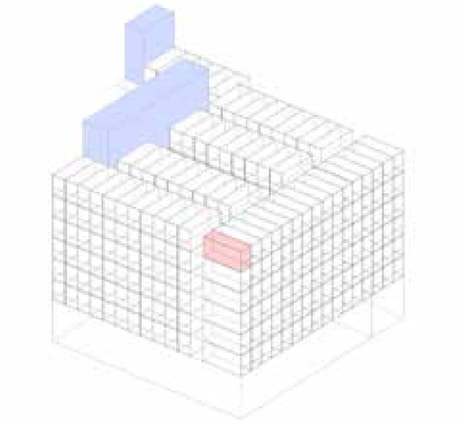
MODULES

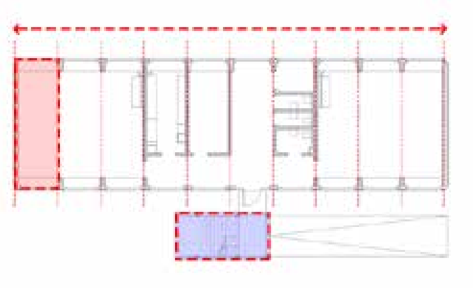
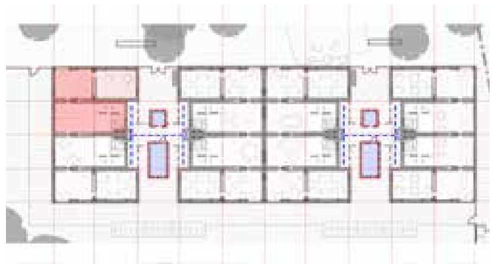
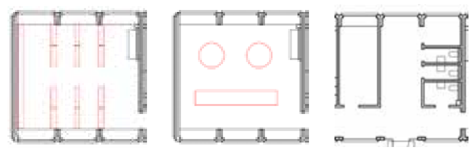
370	14
Modules	**Unit area (m^2)**
2.2m x 6.3m	55
Module Size	**Modules per floor**

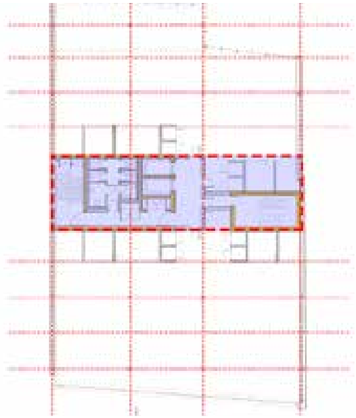
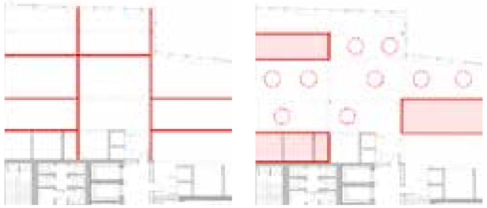
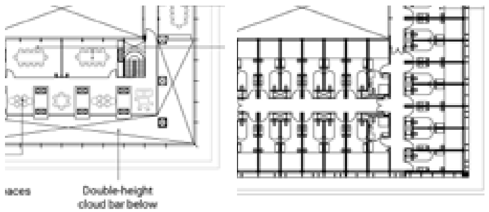
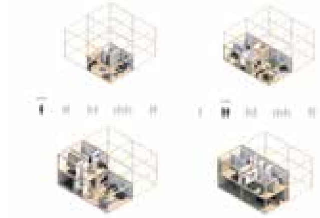
CONSTRUCTION DATA

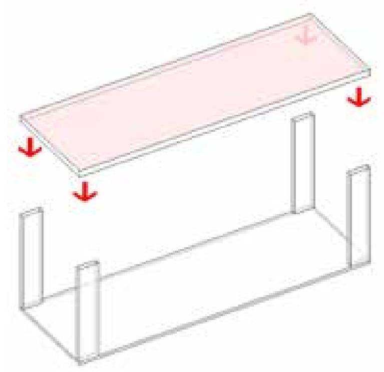
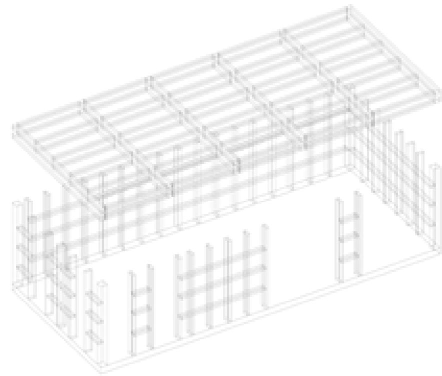
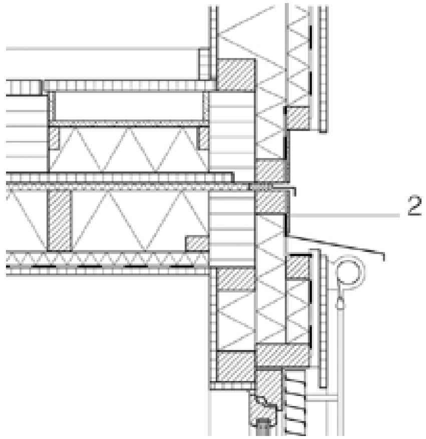
09	1200
Stories	**Typical Floor Area (m^2)**
-	100 — 8 units / night
Months for Construction in Factory	**Days to Assemble on site**
No	Very High
Flexible/ Movable Interior Partitions	**Degree of Prefabrication**

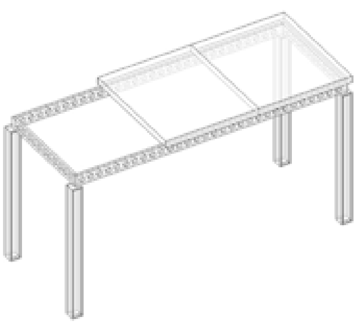
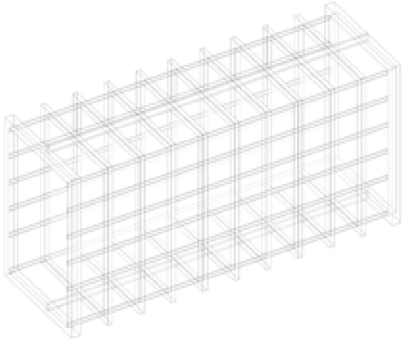
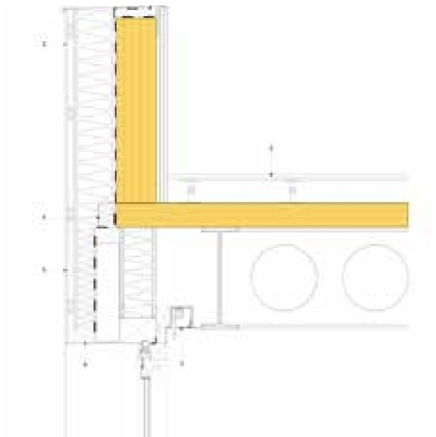
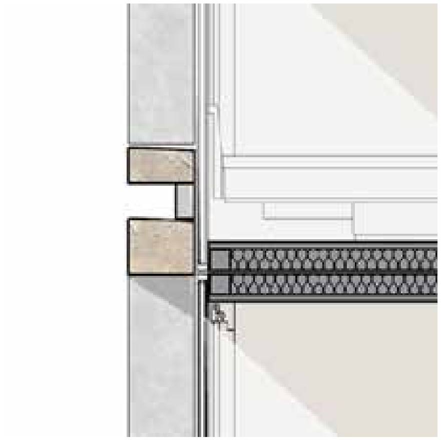
PROJECT NAME	Modular Schools In Zurich (Timber)	Lady Well Co living (Timber)
MODULE SIZE	 Core module used to develop the whole structural system.	
STRUCTURAL SYSTEM	- Sectional Volumetric Profiles	- 4 Sided Volumetric Modules
STRUCTURAL SYSTEM DIAGRAM		
MATERIAL - PRIMARY/ SECONDARY	- Cross Laminated Timber. - Timber Frame Wall construction with panel systems.	- Timber Frame Construction. - Timber Frame Wall construction with panel systems.
DEGREE OF PREFABRICATION	- Medium - Partially complete room modules with interior fittings prefabricated in factory and placed on site.	- High - Complete room modules with interior fittings prefabricated in factory and placed on site.

6 Orsman Workspace (Hybrid System)	Ctizen M Tower (Steel)	Urban Village (Timber - Proposed Project)
		
- Frame Structure	- 4 Sided Volumetric Modules	- Frame Structure
		
- Steel Column - CLT Slab Hybrid Construction. - Exposed CLT & custom wall partitions.	- Steel Cage Construction. - Wall panels and insulation added according to regulations.	- Timber Frame Structure - Exposed CLT & custom wall partitions.
- Low - All structural element prefabricated and assembled on site.	- Very High - Complete room modules with interior fittings prefabricated in factory and placed on site.	- Low - All components prefabricated separately and assembled on site.

PLANNING/ ORGANISATION	Linear stacking 	Cluster Stacking 
CIRCULATION	- Single External Staircase for vertical circulation. - The corridor is a part of the interior space in modules.	- Two External Staircases and Lifts for vertical circulation. - Minimum singely loaded corridor adjacent to vertical cores.
FLEXIBILITY PARAMETERS	 Multiple arrangements for classrooms and services with flexiblility in partitions.	  Co-Living use Co-working use
FACADE TYPE	- Fixed, Pre-Attached, modular - Timber Frame Construction with modular fixed opening.	- Fixed, Pre-Attached, modular - Timber Frame Construction with modular fixed opening.
ADAPTABILITY FACTOR	- The Pavillion can be dismantled and moved to another site for adaptive reuse. - The modules provide freedom for open planning or introduction of partition according to user needs.	- The Project was designed with a vision to provide possibility to dismantle and move the built modules to a new site. - Having been designed for co-living, the space has already evolved for co-working purposes.

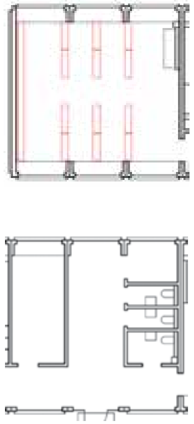
Frame Structure  - One Staircase and Two Lifts for vertical circulation. - Central vertical core connects open floor plans on both sides on all levels.	Doubley Loaded Stacking  - Two Staircases and Four Lifts for vertical circulation. - Long doubley loaded corridors around the central courtyard.	Frame Structure 
 Multiple arrangements for workspaces on an open floor plan.	 Ground floor with frame structure to have multifunctional use and above floors with typical module stack.	 Multiple arrangements for living and working units.
- Modular fixtures used for facade of the frame structure. - Building facade can have variable combinations.	- Room Modules with fixed standard opening design - Building facade can have variable combinations.	- Variable, Post-Attached, modular - Building facade can have variable combinations.
- The open plan for usable floorspace provides endless possibilities for offices and co-working functions to adapt and create their unique environments.	- As the modules are specifically designed for affordable luxury hotel rooms, there is no possibility to adapt to a different use.	- The open structural grid with a catalogue of customisable panels and fixtures offers a great adaptability to use spaces for multiple functions.

SINGLE UNIT		
STACKING/ JOINERY	 	 
DURATION OF ASSEMBLY	30 days - complete fittings in 4 weeks	30 days - 16 units/ week

		
  	 	 
91 days - 10-14 days per floor	100 days - 8 units/ night	- Project at conceptual stage

2.6 Inferences

MAJOR LEARNING POINTS FROM CASE STUDIES



FLEXIBILITY IN INTERNAL LAYOUTS

2 SIDE OPEN SECTIONAL MODULES

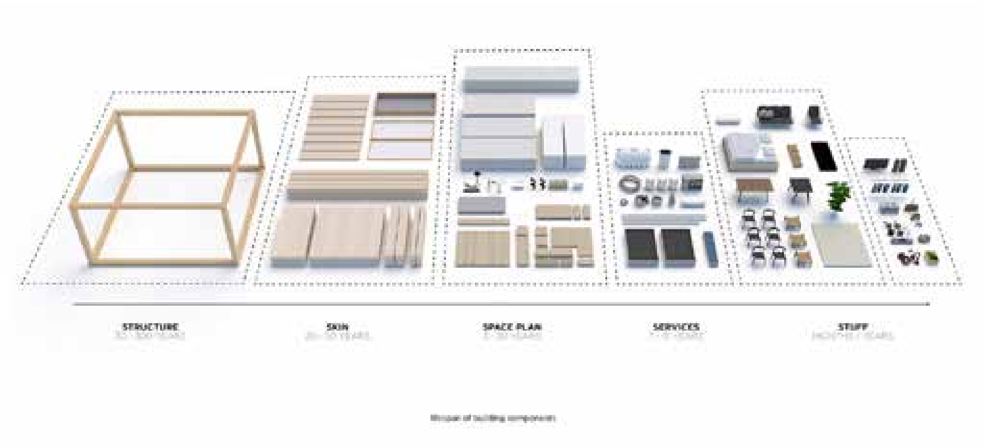
MODULAR SCHOOLS IN ZURICH

QUICK BUILD - AFFORDABLE ADAPTIVE COMMUNITY SHARING SPACES

PLACE LADYWELL

STANDARDISED CONSTRUCTION CHAIN TO INCREASE PRODUCT QUALITY & MAXIMIZE GLOBAL EXPANSION.

CITIZEN M TOWER LONDON



OPTIMIZING THE BEST OUT OF SELECTED MATERIALS

ORSMAN 6 WORKSPACE

COMMUNITY PARTICIPATION THROUGH MODULAR APPROACH

URBAN VILLAGE PROJECT

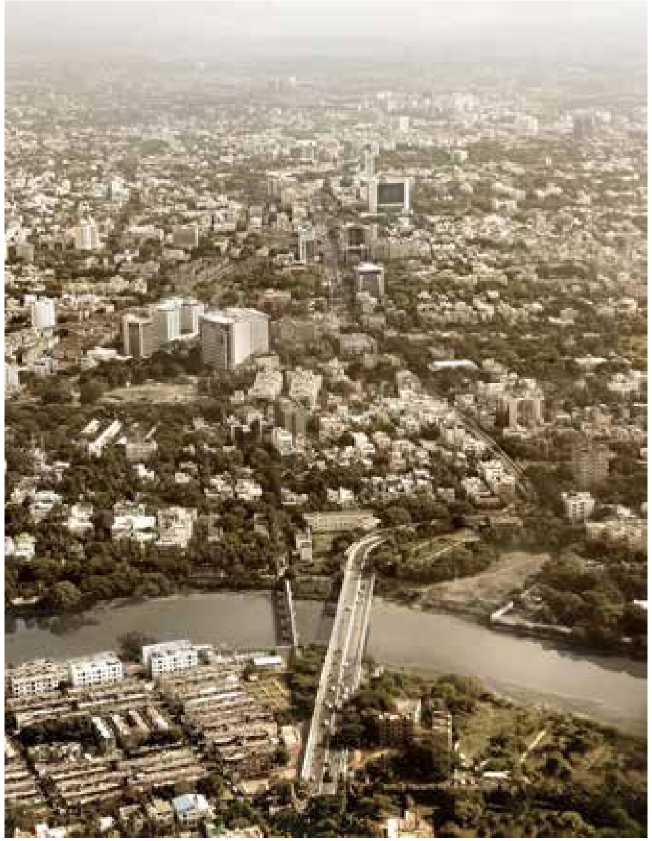
Part 2

INTERVENTION

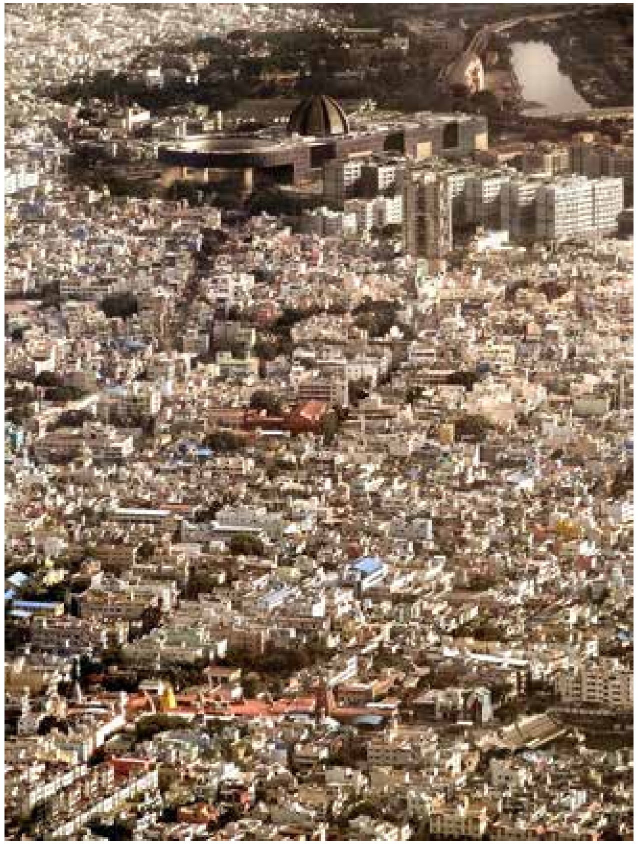
Site Study & Design

Source - Getty images

MRC NAGAR



MOUNT ROAD



TRIPLICANE ASSEMBLIES

Source - Scroll.in

Source - The New Indian Express

Source - India Pos

Source - Moin Mariner

Chennai, situated on the shores of the Bay of Bengal is the capital of the Tamilnadu state and it is the fourth largest metropolis in India. It's older name' Madras' is officially changed to 'Chennai' in 1996. Chennai Metropolis [with latitude between 12°50'49" and 13°17'24", and longitude between 79°59'53" and 80°20'12"] is located on the coramandal coast in South India and the land is a flat coastal plain. Three rivers viz. Kosasthalaiyar, Cooum and Adyar pass through Chennai Metropolitan Area and these rivers are placid and meander on their way to the sea. Buckingham Canal, a man made canal, is another large waterway which runs North-South through this metropolis. Sholavaram lake, Red Hills lake and Chembarambakkam lake are the three large lakes in the area.

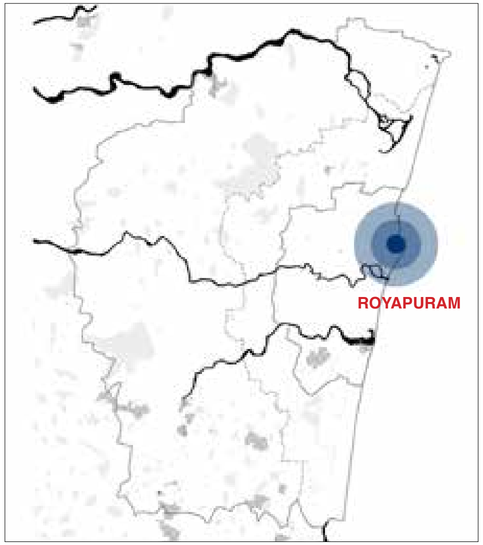
Chennai lies on the thermal equator and most of the year it is hot and humid. Highest temperature attained in May-June is usually about 40°C (104°F) for a few days. The coldest time of the year is early January and during that month the temperatures are about 20°C (68°F). Predominant wind direction is from South East to North West.

Since Chennai was the capital of the erstwhile Madras Presidency covering most of the areas now under the states of Andhra Pradesh, Karnataka and Kerala it has inherited a mix of diverse cultures and languages.

Chennai ranks 15th in the whole world in terms of it's population density (25,501 inhabitants per sq km) and 6th in India making it one of the biggest urban centres of India. Moreover, Chennai Port plays a very major role in marine transportation from India to Far East Asia and South East Asia. Having an advantage of the location, a wide variety of industries like machinery industry, automobile industry, electric and electronic industries etc. have established a base there.

1.2 Focus Area: Royapuram

Chennai city on the South coast of India



Royapuram in the city centre near port of Chennai

Source - Resilient Chennai: Preliminary Resilience Assessment by Dalberg Advisors

Royapuram is one of the central zones of Chennai in the vicinity of which, the origin of Chennai (formerly known as Madras) can be traced. Even during the Chola times, the region existed as a renowned settlement. Royapuram is a vibrant urban centre famous for it's Marina Beach, Chennai City Port and the Royapuram Railway Station. The Royapuram railway station was the first railway station to be established in South India and to this date is the oldest surviving station in the subcontinent of India.

The distinct characteristics of Royapuram include a continuous built area with tightly packed, fine grained land parcels brimming with unceasing pedestrian activities. Close proximity to large and important institutional buildings, temples, churches and mosques create big visual landmarks in the streetscape.

Source - Google Maps

Source - TNagar Ranganathan Street Wikimedia Commons

Source - ITDP India

Source - Adobe Stock

Source - Getty images

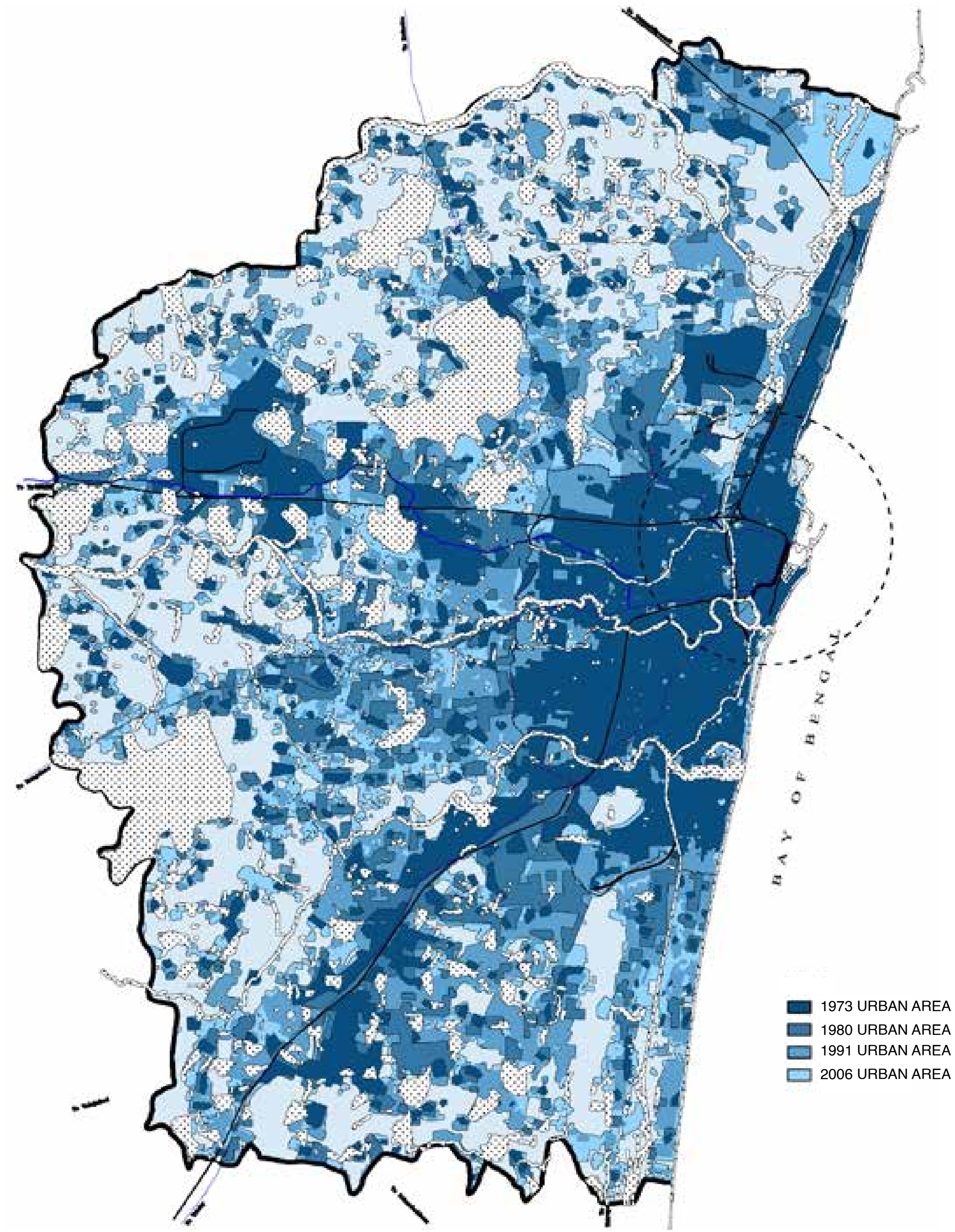


fig. Chennai Growth Pattern
Source - Chennai Metropolitan Development Authority

2.1 ROYAPURAM - EPICENTRE OF URBAN GROWTH AND METROPOLITAN ACTIVITIES

Over the last 40 years, the city has expanded inland, in a radial manner. There are distinct rings from the centre of the city, at radii of 5km, 10km, 15km and 20 km, where the population density, rate of population change and nature of urbanisation varies drastically. Royapuram is at the centre of the innermost ring where highly dense morphological paterns are observed. Royapuram is an illustrious mix of commercial activities, the second largest Indian port, a fishing harbour, substantial industries and numerous professional and institutional buildings mixed with an extensive residential fabric. As the oldest part of the city, all the major government buildings and other buildings of high historic and architecture value are found in Royapuram, George Town, Triplicane and other surrounding areas. The availability of public transport is very high in this part of the city, owing to the fact that a train station, is present in this part of the city and therefore, all other transit modes have an intersection point here.

fig. Chennai Historic Centre

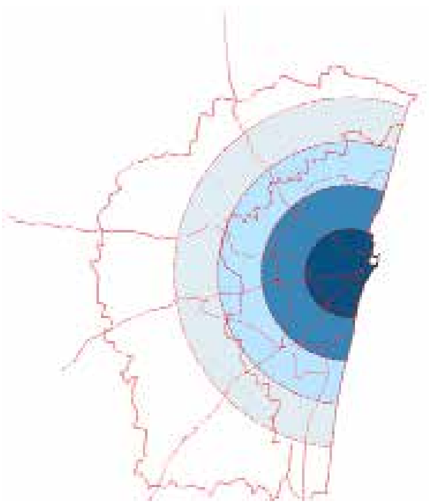


fig Chennai Growth Pattern

2.2 ROYAPURAM - ISSUES ARISING DUE TO POPULATION DENSITY

Royapuram is one of the densest zones of Chennai with the population density of 13,607 people/km^{2}. The total population in the city centre has doubled in the last 40 years(1971 -2001). Therefore, in this part of the city, people are living in increasingly congested environments. The growing concentration of people poses a fundamental challenge to the provision of economic opportunity, the development of adequate infrastructure and livable housing, and the maintenance of healthy environments. Urban adaptation, flexible multi-functional spaces and infill development can aid in addressing the issues of urban density in unplanned urban centres.

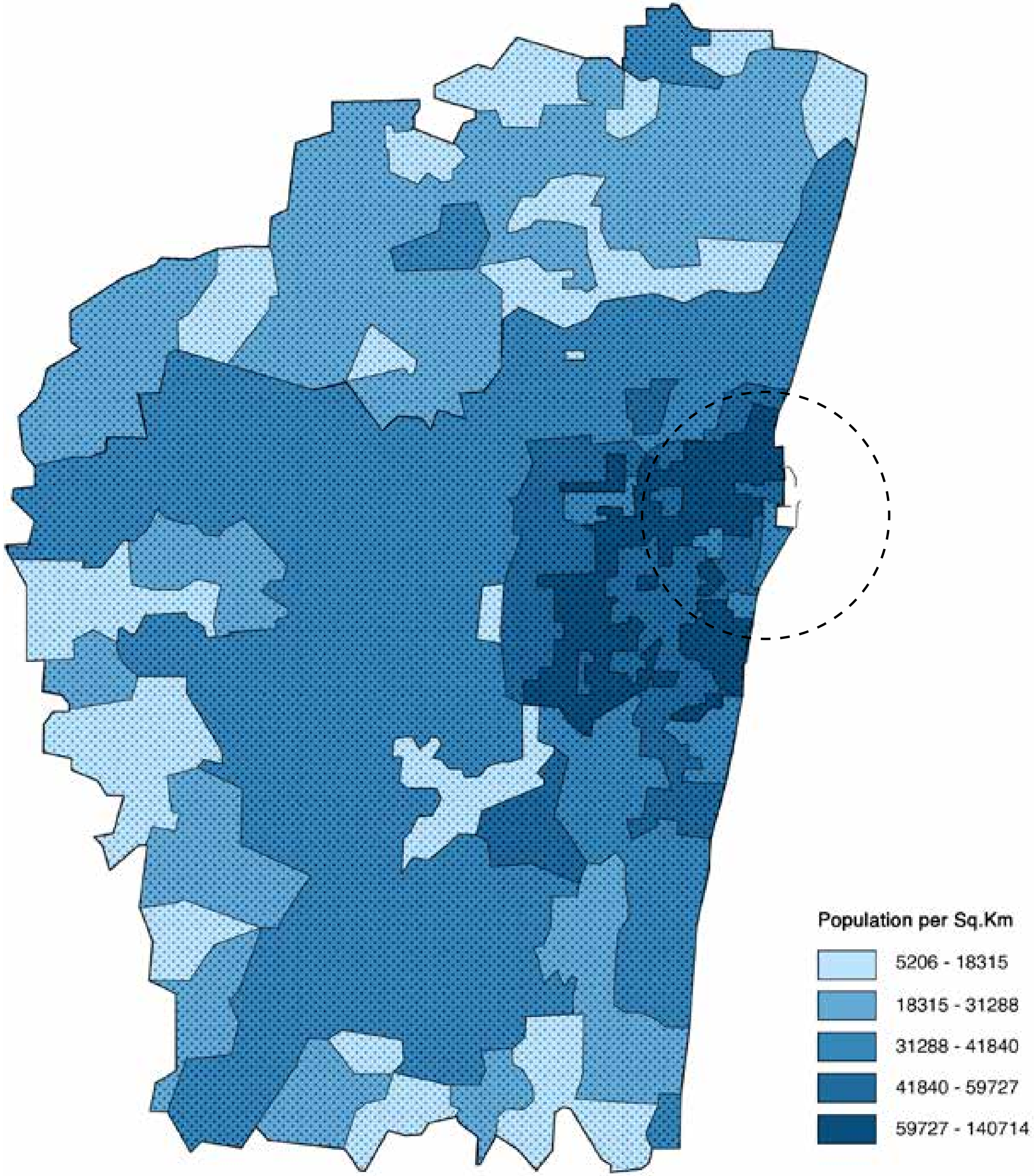
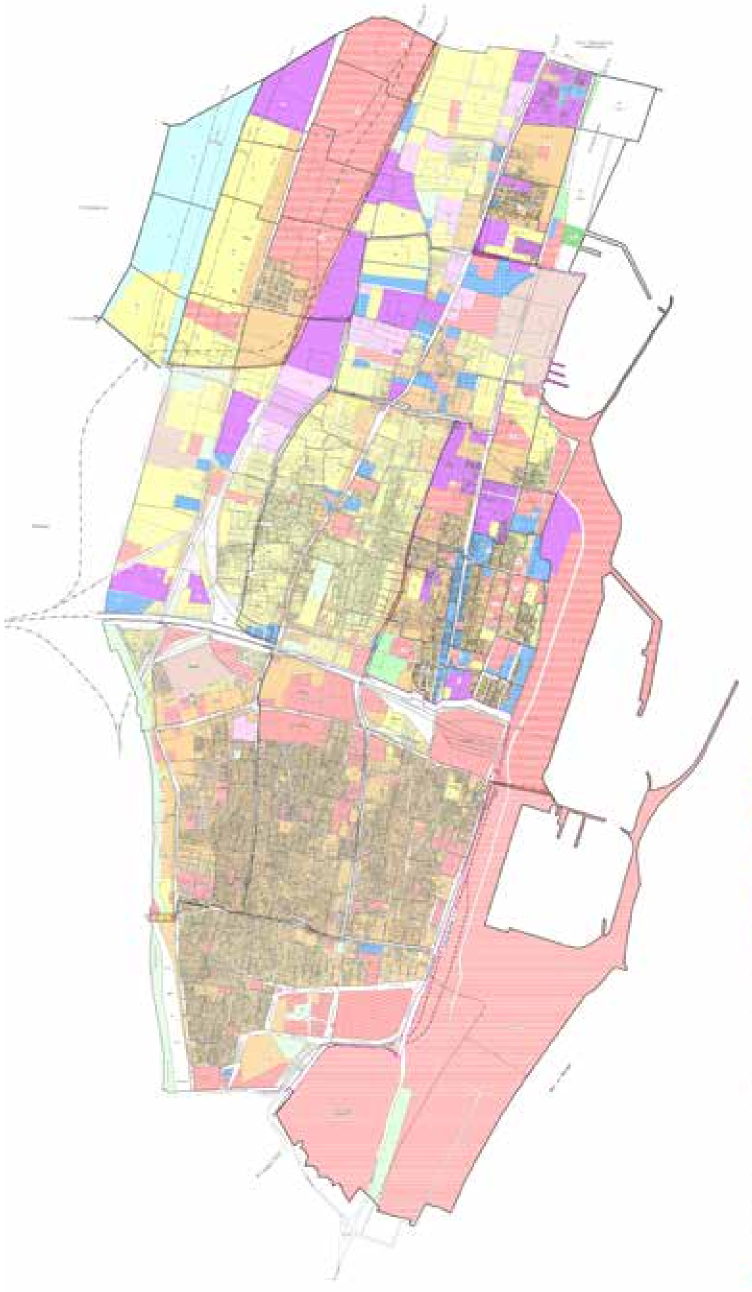
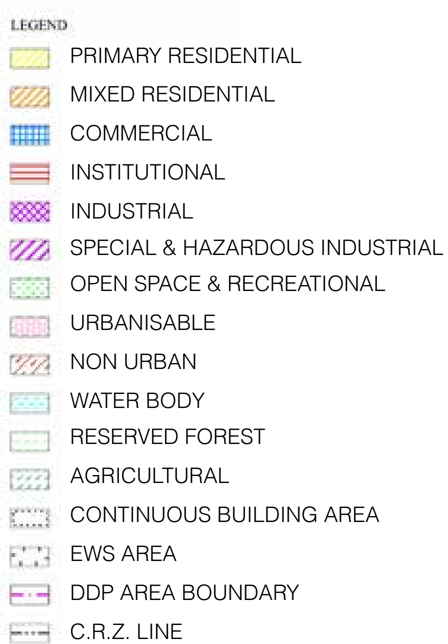


fig. Chennai Population Density Map
Source - Chennai Metropolitan Development Authority

RANGANATHAN STREET

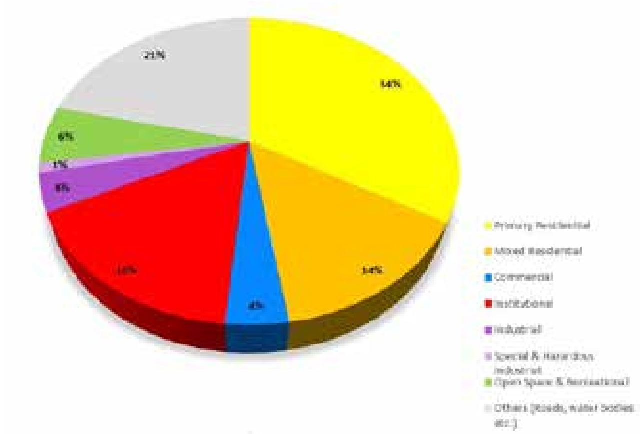
2.3 LANDUSE

The land use distribution of Royapuram signifies the extensive amount of institutional buildings consisting of educational facilities, medical facilities, offices, administrative and public buildings as well as harbour, port and associated infrastructure are prevelant in the area.
Subsequently, low rise mixed use models of commercial stores on the ground and residences on higher storeys are also widespread in Royapuram.

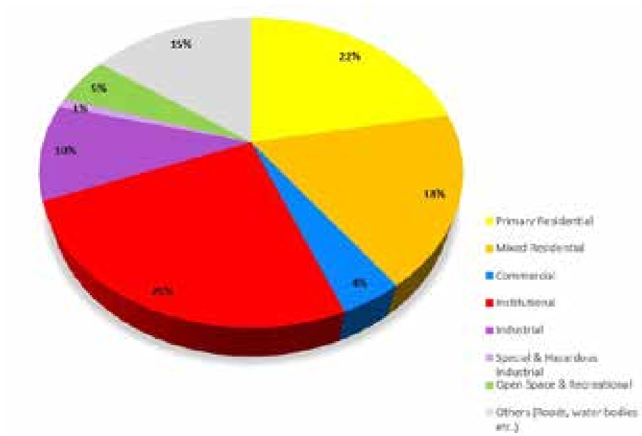



ROYAPURAM LAND USE MAP

fig. Royapuram Landuse Map
Source - Chennai Metropolitan Development Authority



CITY LAND USE DISTRIBUTION



ROYAPURAM LAND USE DISTRIBUTION

2.4 MORPHOLOGY - FIGURE GROUND MAP

The figure ground map further demonstrates the high built density in Royapuram. This part of the city is a juxtaposition of extensively built environments that are low rise and high density along with larger institutional and government buildings.

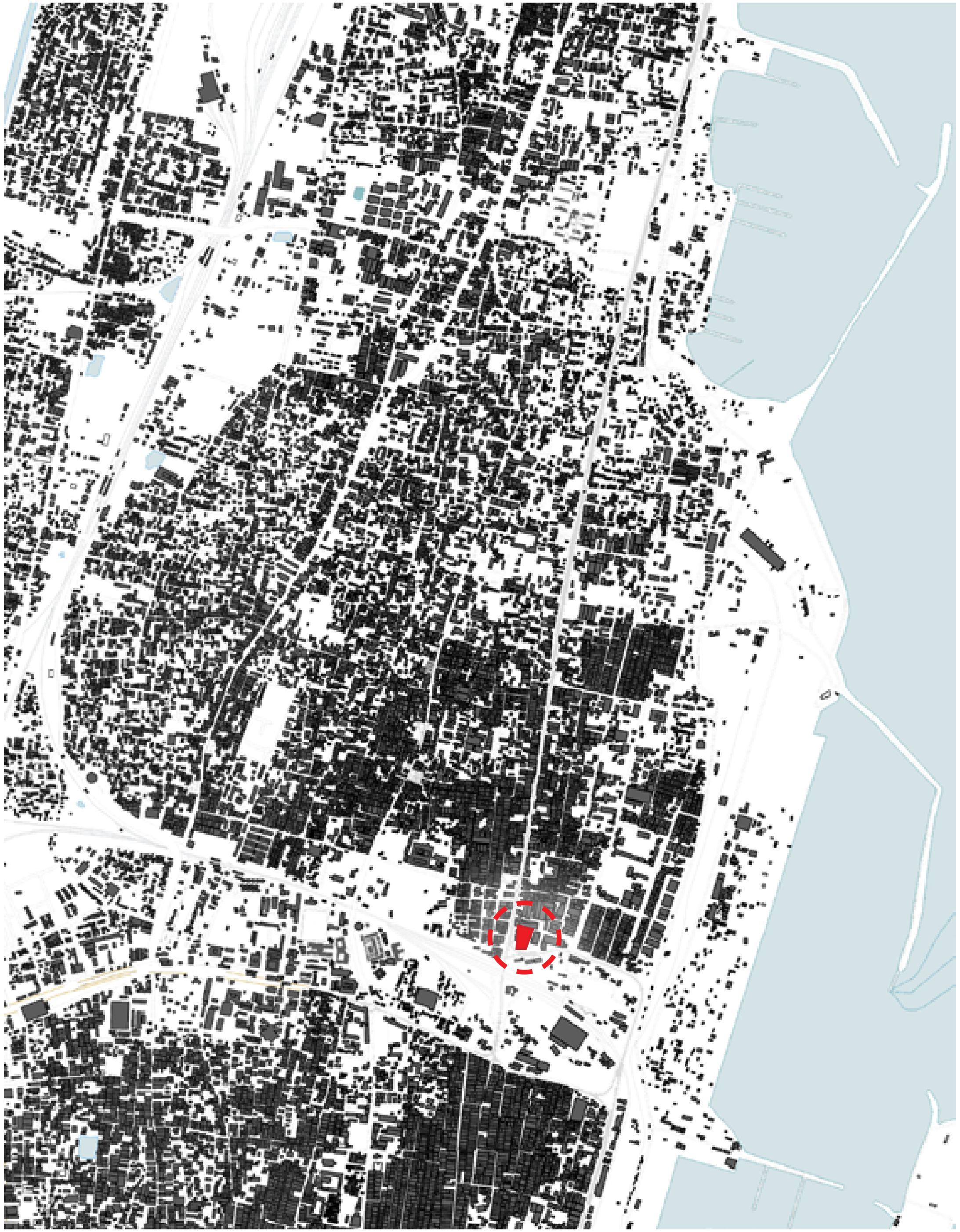


fig. Royapuram Figure Ground Map
Source - OpenStreetMap

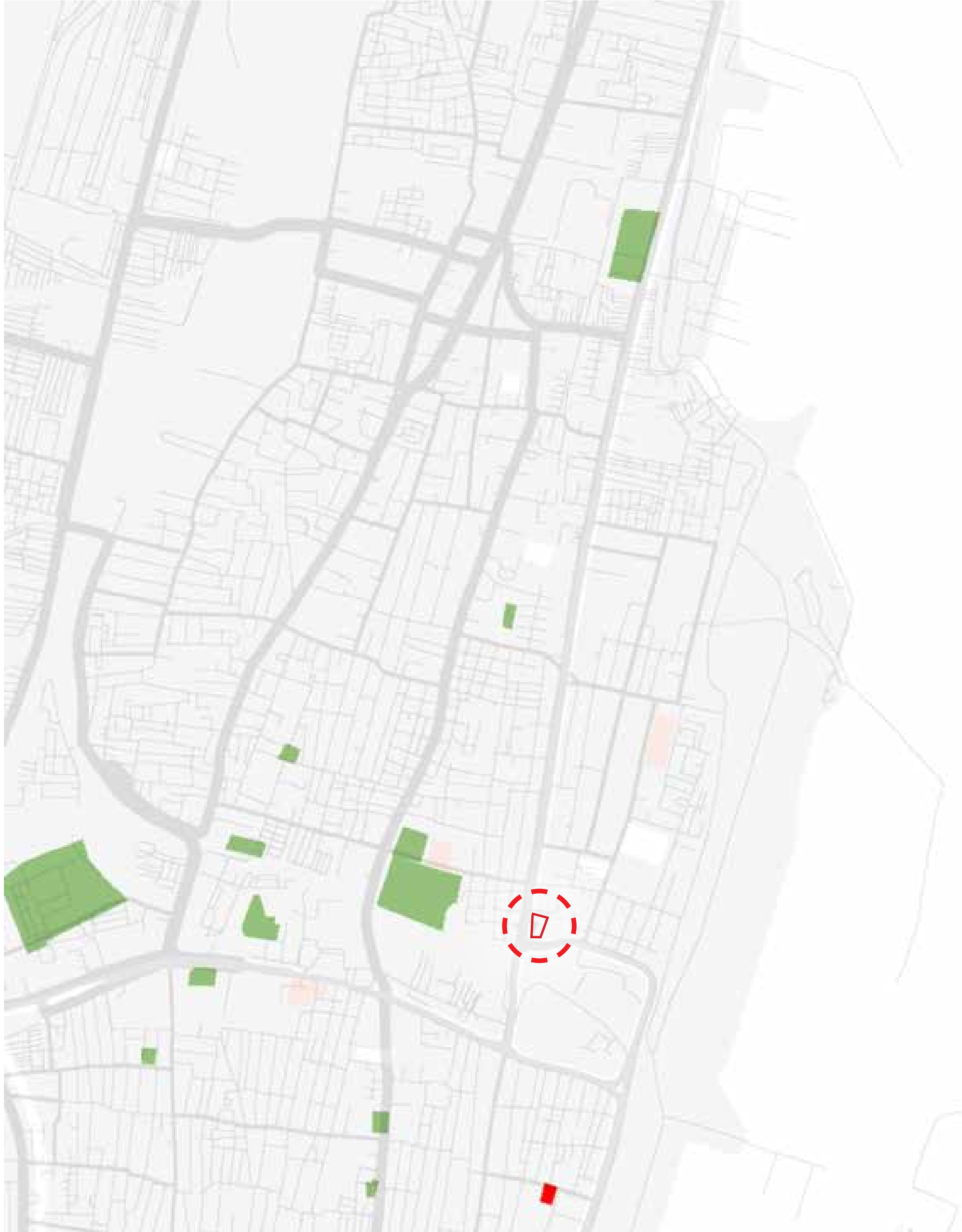
MORPHOLOGY - ROAD NETWORK

The primary roads and streets of Royapuram are dedicated to commercial and mixed use activities which attracts a lot of footfall and activity. The secondary roads are majorly residential and mixed use commercial with residetial.

Mixed Use Streets

Commercial Use Streets

fig. Royapuram Road Network Map
Source - OpenStreetMap



MORPHOLOGY - GREEN / OPEN SPACES

High dense situations in Indian cities mean not only a higher built density, but a very high population density as well, owing to the fact that the space available per person in quite low. Chennai city has very low amount of open space available with a ratio of just 0.8 sq.m per person, which stands in stark contrast to the prescribed WHO standard of 9 sq.m person. Royapuram is one such zone of Chennai where the amount of green and open spaces is much lesser than the highly dense built environment.

fig. Royapuram Open/Green Spaces Map
Source - OpenStreetMap

3.1 SITE LOCATION: MS Koil St, Royapuram, Chennai (13°06'23.7"N 80°17'29.5"E)

SITE AREA: 5,100 sqm

SITE USE: Disused Government Staff Housing

SITE SELECTION

Located at the intersection of the commercial street and the flyover going above the railway tracks are the old government staff living quarters. However, due to safety concerns arising out of the old and deteriorating structure and foundation of the buildings, the premises were made to vacate by the Municipal Corporation of Chennai. Due to which the municipal corporation of Chennai is planning to develop the site for a mixed use proposal.

The salient feature of this site is it's close proximity to the main commercial streets (MS Koil road, Monegar Choultry Road and Thiruvottiyur High Road), Royapuram Railway station, all the institutional and administrative buildings and the port.

DISUSED GOVERNMENT STAFF HOUSING
(To be demolished)

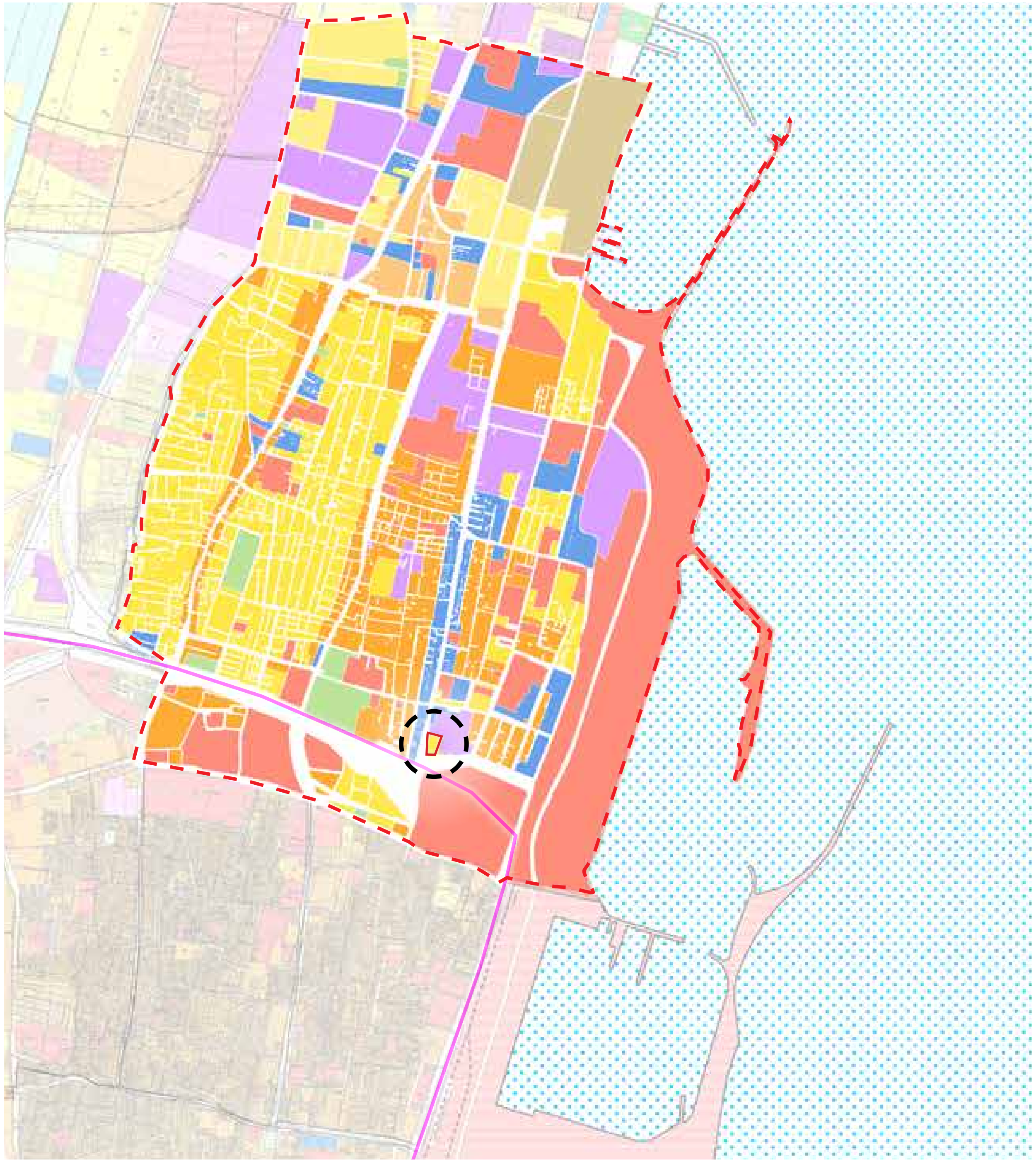
Source - Google Earth Pro Images

3.2 MACRO CONTEXT

The high built density when observed with the respective land use, highlights the high population density of residents and the lack of amenities required to sustain the ever chabging need of the dynamic populace.

3.3 LAND USE MAPPING SURROUNDING THE SITE

In the vicinity of the site, the functional land use is a mix of major commercial and mixed use activities along with the institutional and administrative usages.



RESIDENTIAL - MIG

RESIDENTIAL - LIG

MIXED USE - MIG

MIXED USE - LIG

INSTITUTIONAL

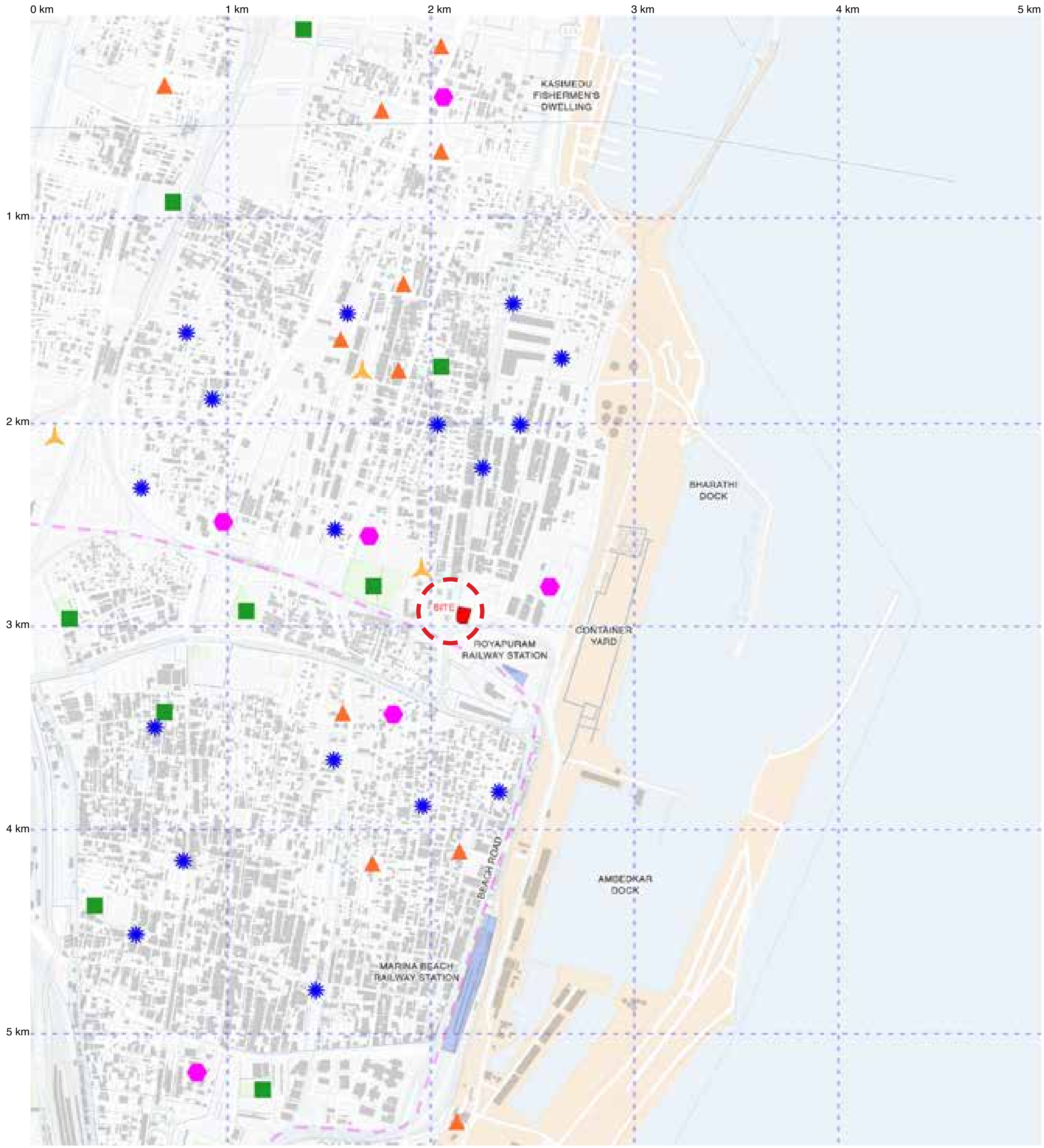
COMMERCIAL

INDUSTRIAL

OPEN/ GREEN

INFORMAL SETTLEMENTS

Source - Chennai Metropolitan Development Authority



3.4 IDENTIFYING THE EXISTING AMENITIES IN CONTEXT

The older existing infrastructure and amenities can be dated back to the post independence era and the newer facilities are not dominantly developed keeping in mind the future adaptations or flexibility in usage as is the need of the hour.

Comprehensively studying the context demands development towards a new direction with flexibility principles a the core. As a dynamic of qualified urban space creation can facilitate spaces to provide multiple opportunities for the general public.

INSTITUTIONAL
COMMERCIAL
INDUSTRIAL
OPEN/ GREEN
INFORMAL SETTLEMENTS

Source - OpenStreetMap

Royapuram Railway Station
Source - Google Earth Pro Images

Chennai Port
Source - Google Maps Images

Kasimedu Fishing Harbour
Source - Live Chennai News

Administrative offices on Beach Road
Source - Google Earth Pro Images

1. MS KOIL Road

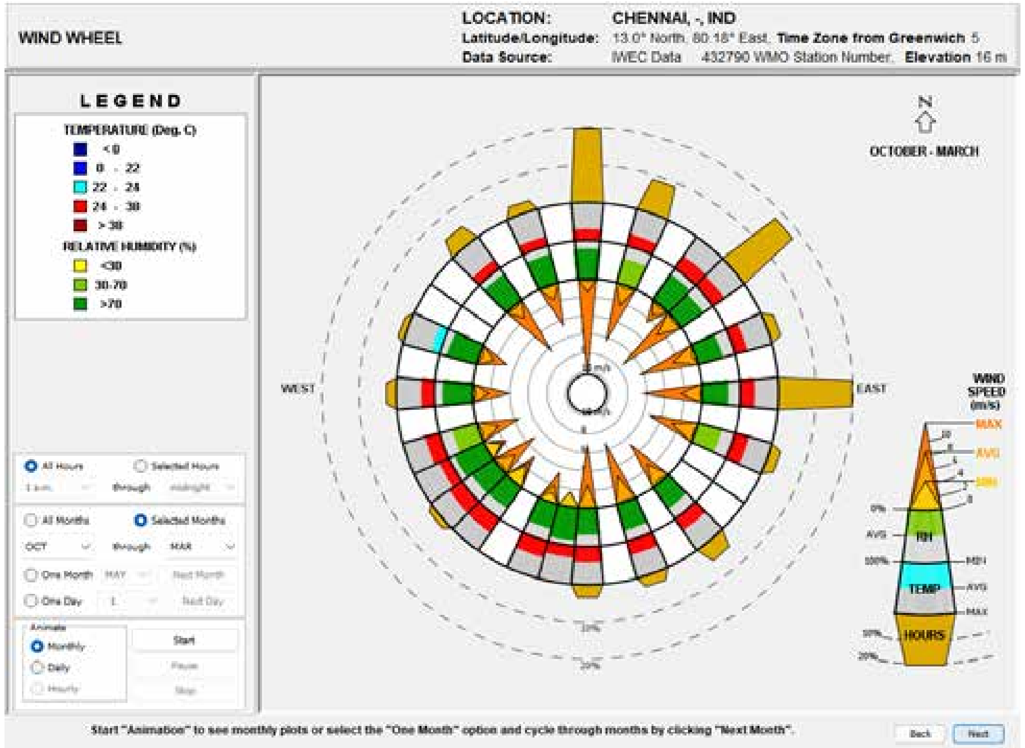
One of the most significant commercial street of Royapuram, MS Koil road houses several busineeses and public facilities making it an active public spot. As the site is located on this street, it becomes accessible with respect to the physical as well as socio-cultural realm.

2. THOPPAI STREET

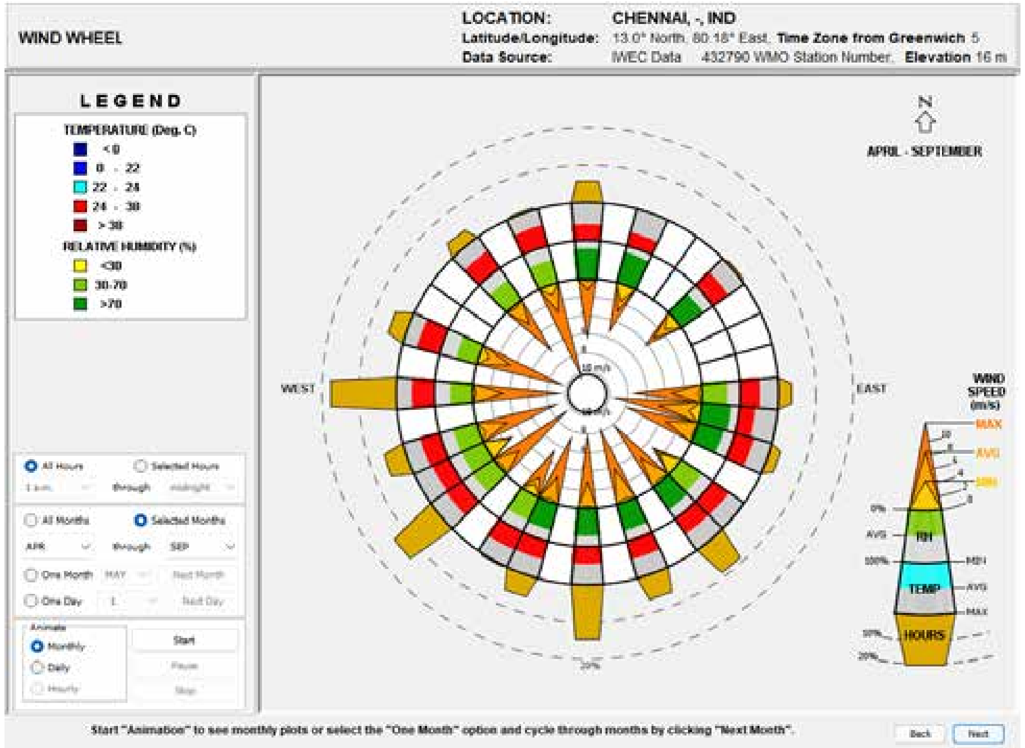
Having mixed use with commercial shops on the ground floor and residences on the upper storeys, is one of the pecular features of the primary and secondary streets in Royapuram. Thoppai street is one such street which showcases the fundamental characteristic of the built fabric around the site.


ST ANNE'S HIGH SCHOOL
ST PETER'S COMMUNITY CENTRE
BHAGWAN MAHAVIR EYE HOSPITAL
1
MS KOIL ROAD
2
THOPPAI ST
SITE
N TERMINUS ROAD
ROYAPURAM RAILWAY STATION
R.S.R.M GOVERNMENT HOSPITAL
CHENNAI CORPORATION PARK
RESIDENTIAL
MIXED USE
RESIDENTIAL
MIXED USE
INSTITUTIONAL
GREEN / OPEN
ROAD
RAIL LINE

CLIMATE DATA FOR DESIGN CONSIDERATIONS



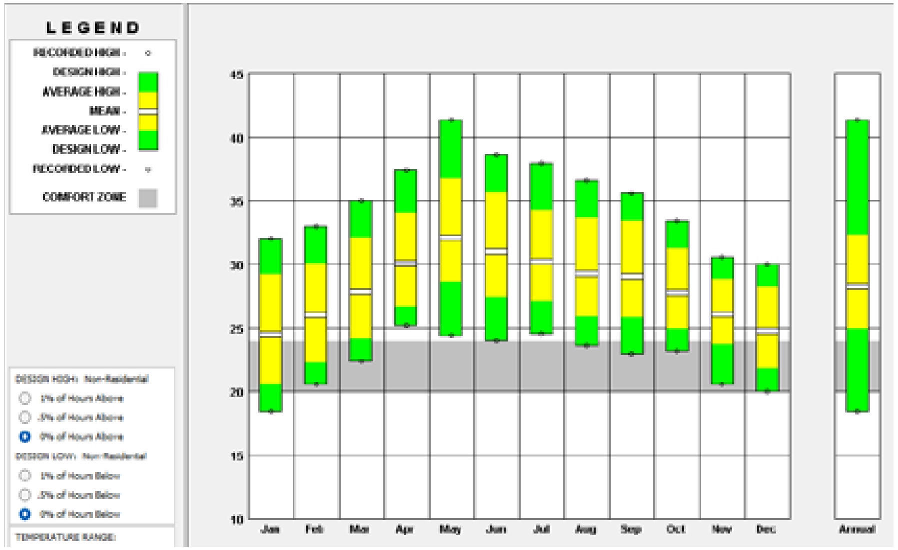
Wind Rose Diagram for October - March



Wind Rose Diagram for April - September

The Predominant weather in Chennai being Hot and Humid, it becomes very important to design for optimum ventillation and open up to west winds for better environmental comfort.

Source - Climate Consultant



Average Monthly Temperature

Source - Climate Consultant

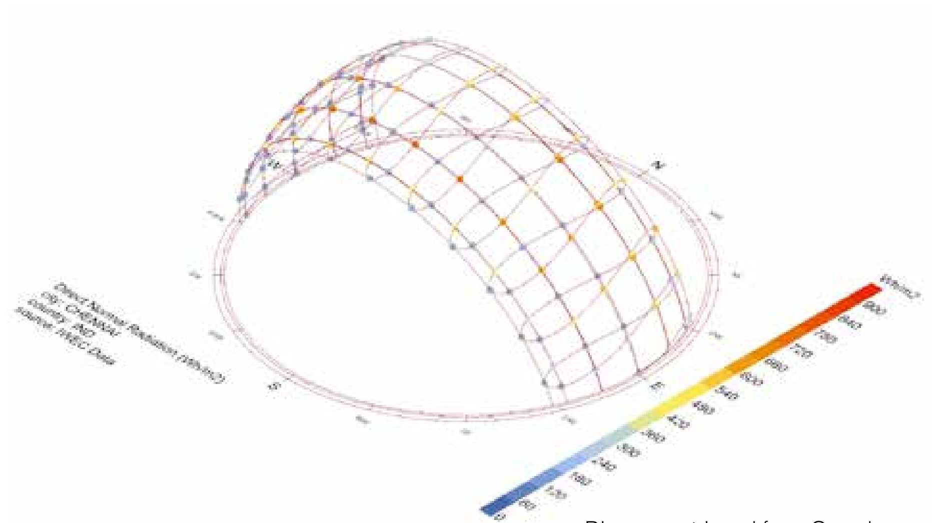
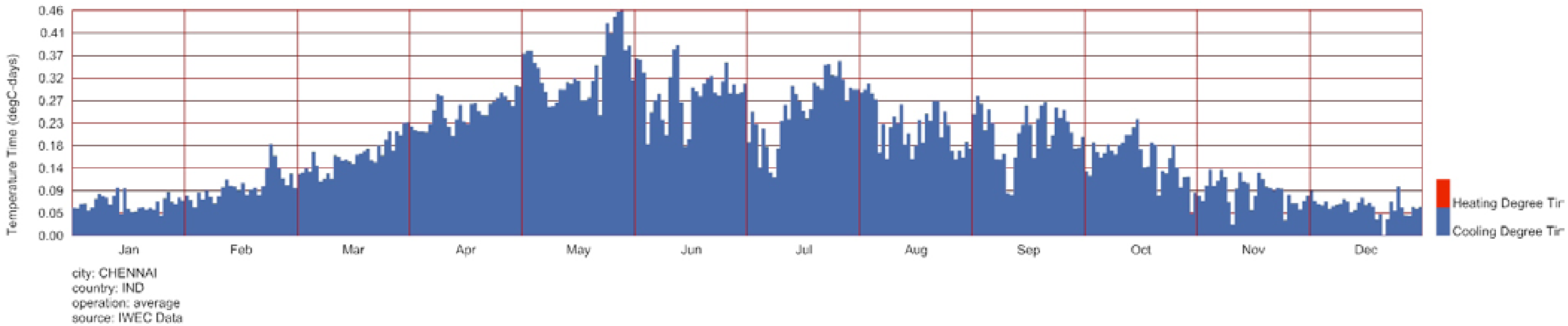


Diagram retrieved from Grasshopper

Sun Path Diagram



Heating Degree Base - 12° C
Cooling Degree Base - 24° C

Cooling Degree Days

Diagram retrieved from Grasshopper

With longer summers and high levels of humidity, it becomes important to notice that there is a requirement for cooling throughout the whole year especially from April - September.

4. DESIGN PROPOSAL

4.1 DESIGN OBJECTIVES

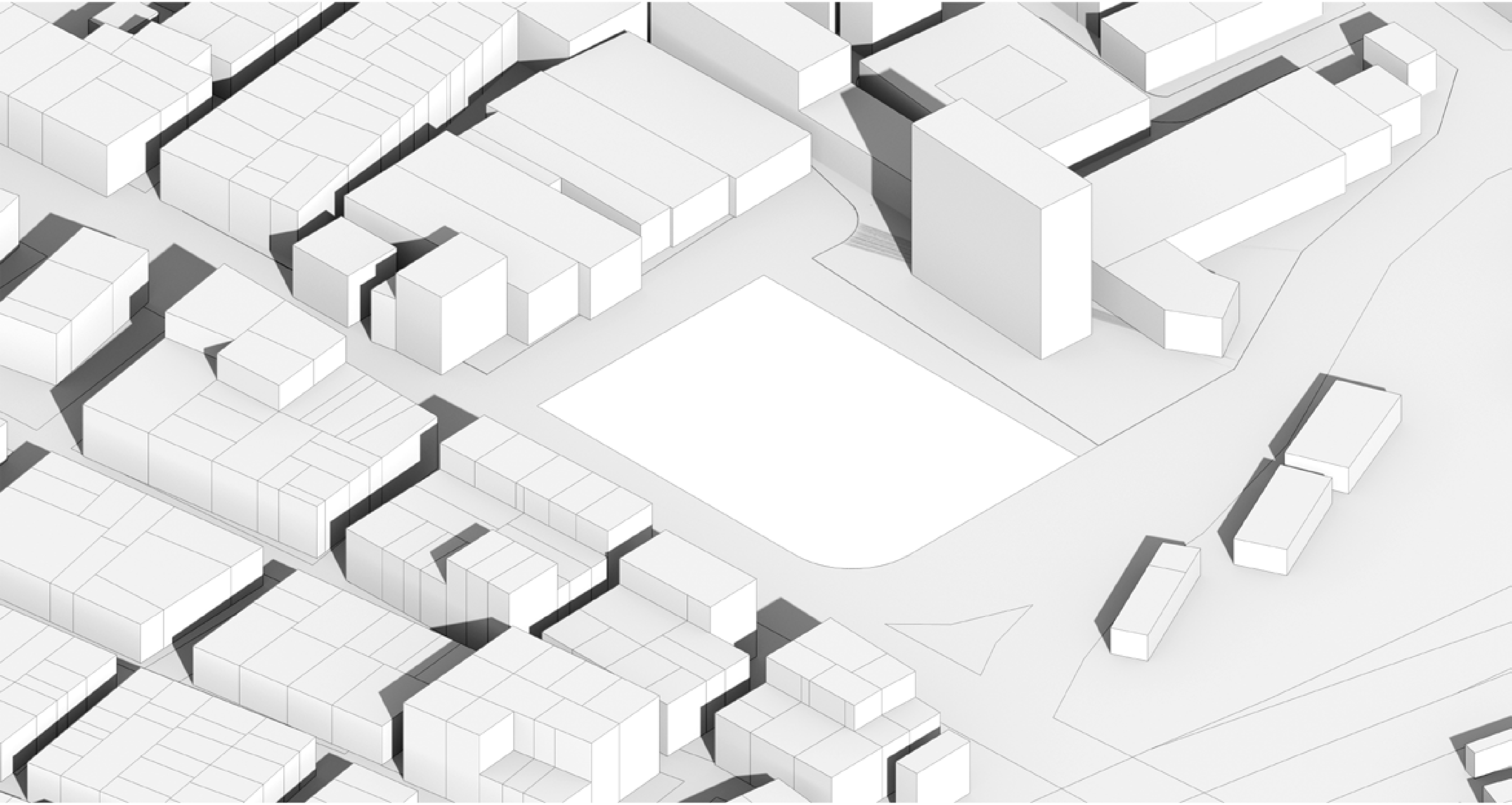
Objectives

1. To design Co Living, Co Working Spaces to provide flexible solutions to emerging urban needs.

2. To Design prefab modules which can be standardised and incorporated as a global model of development in different configurations for an Investor Company.

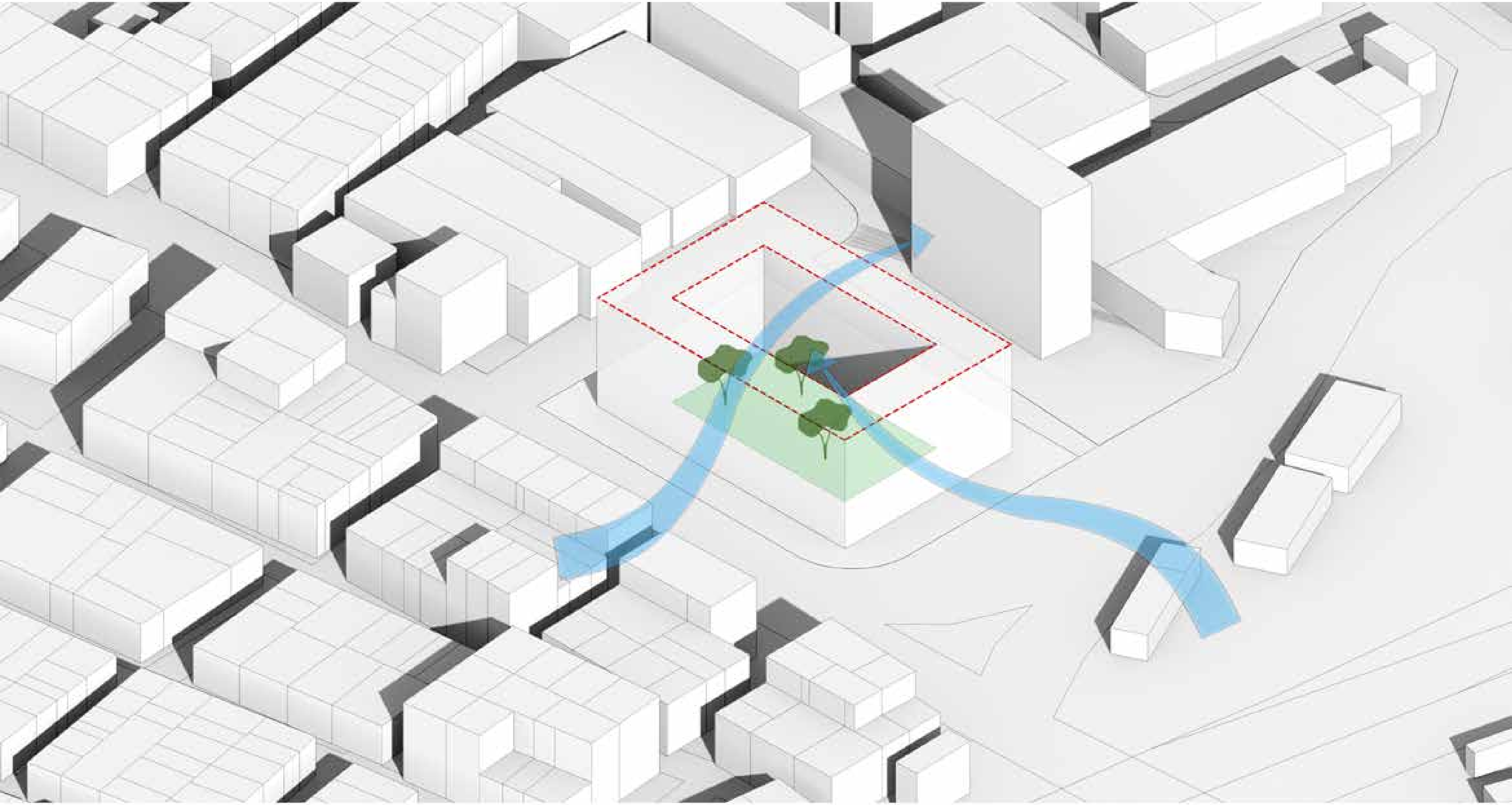
3. To provide vibrant urban spaces for community engagement based on the analysis of Immediate Context.

4.2 CONCEPT & DESIGN DERIVATION



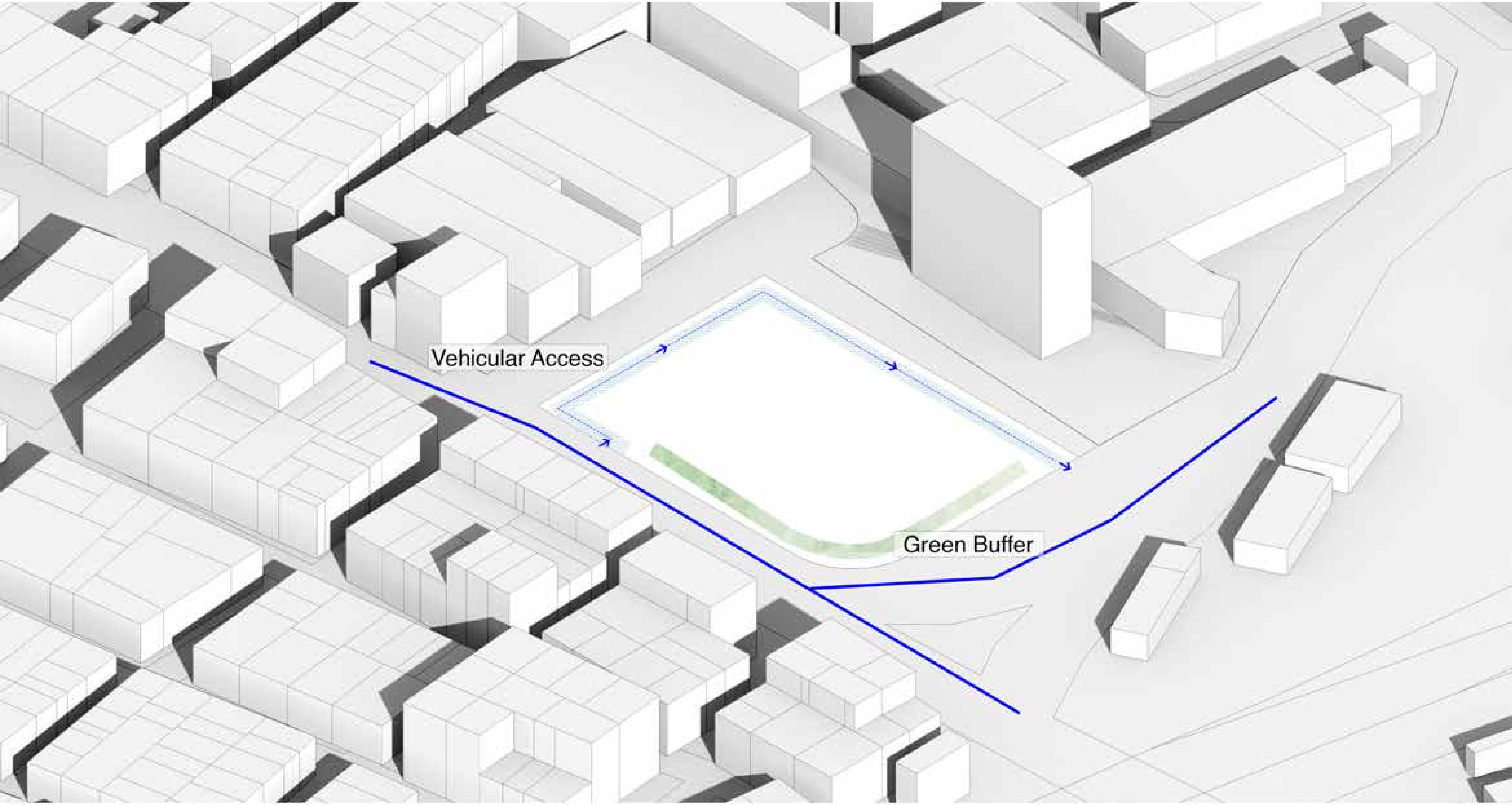
THE SITE

Area with disused government housing buildings near to Port, a Railway Station and a mixed use area with market and commercial activities.

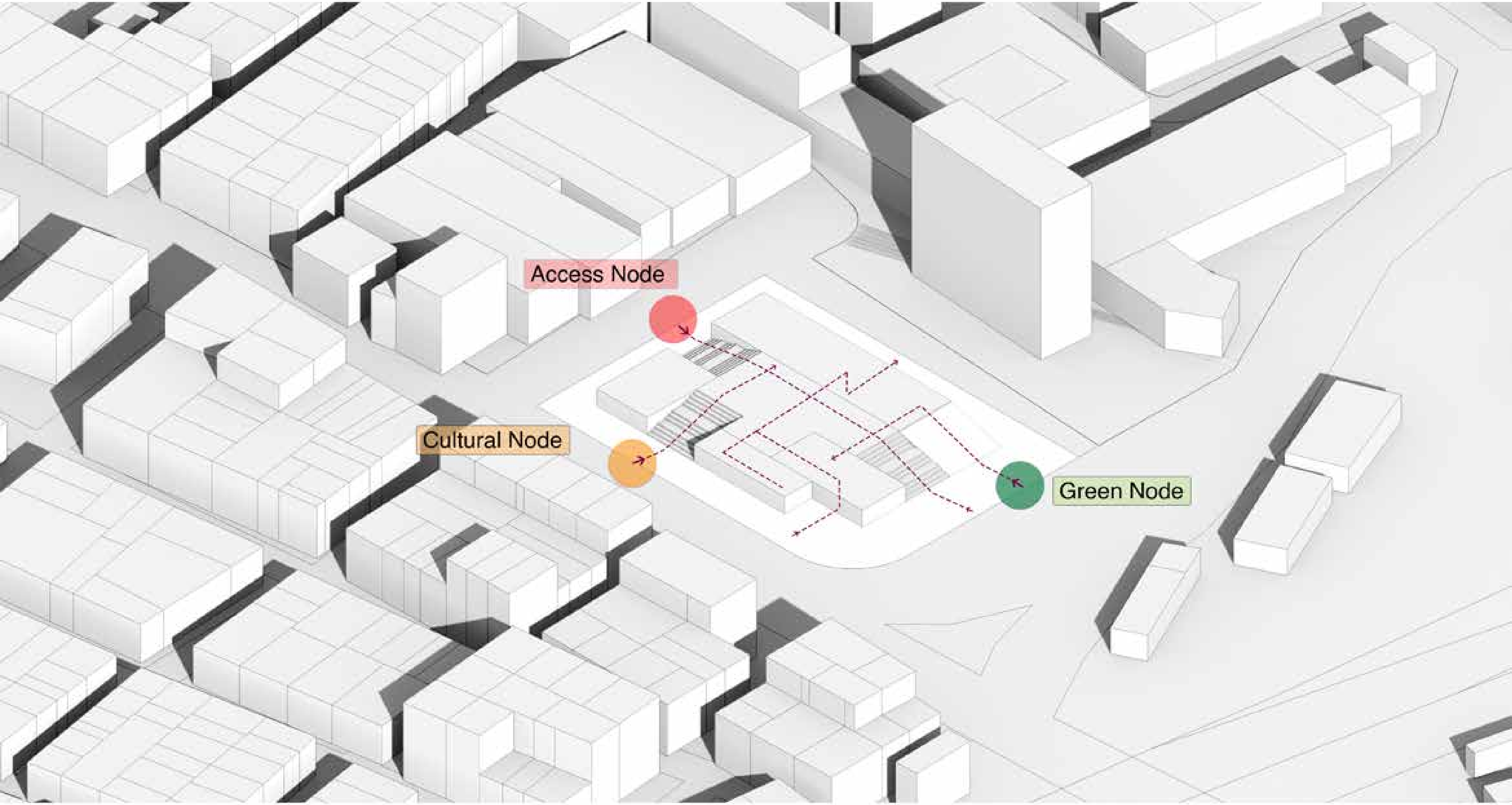


TRADITIONAL COURTYARD TYPOLOGY

For efficient ventillation in Hot and Humid Climate of Chennai.

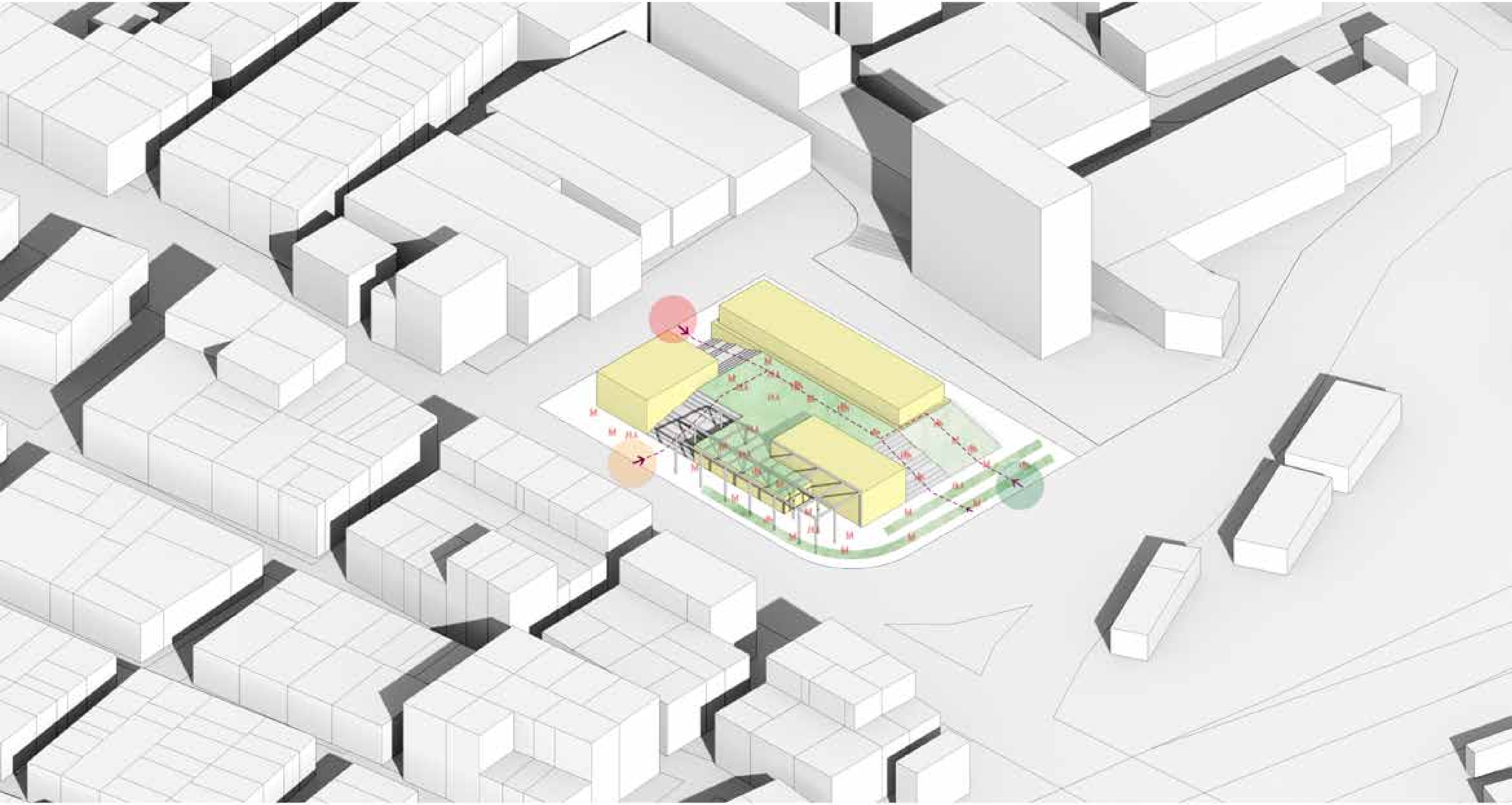


GREEN EDGE
Softening the busy urban edge and addressing the issue of lack of green public spaces in the context.



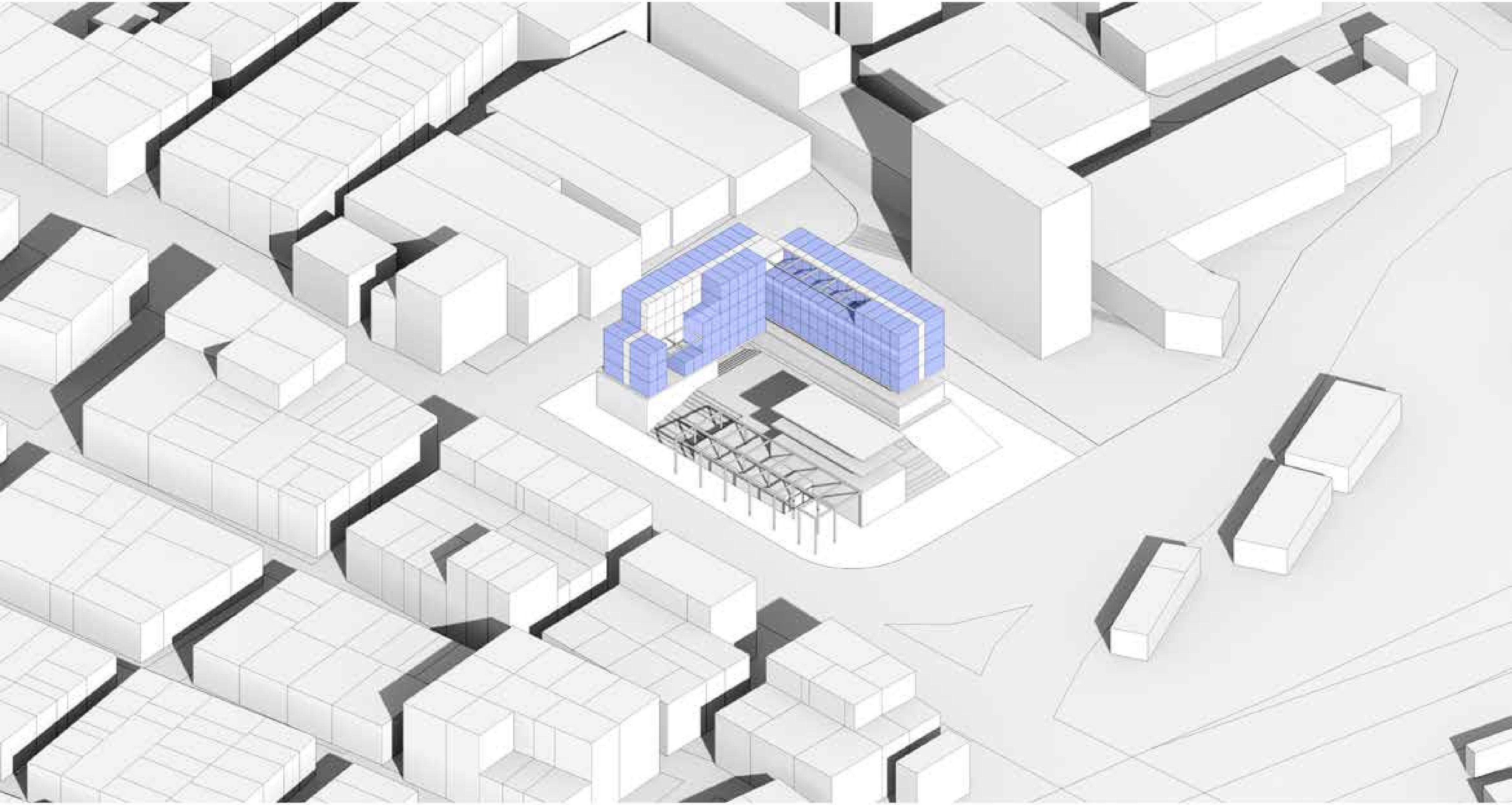
CONTEXT RESPONSE

Connecting the critical nodes with an elevated urban courtyard.



MULTI-FUNCTIONAL PUBLIC SPACES

Flexible Market and Co-working blocks opening up to the green areas and cafeteria.

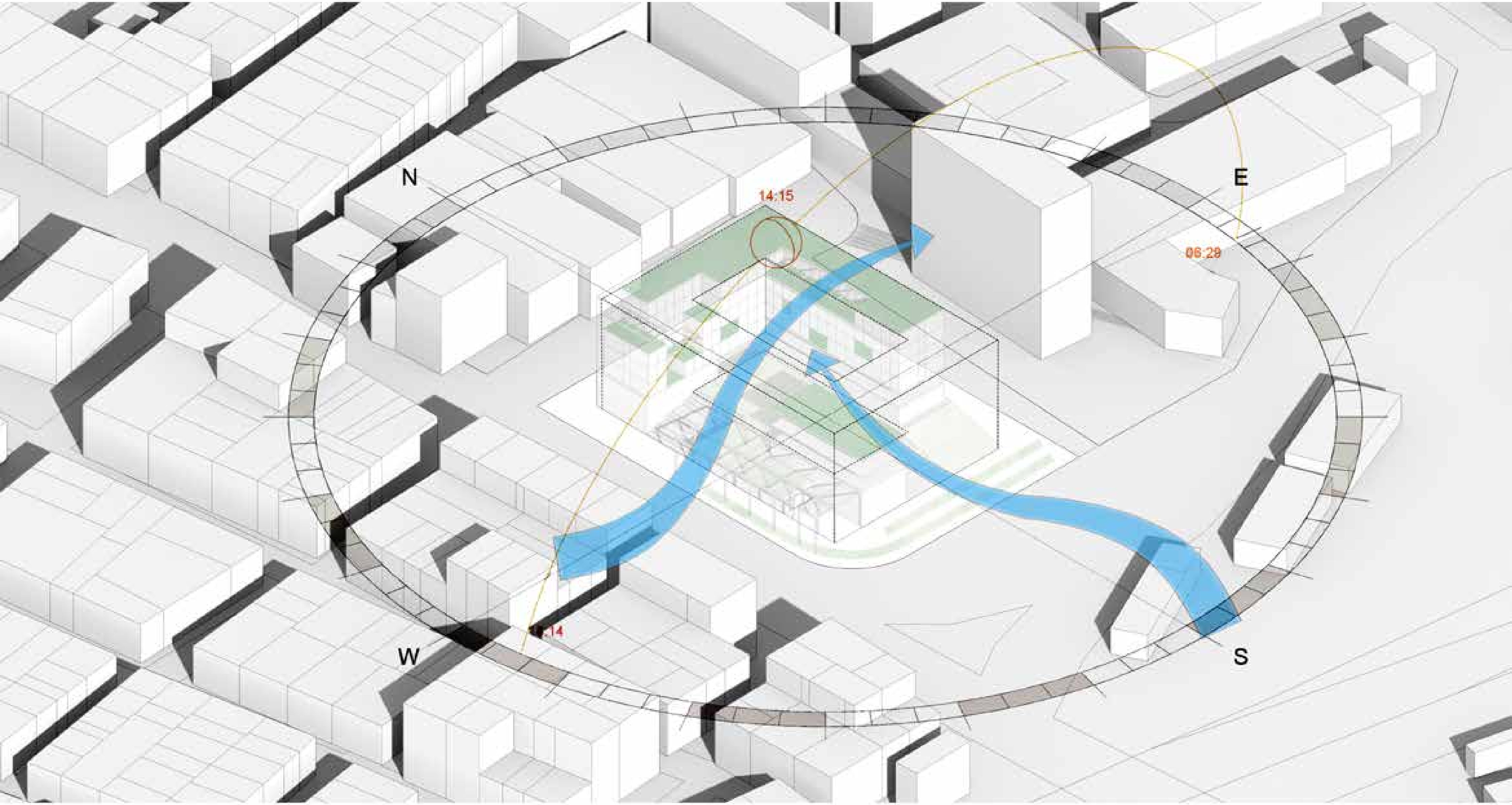


MODULAR COLIVING

Upper Floors assembled with modular coliving blocks manufactured at factory.

CO-GREEN SPACES

Green terraces integerated at all levels to create a vibrant meeting and sharing environment.



CLIMATE CONSIDERATION

Opening up to maximum winds, the spatial organisation of courtyard creates a green filter to cool down the micro environment of the site.

4.3 TECHNICAL DRAWINGS

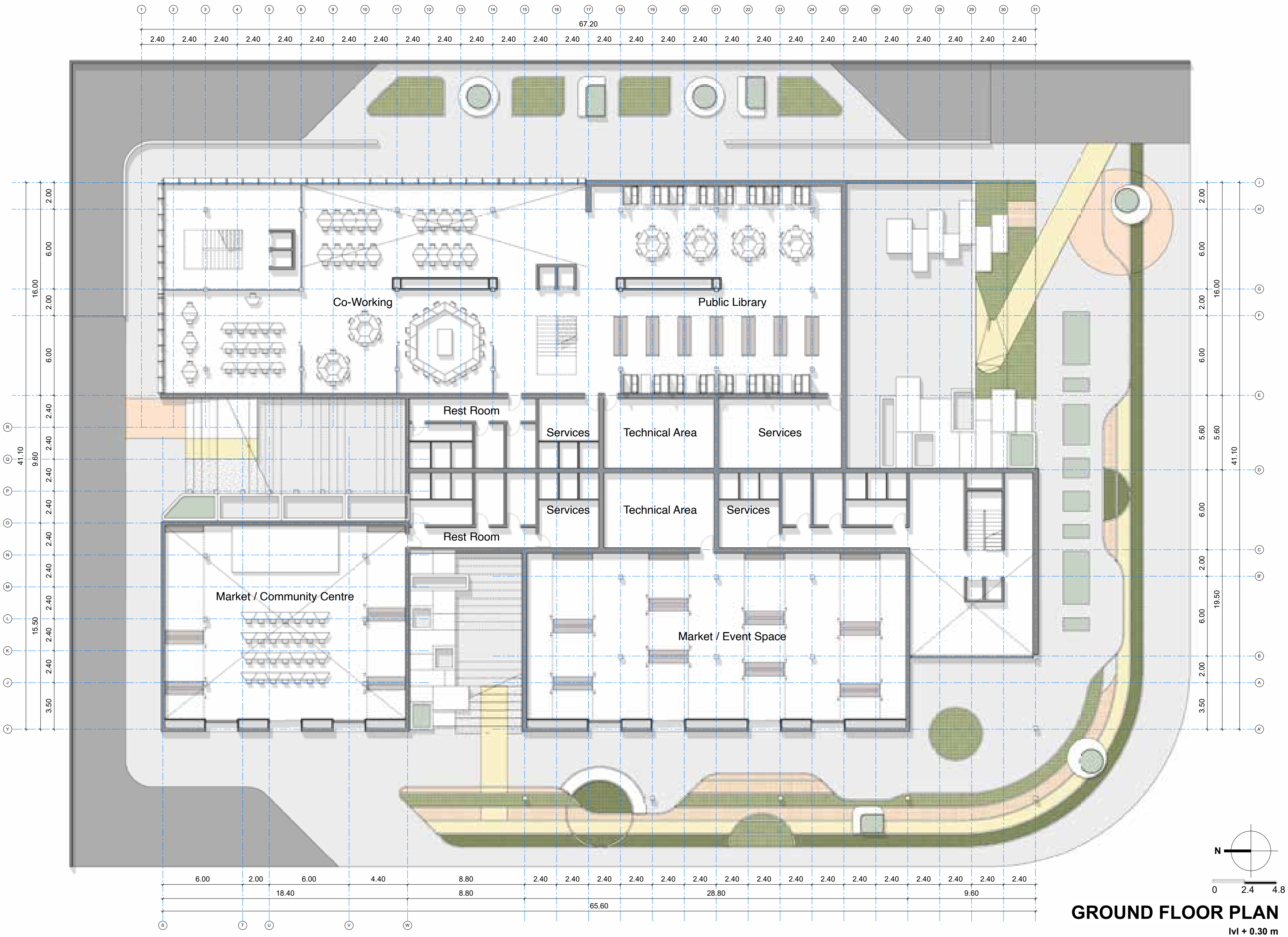
- FLOOR PLANS
- SECTIONAL AXONOMETRIC VIEWS
- STREET VIEWS

SITE OVERVIEW

Flexible Co-Workng, Co-Living and Community centres opening up to shaded green spaces generating a vibrant shared environment.

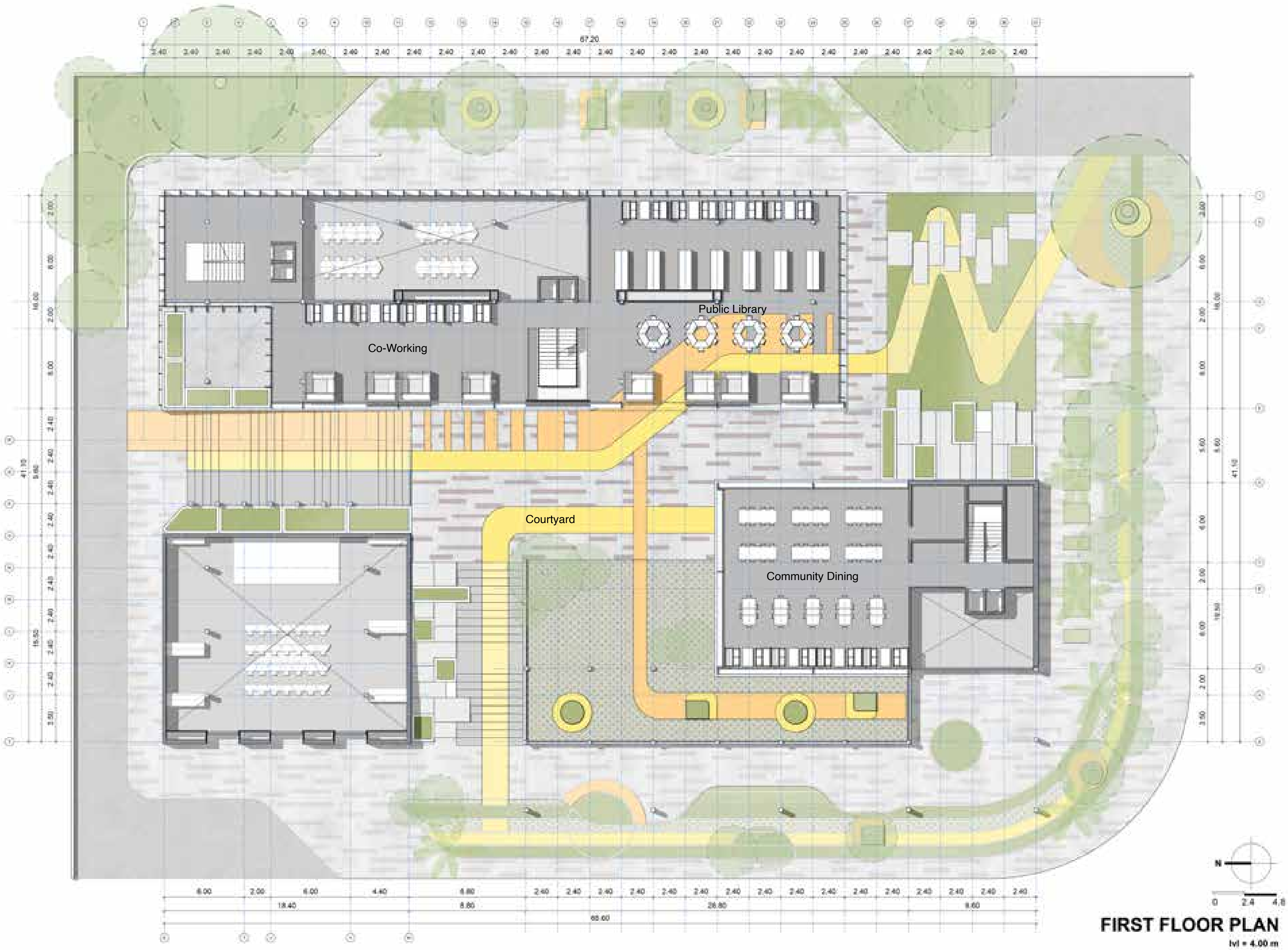
Site Plan

URBAN IMAGE



GROUND FLOOR PLAN

lvl + 0.30 m



FIRST FLOOR PLAN

lvl + 4.00 m

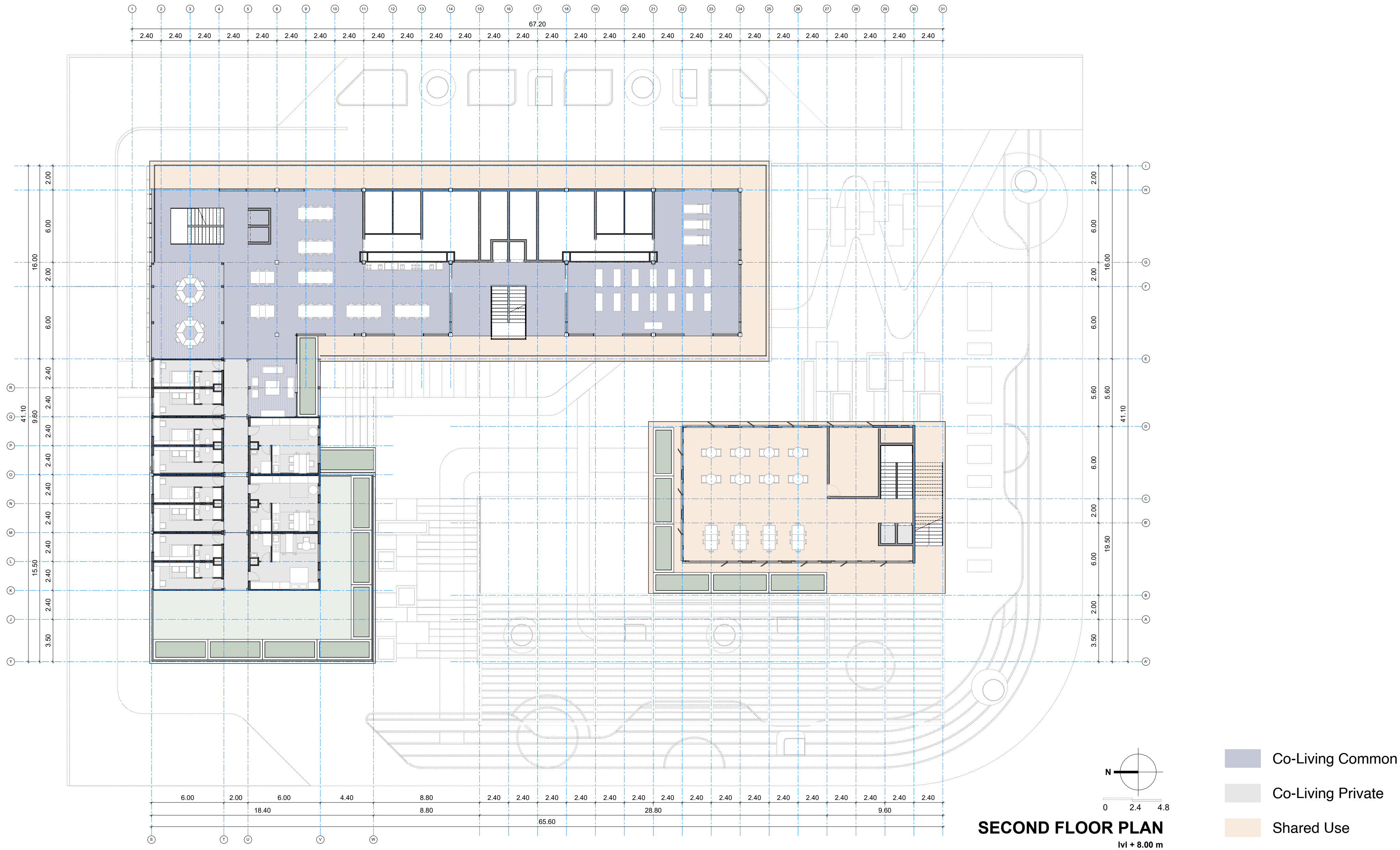
In the existing dense fabric of Royapuram, response to the market street and the lack of green areas become the starting points of desgin. The project is devised to provide a platform for multiple community activities during different times of the day and can adapt to changing requirements seamlessly.

The green edge along the main street creates a buffer from the traffic and softens the streetscape creating a community friendly urban pocket. The central elevated courtyard becomes a focal point of the 3 axis generated by the Access Node, Cultural Node and the Green Node. It not only provides efficient climatic regulation in the project but also helps in activating public activities away from the busy street. The open courtyard is designed to become an extension of the adjacent co-working and community centric built volumes. The vibrant colors of the surrounding are drawn into the site with pop colors in landscape.

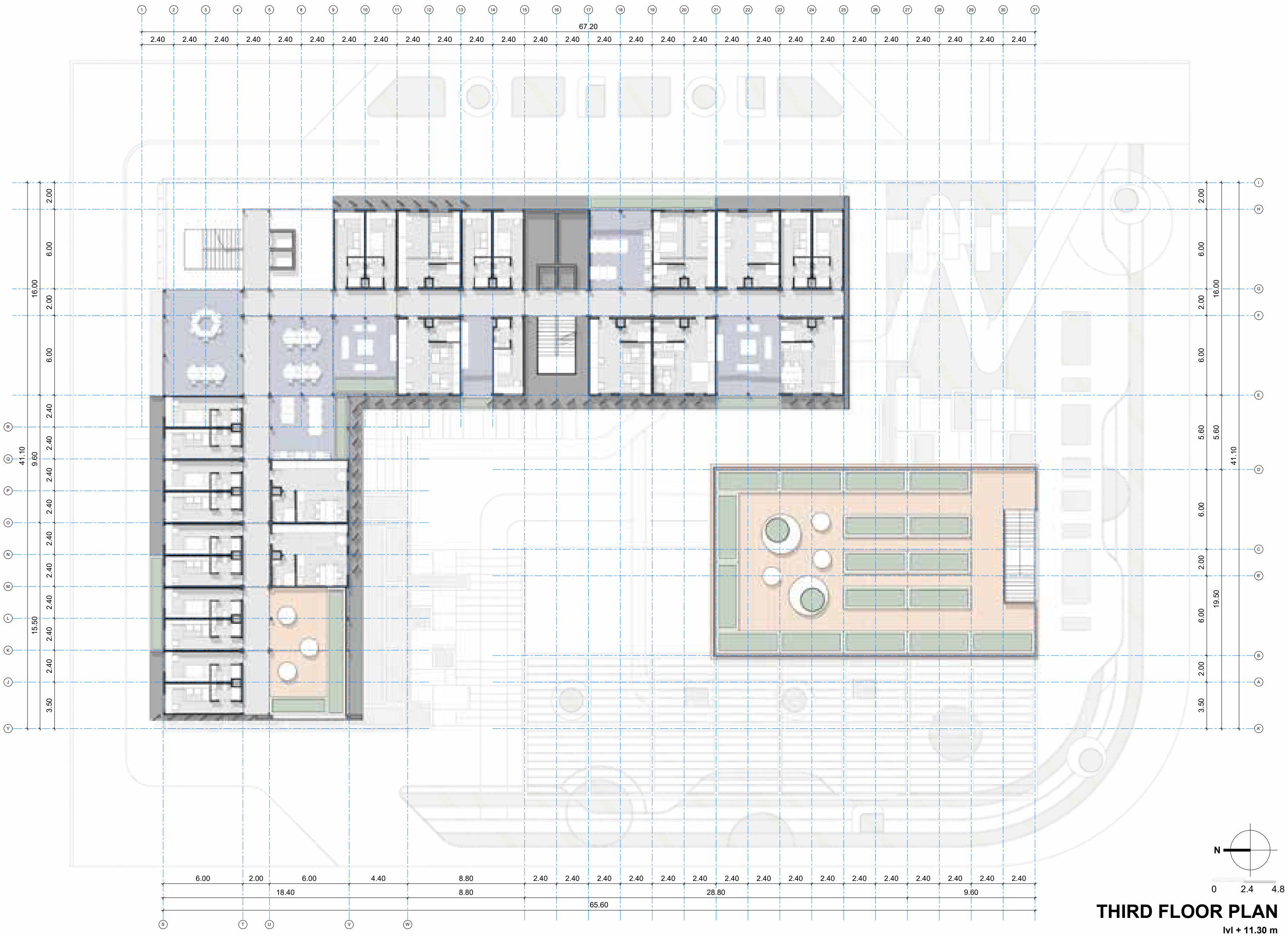
The upper storeys are dedicated to Co-living Areas with shared amenities. The built mass is configured with standardised volumetric modular prefab steel construction. The units are designed keeping flexibility as a core design value for users. All the upper floors are spatially organised with shared green terraces that become a green filter to cool down/ de-humidify the prevalent hot and humid air. The fins cutoff the harsh direct radiation on the built volumes.

Throughout the project, the approach provides a vision to explore the possibilities in adaptability and flexible multifucntional spaces with a modular way of designing the whole system: from interior modular furniture, to urban furniture, Co-working pods, Co-living units and the overall building configuration.

STREET VIEW FROM THE CULTURAL NODE



SECOND FLOOR PLAN
lvl + 8.00 m



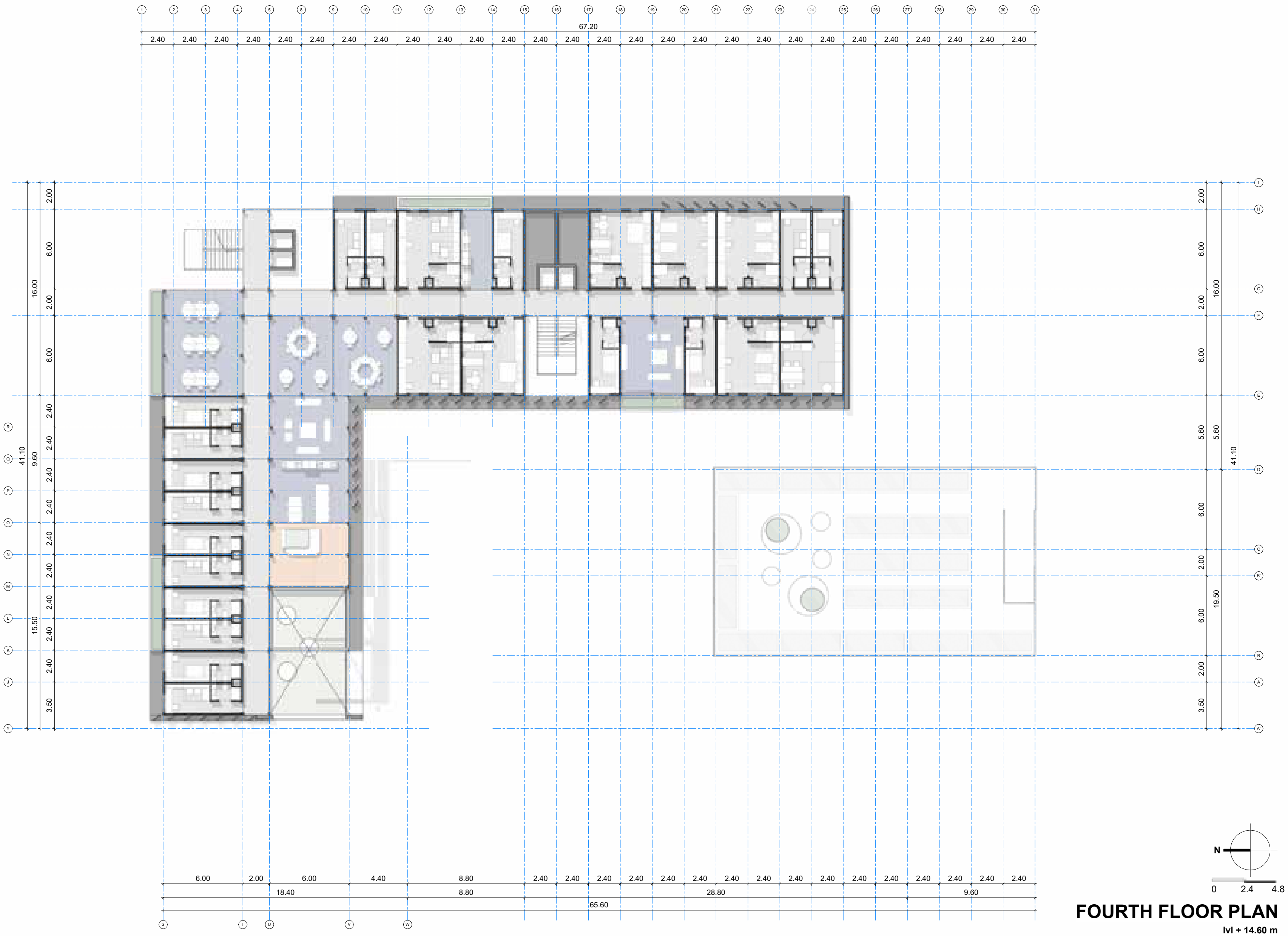
THIRD FLOOR PLAN

lvl + 11.30 m

Co-Living Common

Co-Living Private

Shared Use



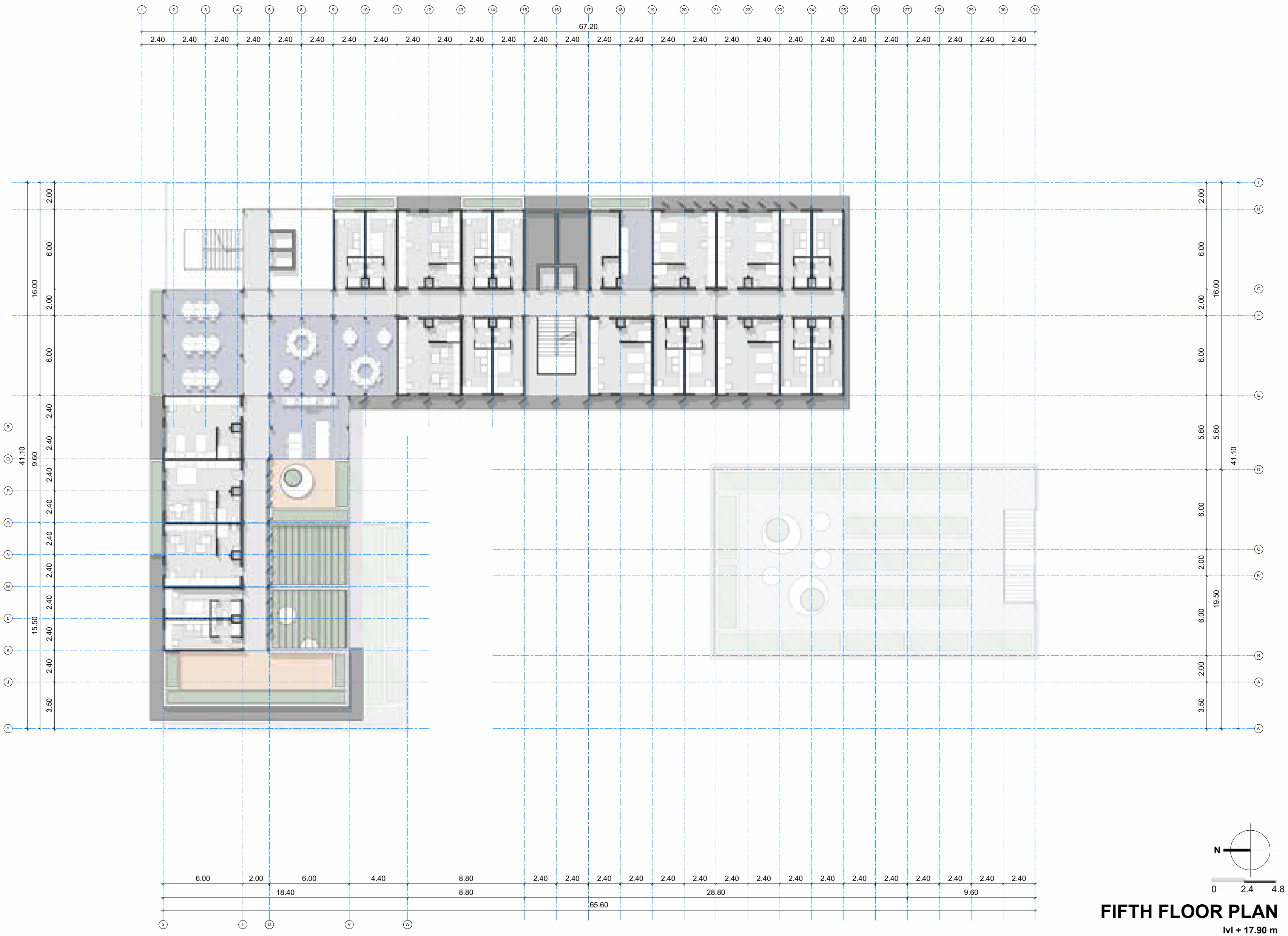
FOURTH FLOOR PLAN

lvl + 14.60 m

Co-Living Common

Co-Living Private

Shared Use



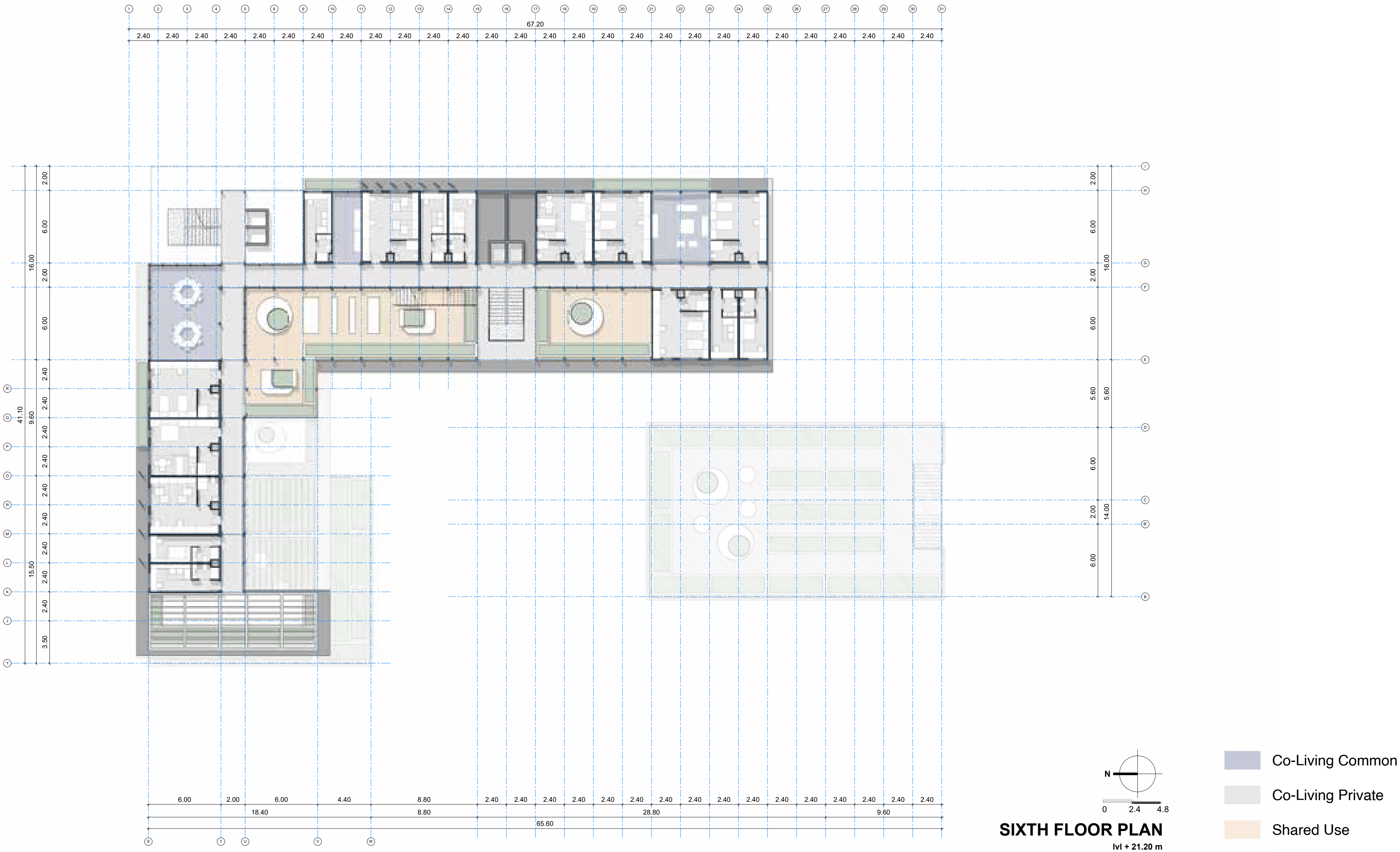
FIFTH FLOOR PLAN

lvl + 17.90 m

Co-Living Common

Co-Living Private

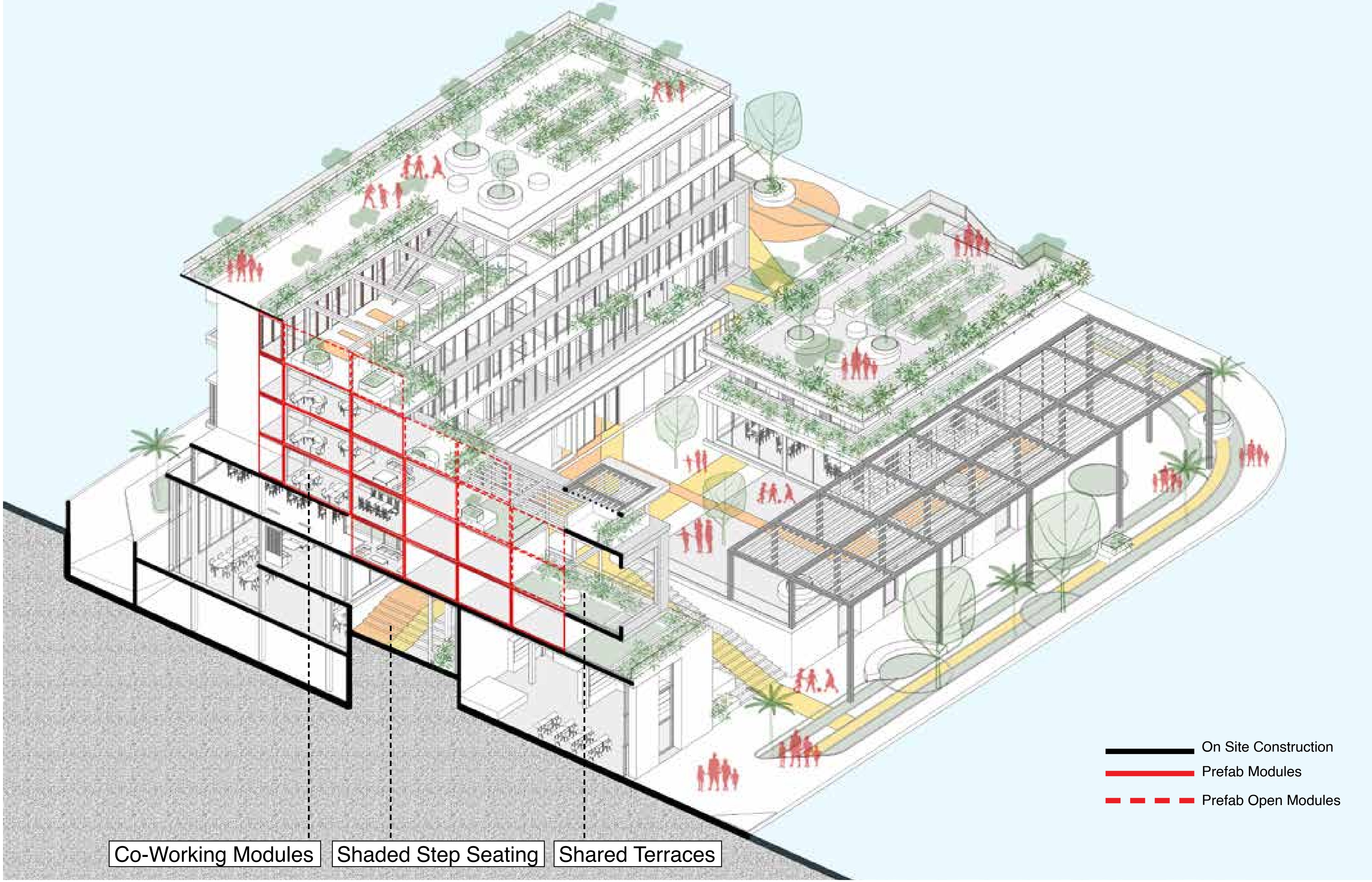
Shared Use

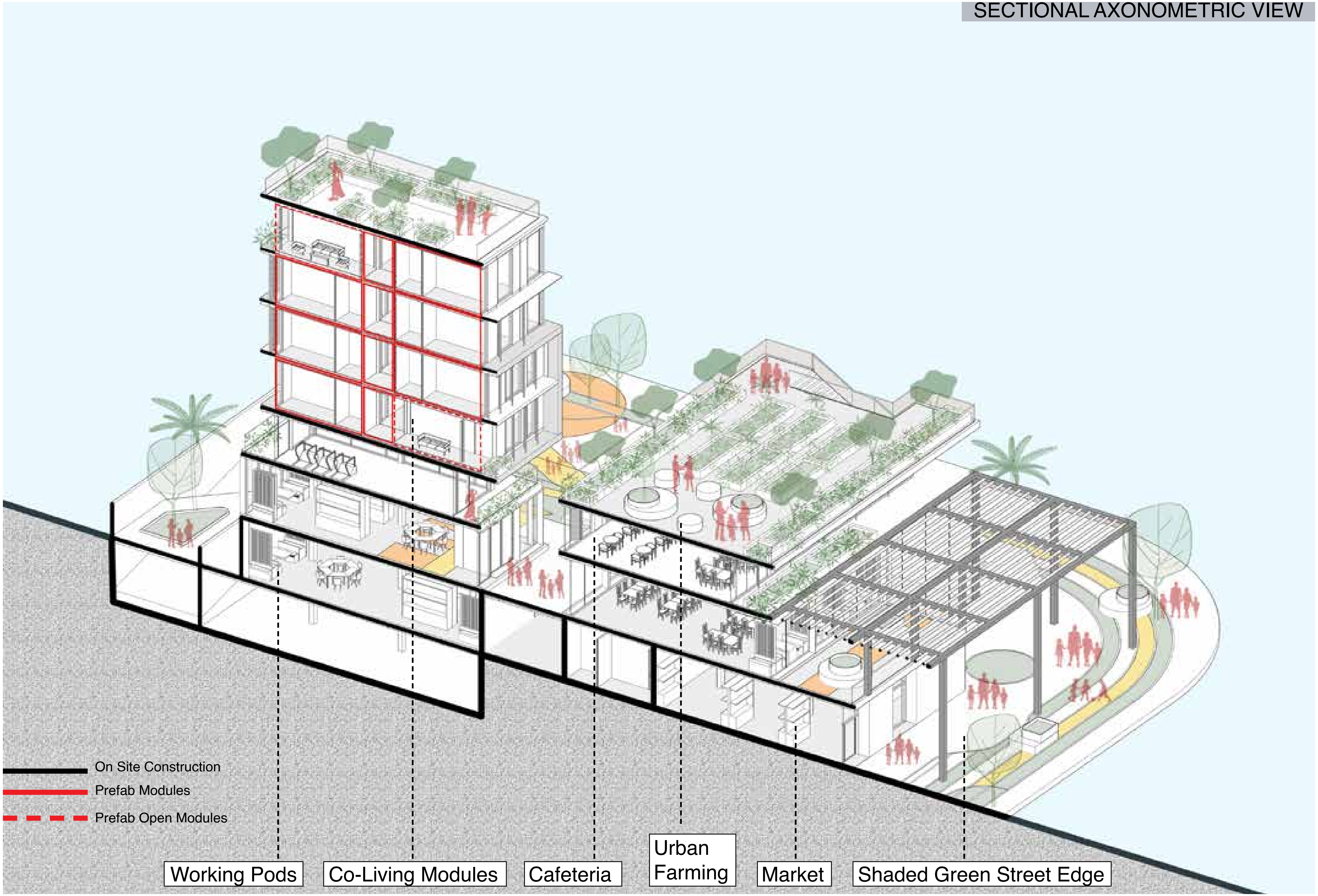


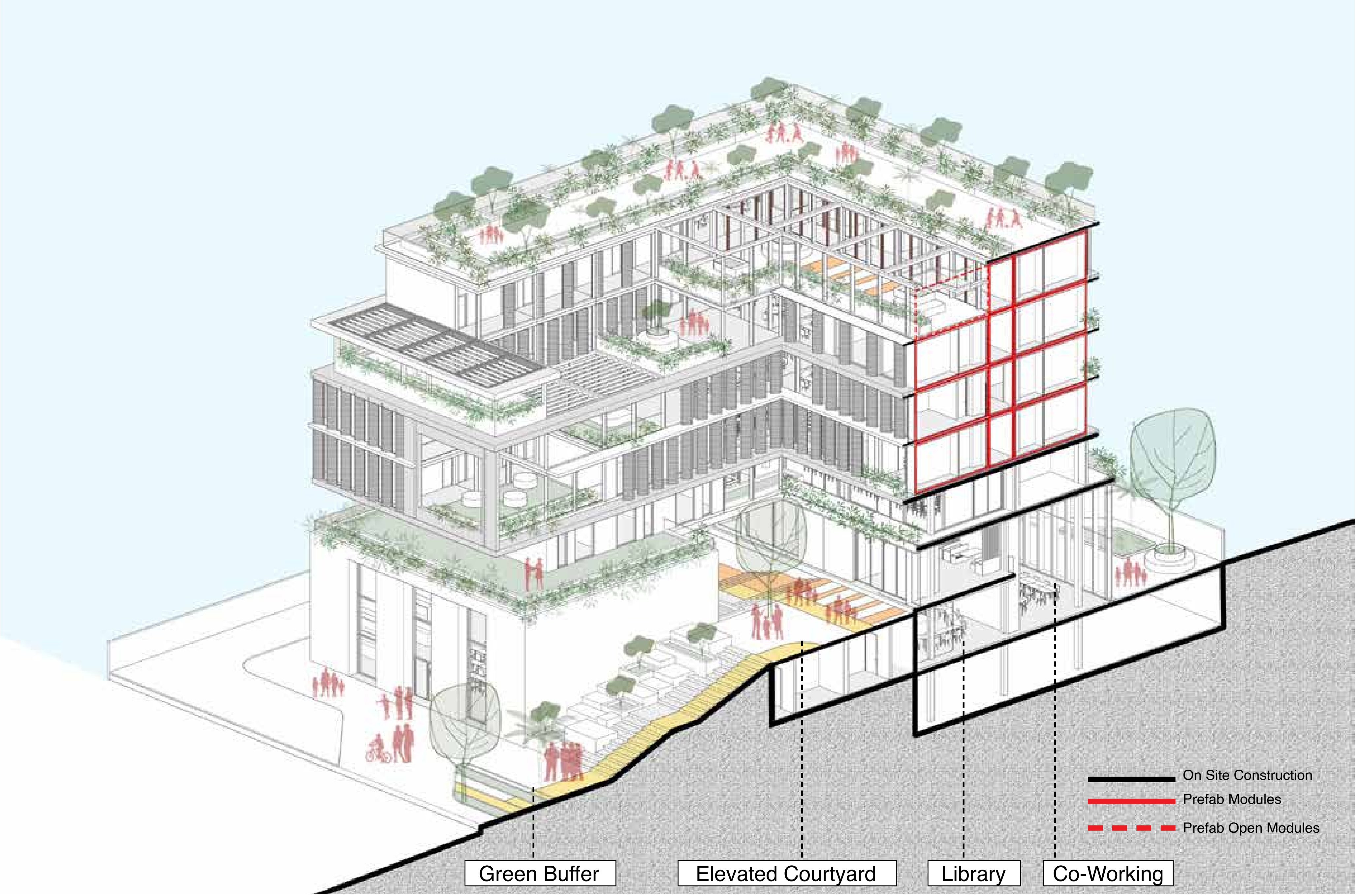
SIXTH FLOOR PLAN

lvl + 21.20 m

PROJECT OVERVIEW


On Site Construction
Prefab Modules
Prefab Open Modules
Co-Working Modules
Shaded Step Seating
Shared Terraces

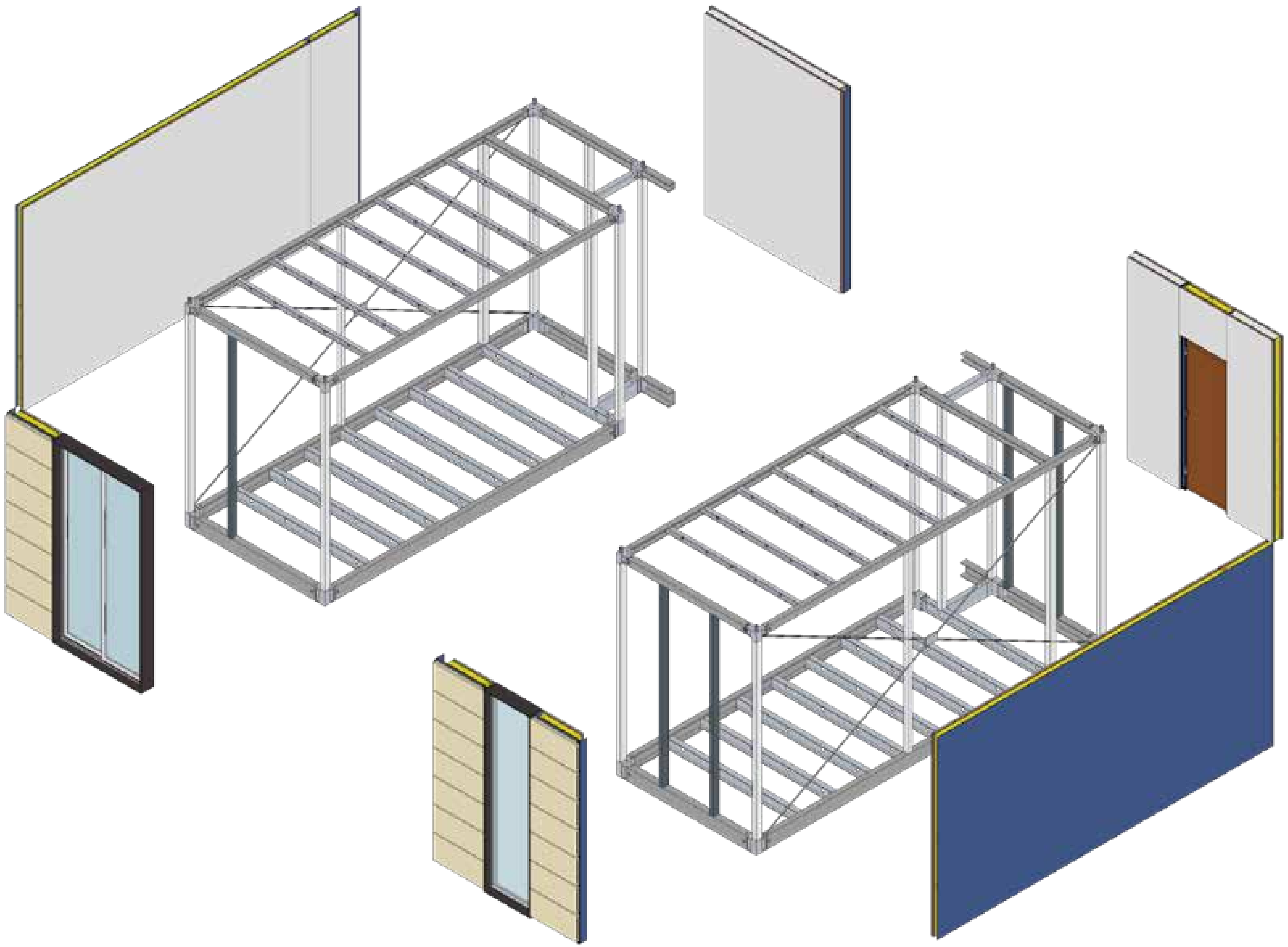

On Site Construction
Prefab Modules
Prefab Open Modules
Working Pods
Co-Living Modules
Cafeteria
Urban Farming
Market
Shaded Green Street Edge


On Site Construction
Prefab Modules
Prefab Open Modules
Green Buffer
Elevated Courtyard
Library
Co-Working

STREET VIEW

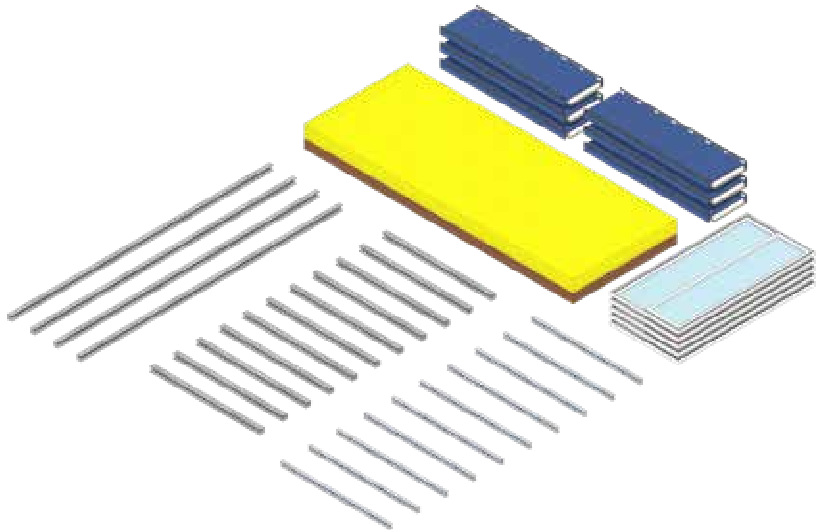
4.4 PROCESS OF BUILDING ASSEMBLY

- FROM OFFSITE FACTORY CONSTRUCTION TO ONSITE ASSEMBLY

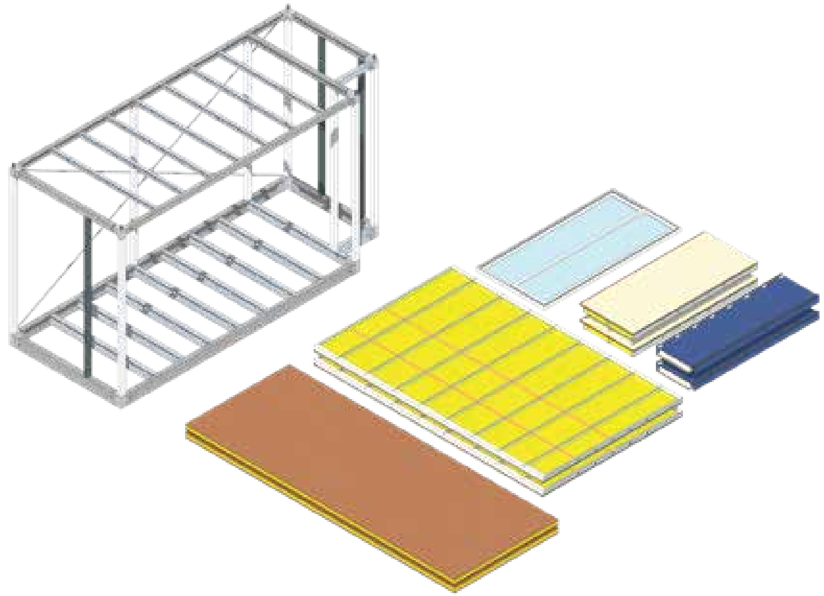


Unit Component System

PREFAB CONSTRUCTION PROCESS - UNIT
Off-Site Factory Construction

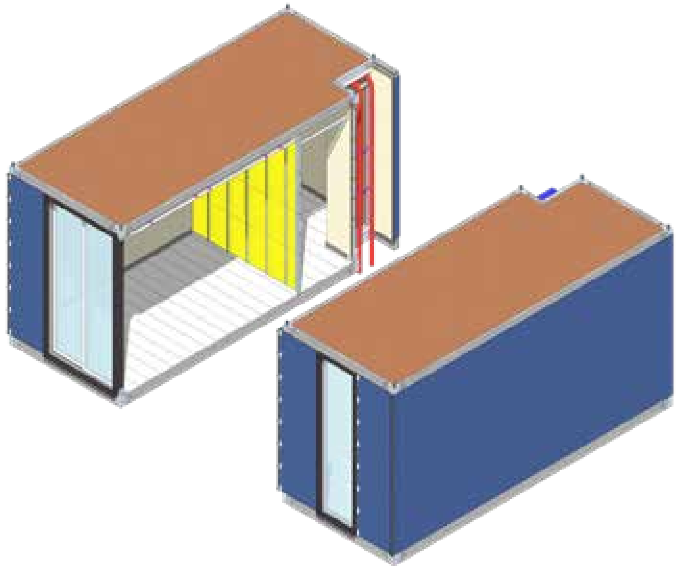


Manufacturing Modular Components

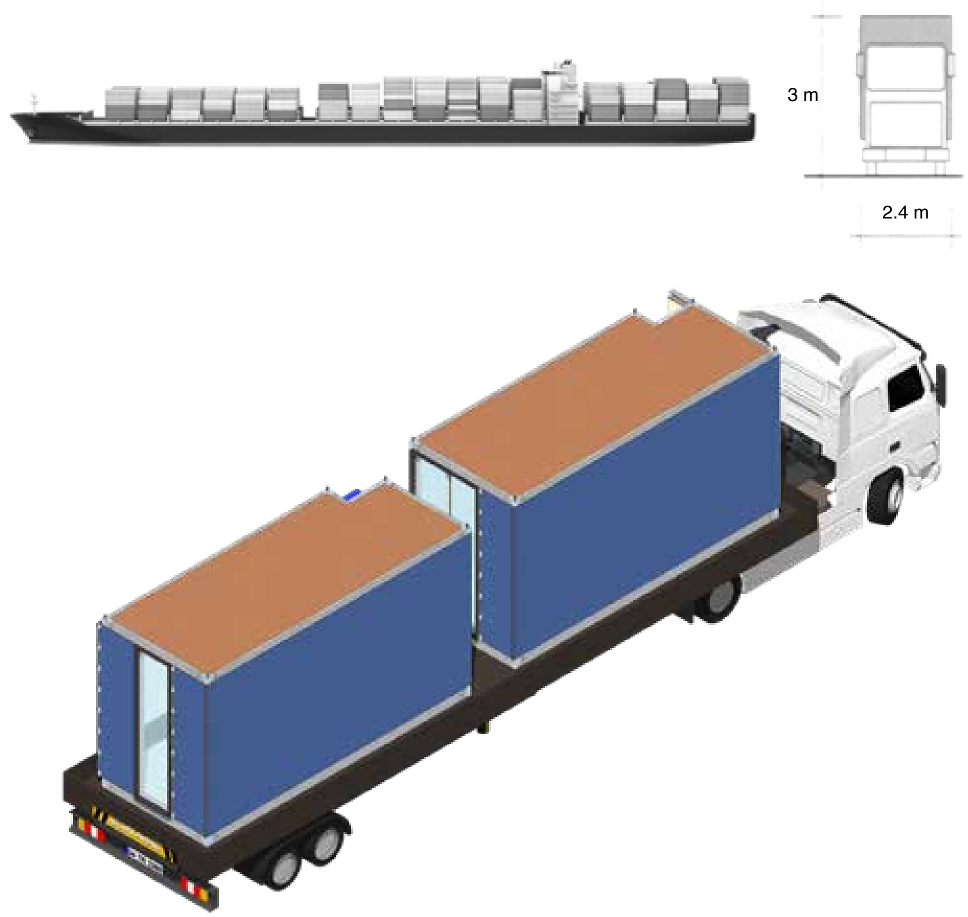


Assembly of Unit Module

1. The component are fabricated and sourced according to their modular design specifications.
2. All the components; floor systems, ceiling systems, wall systems are individually assembled in the production line with maximum precision and are assembeled together inside the factory environment.



Complete Unit Modules with Pre-Installed fixtures



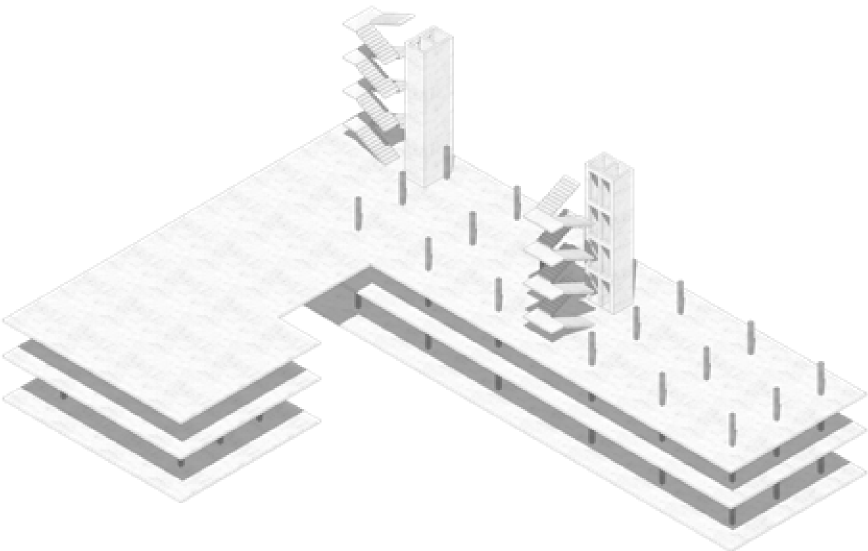
Transportation

The size of module (2.4x6x3.3m) is derived from transportation constraints, makng transportation universally possible.

3. The assembled module with internal service fittings is inspected for the local building regulations transported accoding to the assembly timeine of the construction project.
4. The module is covered with a waterproofing jacket and transported to the site using container trailers.

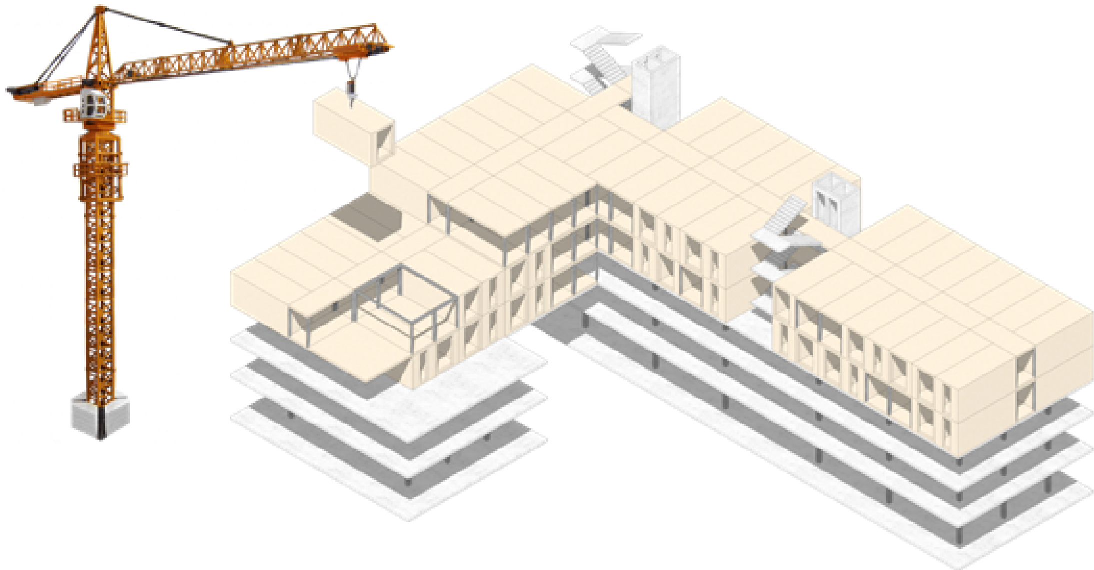
PREFAB CONSTRUCTION PROCESS - BUILDING

On-Site Assembly



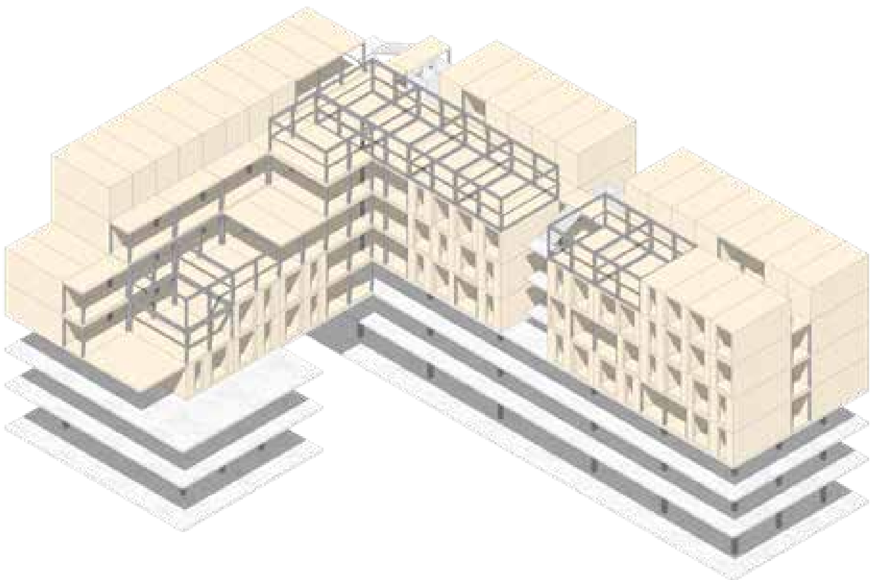
Construction of Podium Level on site simultaneous to offsite module construction.

Precast Circulation Core elements assembled on site

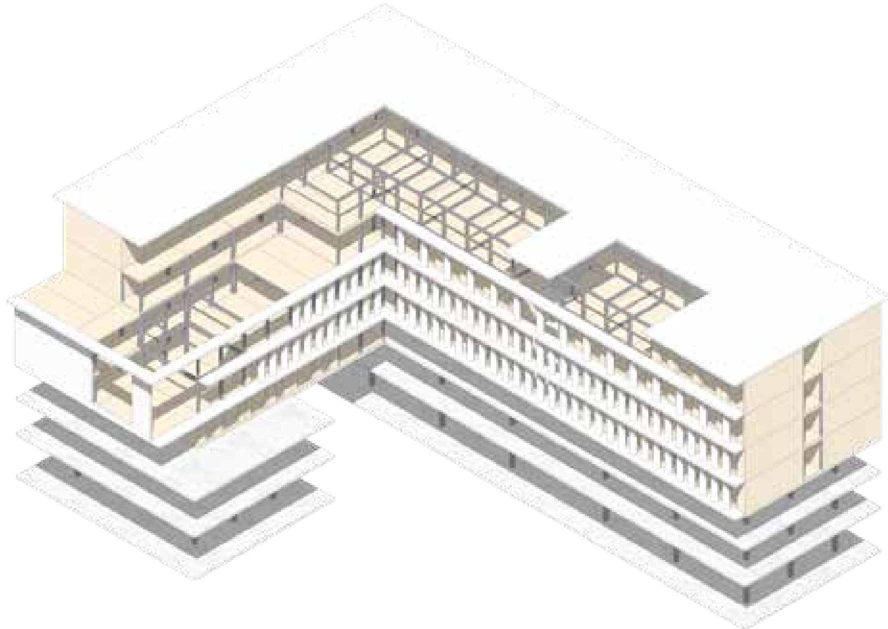


Quick Assembly of Volumetric Modular Units.

5. The base and podium are constructed on site, on which the prefabricated circulation cores are mounted.
6. The transported modules are mounted on the podium with the help of cranes and joined with connection plates on junctions.



Stacking Prototype Typologies according to spatial organisation



Addition of Facade and Terrace elements ON SITE.

7. The room modules, terrace modules and corridor modules are stacked on position.
8. Terracotta facade tiles, slab extensions, building envelope and shading devices are attached to complete the building.

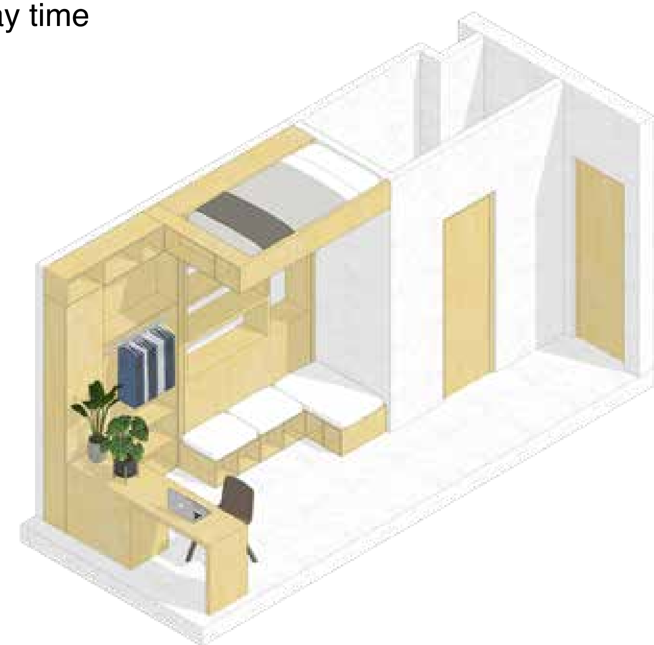
4.5 UNIT TYPOLOGIES

- ADAPTING STRUCTUTAL MODULE IN DIFFERENT CONFIGURATIONS.
- FLEXIBILITY IN UNIT INTERIORS

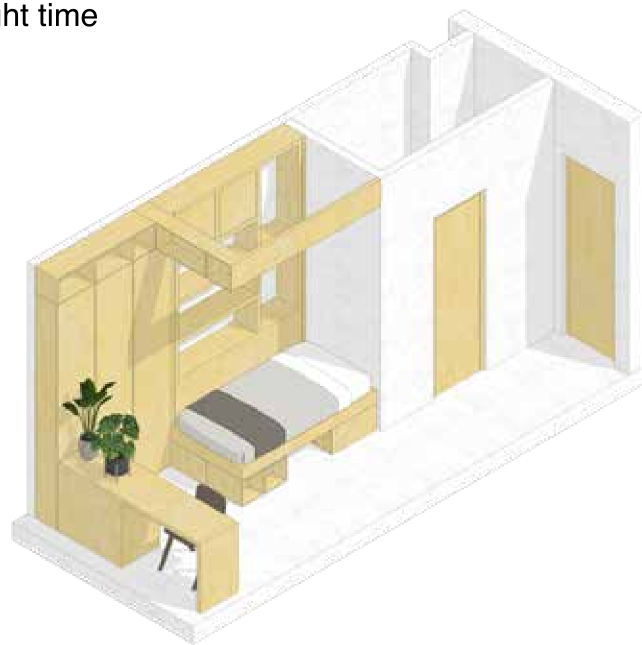
SINGLE OCCUPANCY UNIT

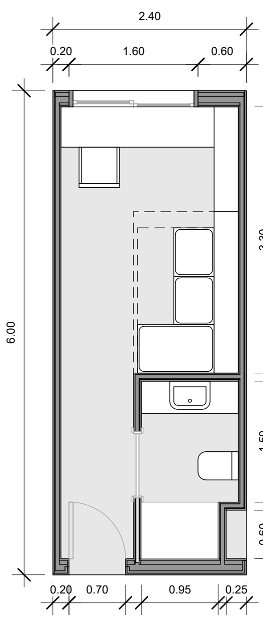
Module Type: Single Unit
Size: 6 x 2.4 x 3.3 m
Area: 14.4 sqm

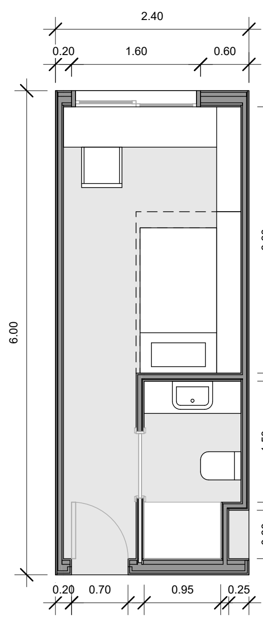
Day time



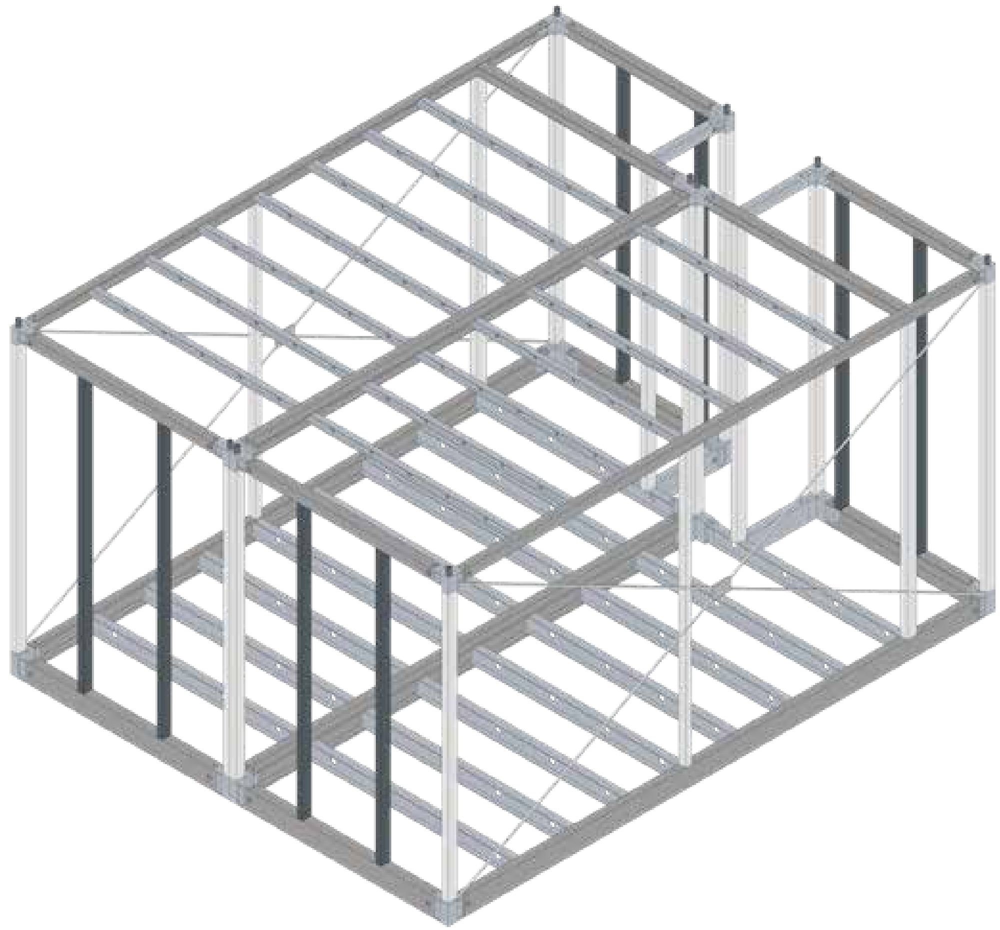
Night time





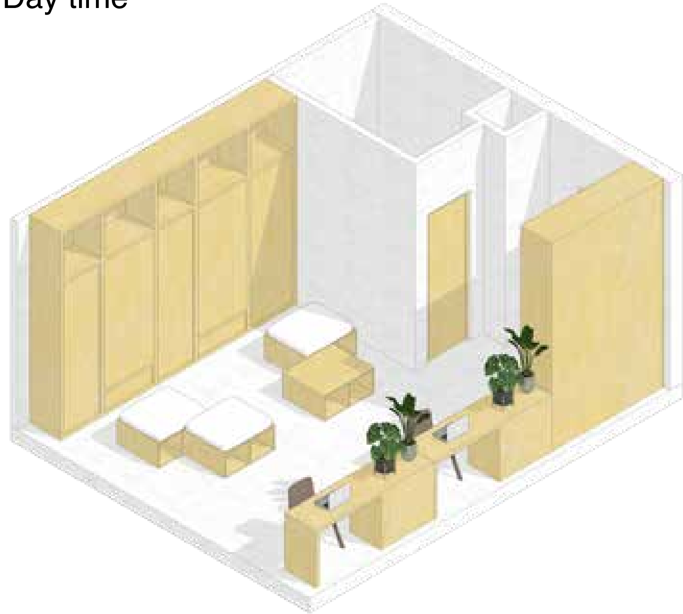


DOUBLE OCCUPANCY UNIT WITHOUT KITCHEN

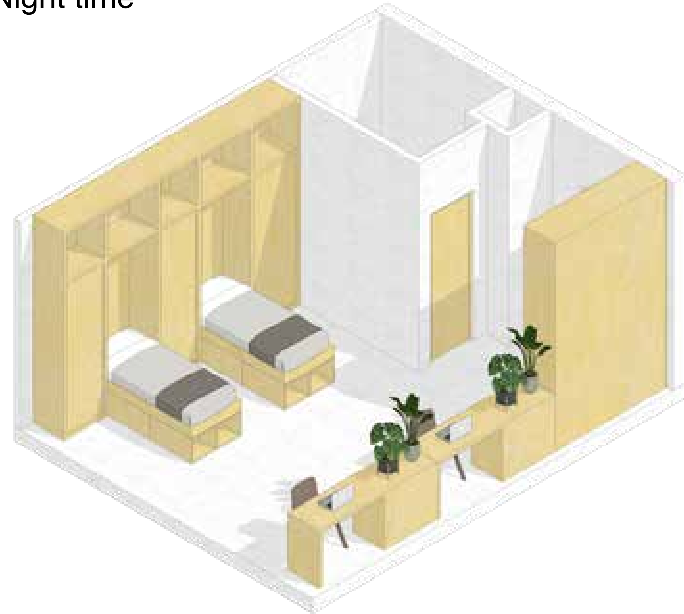


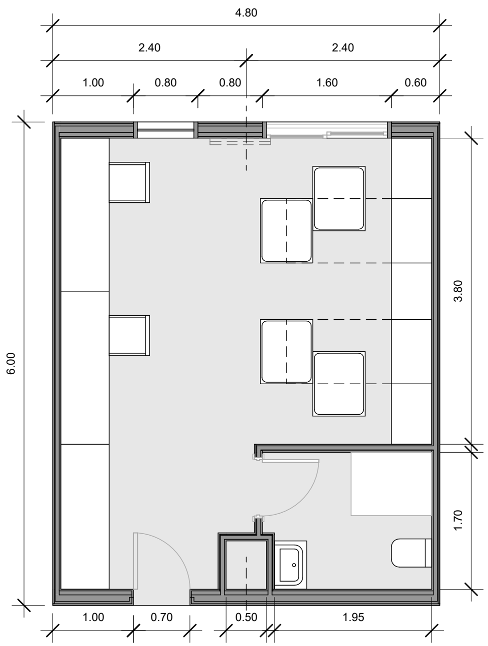
Module Type: Double Unit
Size: 6 x 4.8 x 3.3 m
Area: 28.8 sqm

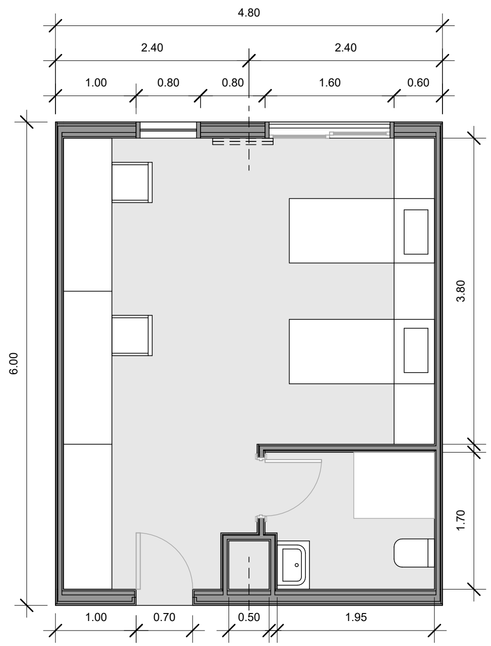
Day time



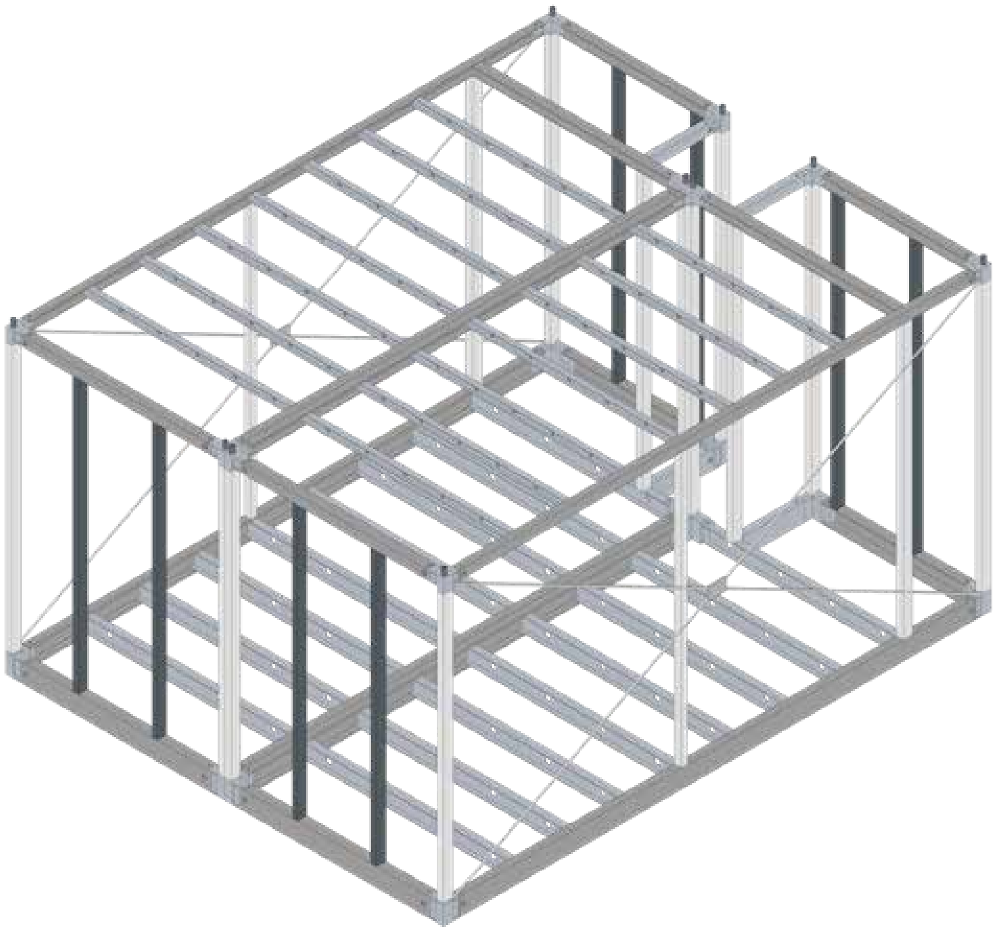
Night time





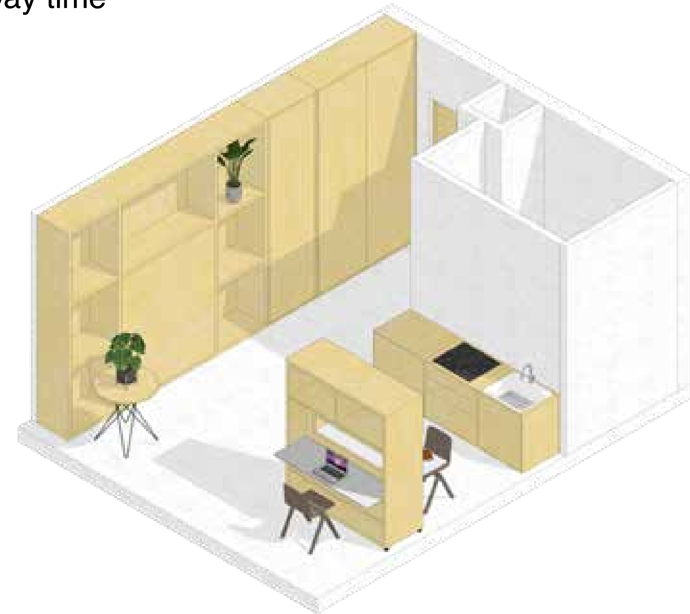


DOUBLE OCCUPANCY UNIT WITH KITCHEN

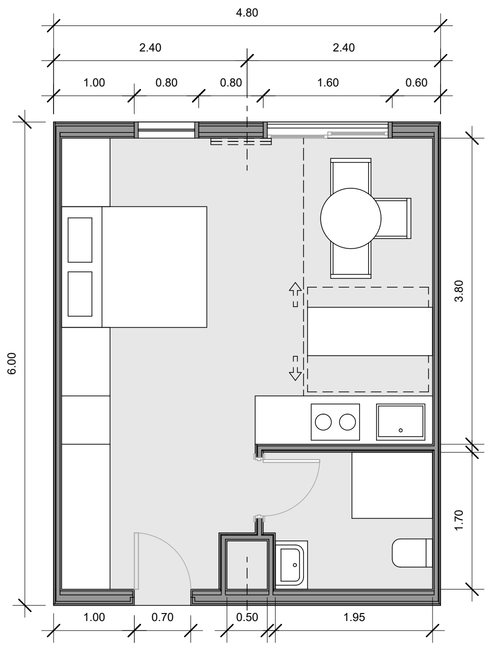


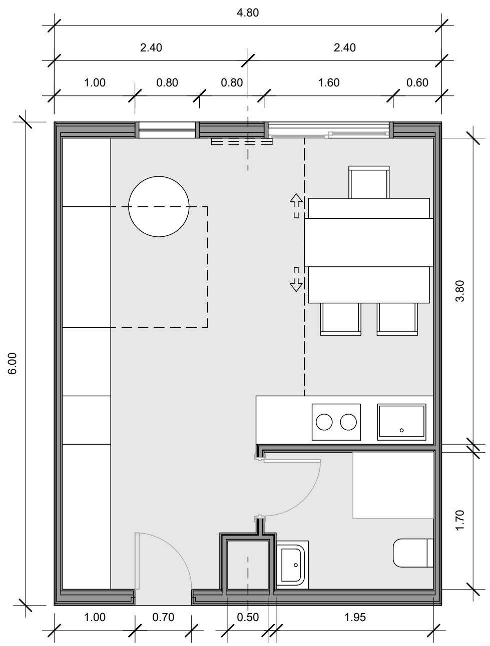
Module Type: Double Unit
Size: 6 x 4.8 x 3.3 m
Area: 28.8 sqm

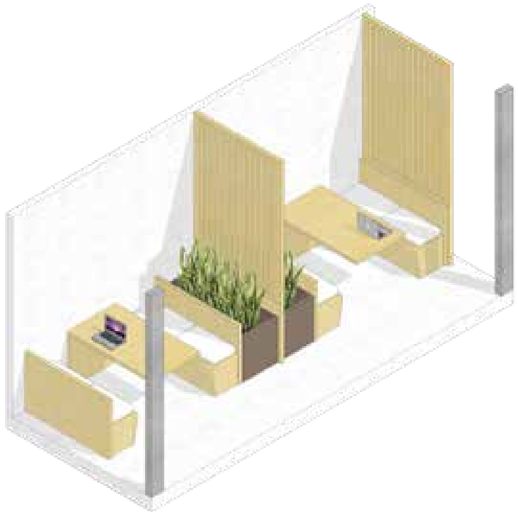
Day time



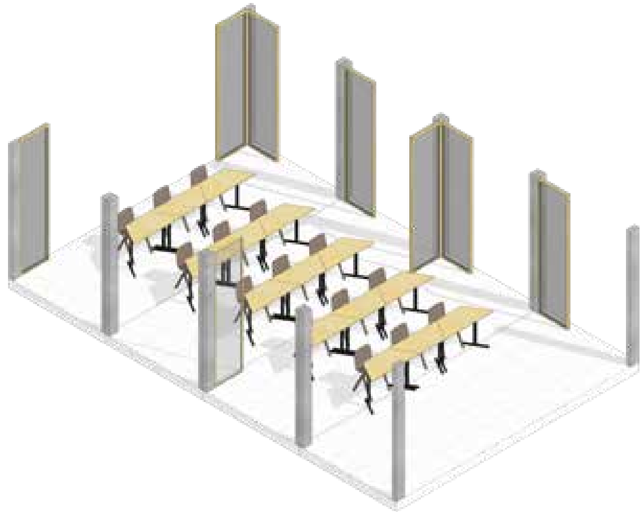
Night time



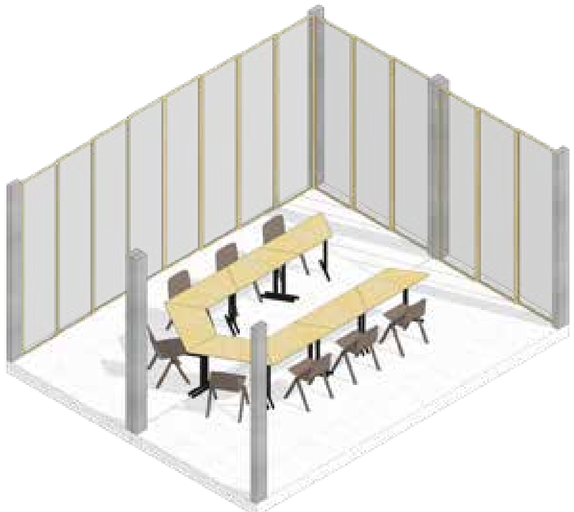




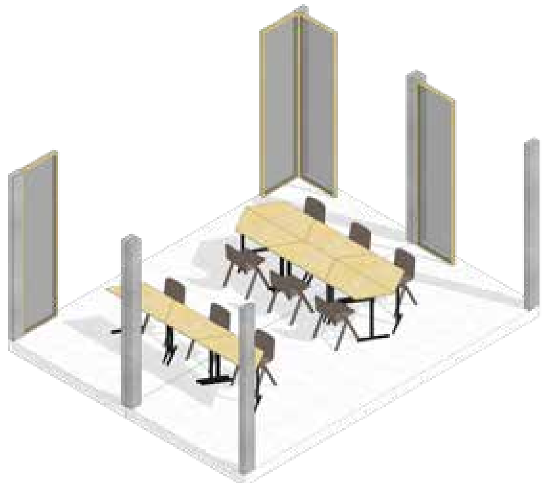
Co-Working Pods



Co-Working Pods - Classroom



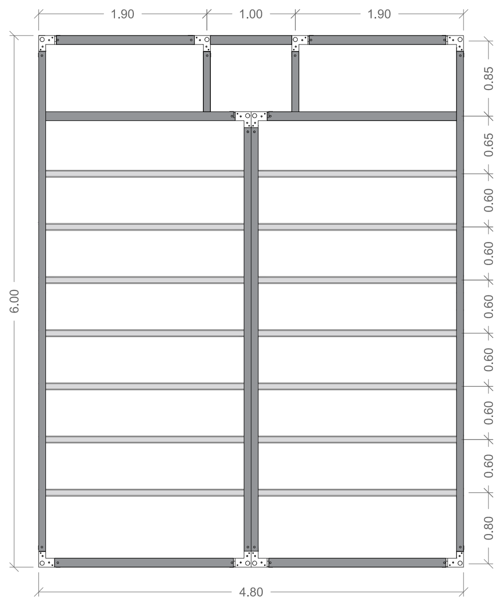
Co-Working Pods - Meeting Room



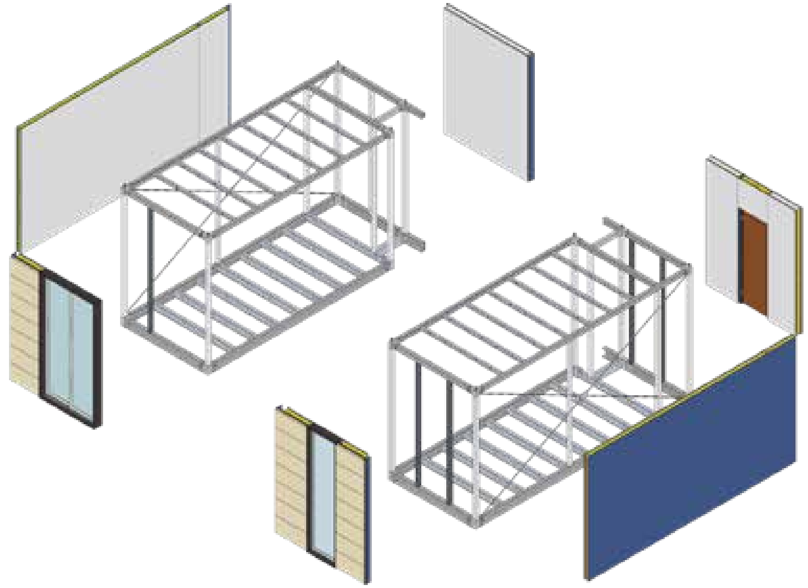
Co-Working Pods - Office Room

4.6 CONSTRUCTION DETAILS

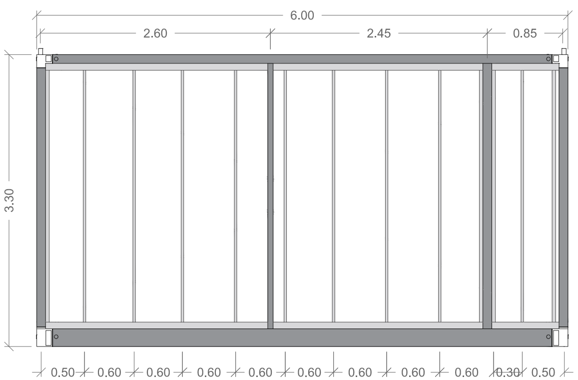
- STRUCTUAL ASSEMBLY, CONNECTIONS AND COMPONENT DETAILS.



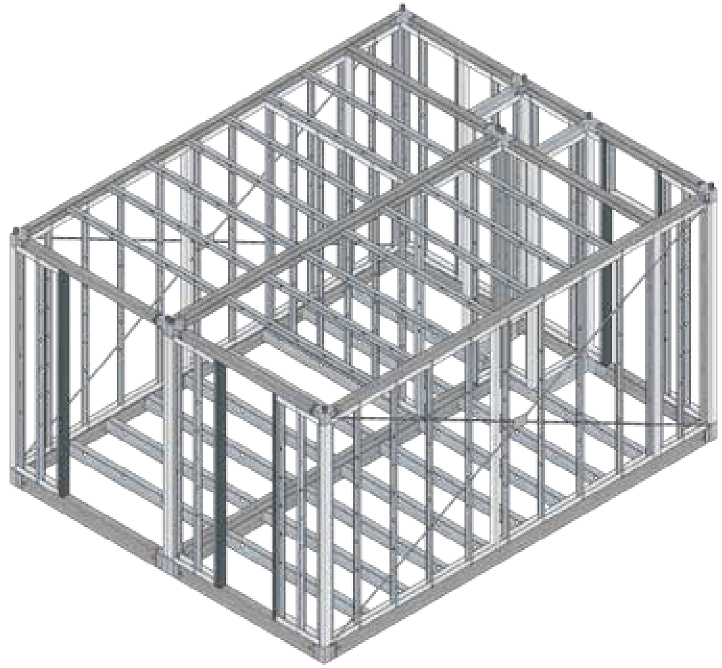
Plan - Structural Beam Framework



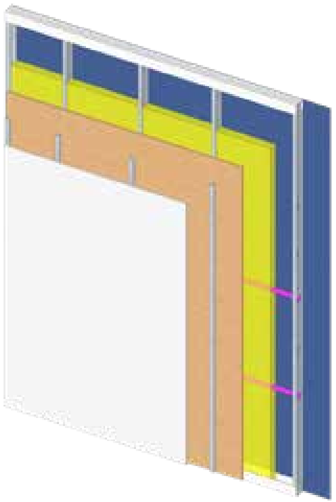
Unit Component System



Elevation - Structural Framework
Non-Structural Wall Members

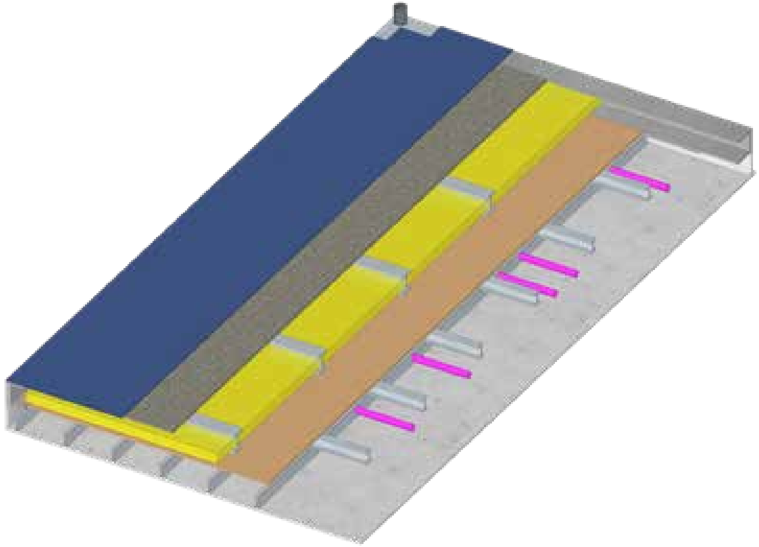


Unit Structure with Lightweight Alluminium framework for walls.



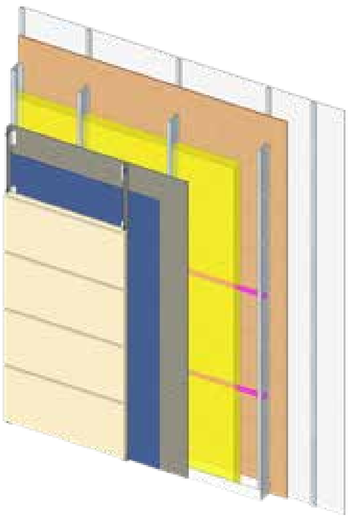
- 12 mm Interior Finish Plasterboard
- Lightweight Alluminium chanel system for cladding
- 15 mm gypsum fibreboard
- 30 mm Insulation
- Wall substructure
- Water Proofing Membrane

Interior Partition Wall System



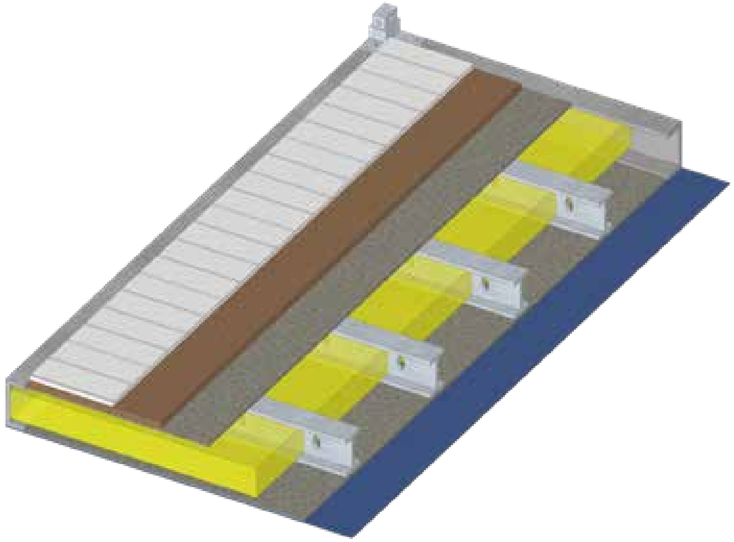
- Water Proofing Membrane
- 15 mm Exterior High Density Board
- Ceiling Structural system
- 50 mm Insulation
- 15 mm plywood sheathing
- False Ceiling System
- Interior Finish Plasterboard

Ceiling Construction System



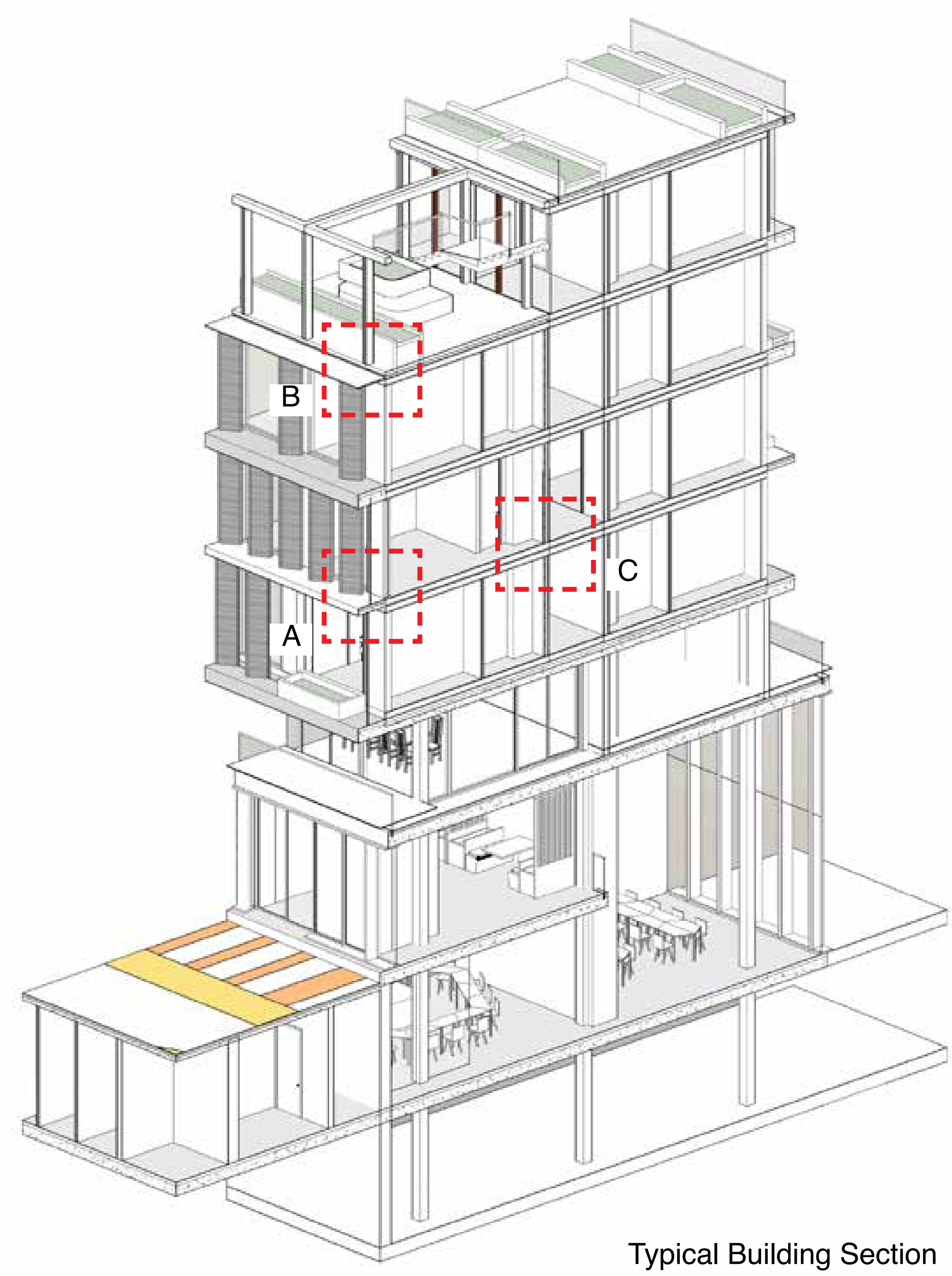
- Terracotta Hollow Cladding Tiles
- Insects Filter Net
- 25 mm Air Gap
- Cladding track system
- Water Vapour Barrier
- 15 mm Exterior High Density Board
- Wall Substructure
- 100 mm insulation between metal channel sections
- 15 mm gypsum fibreboard
- Lightweight Alluminium chanel system for cladding
- 12 mm Interior Finish Plaster Board

Exterior Wall System

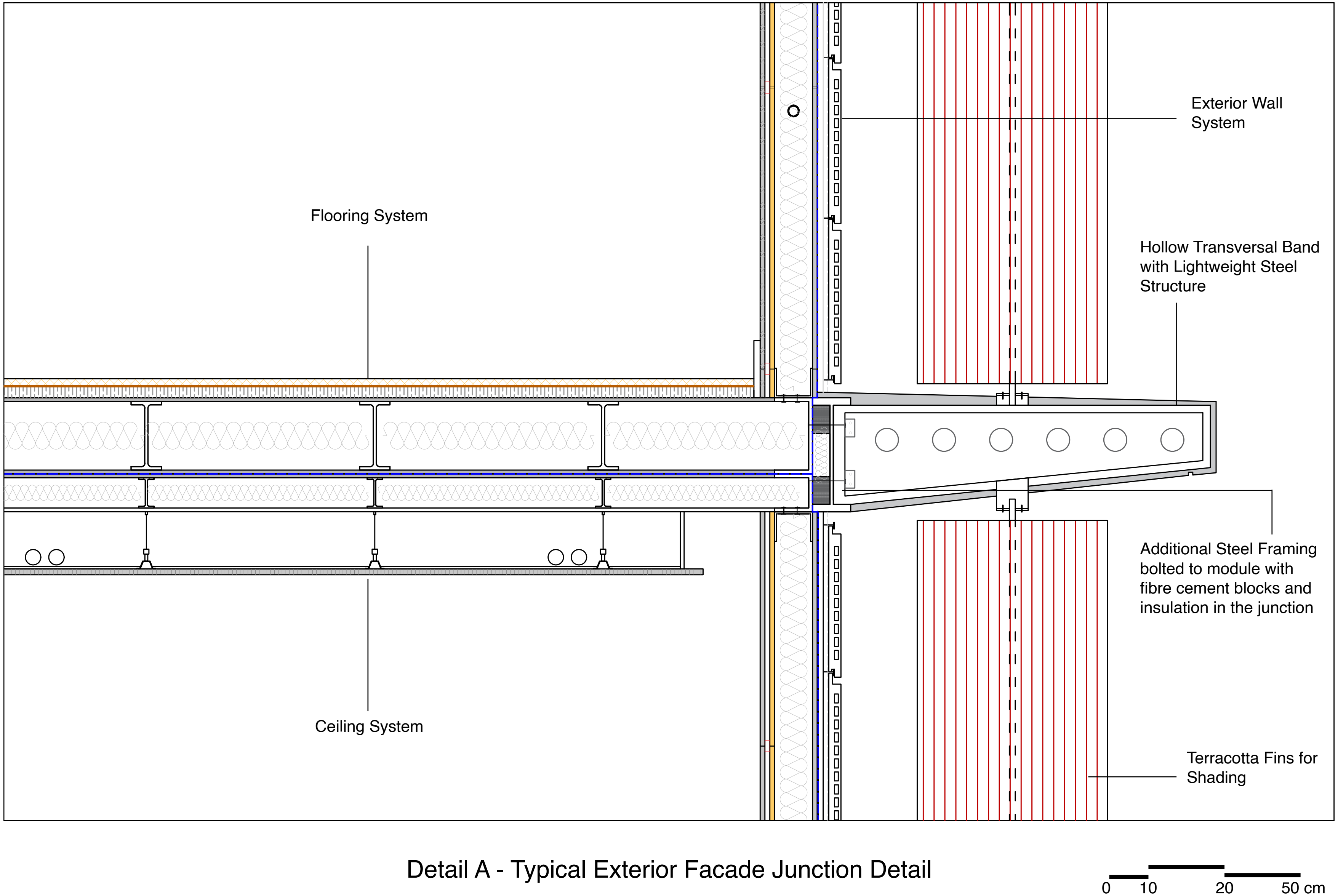


- Flooring Tiles
- 25 mm Dry Screed Board
- 15 mm High Density Board
- Insulation
- Floor Structural System
- 15 mm High Density Board
- Water Proofing Membrane

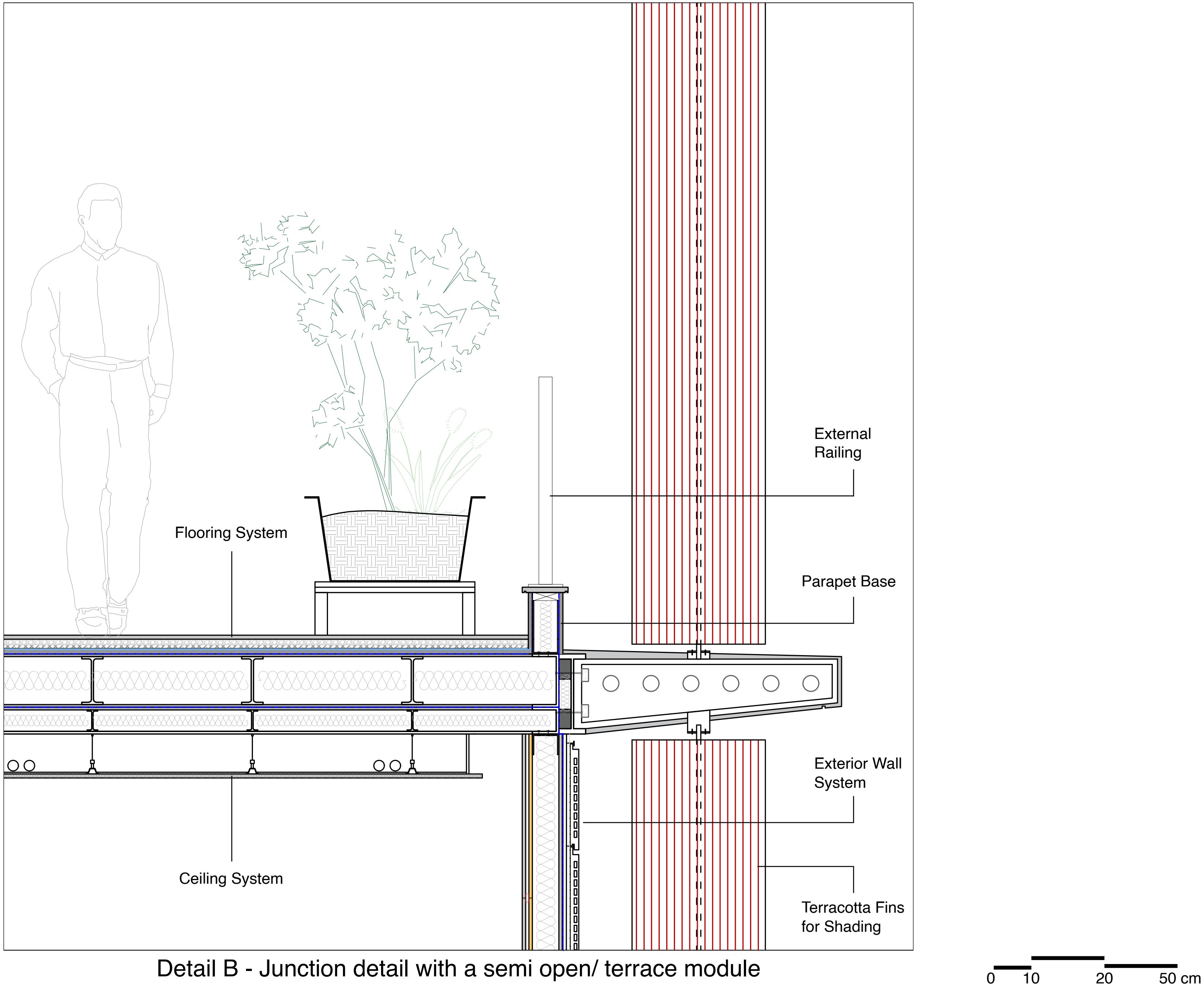
Floor Construction System



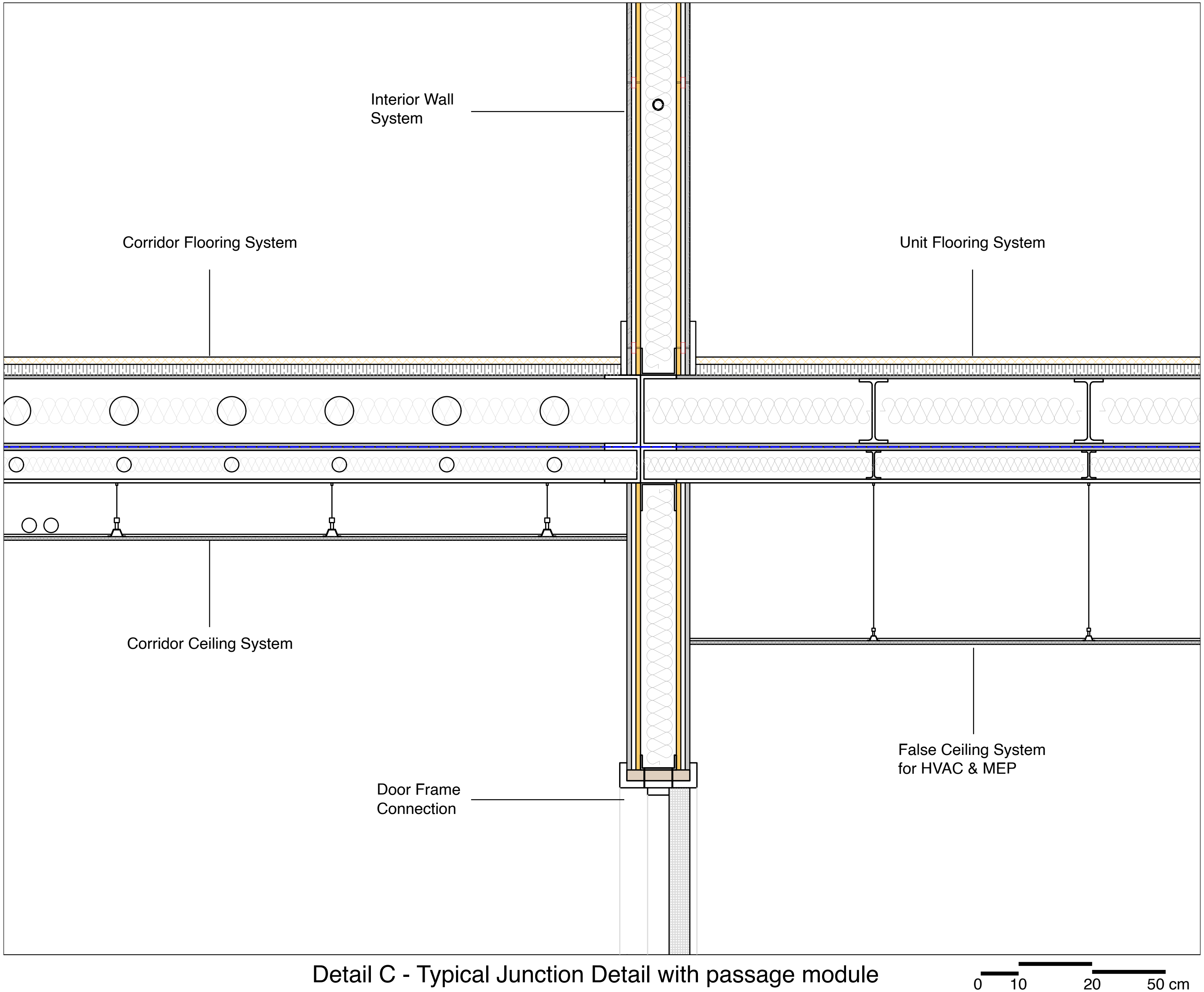
Typical Building Section



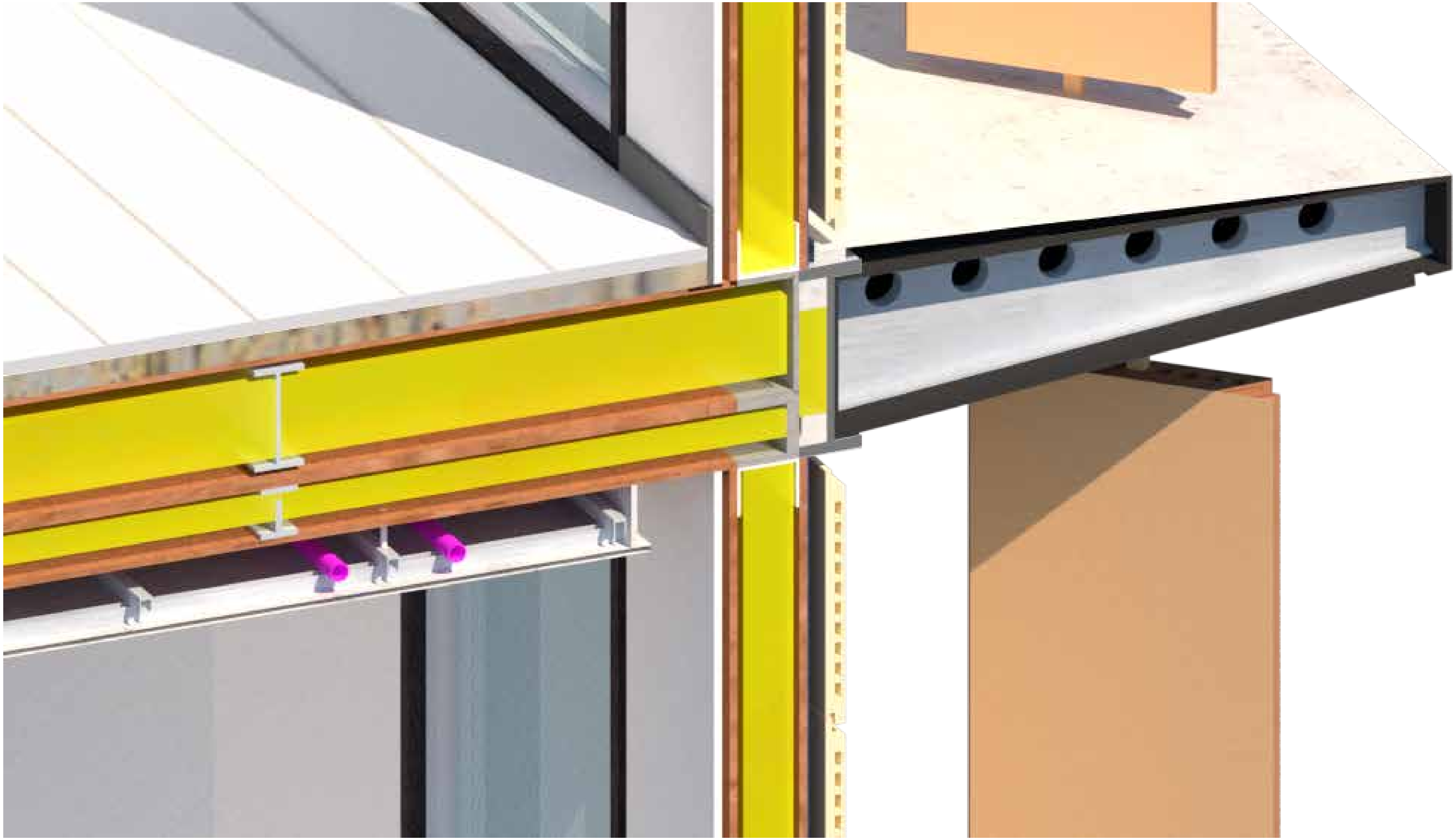
Detail A - Typical Exterior Facade Junction Detail



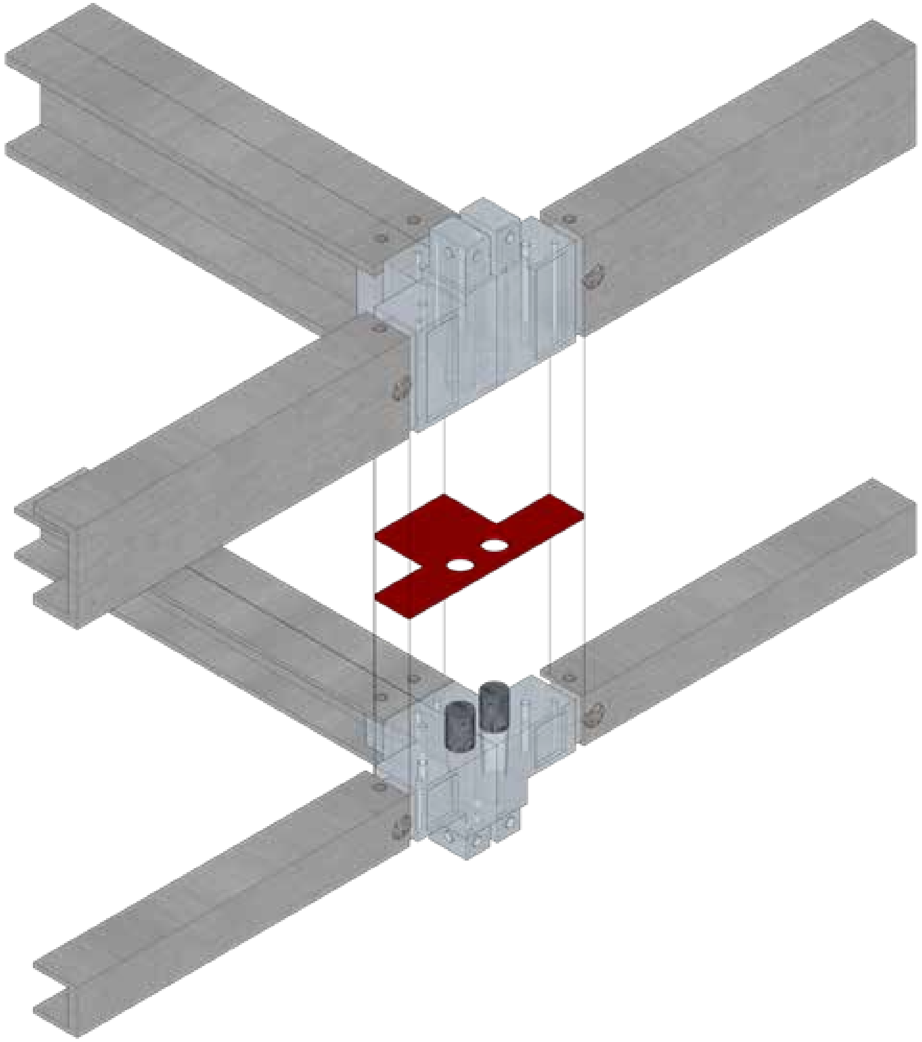
Detail B - Junction detail with a semi open/ terrace module



Detail C - Typical Junction Detail with passage module

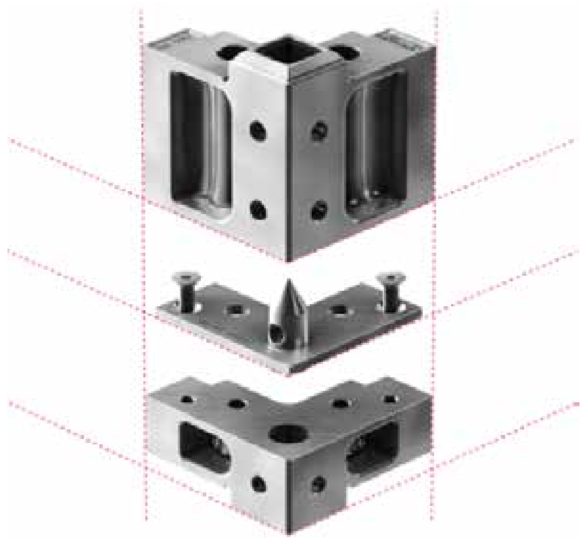


Typical Exterior Facade Junction Detail



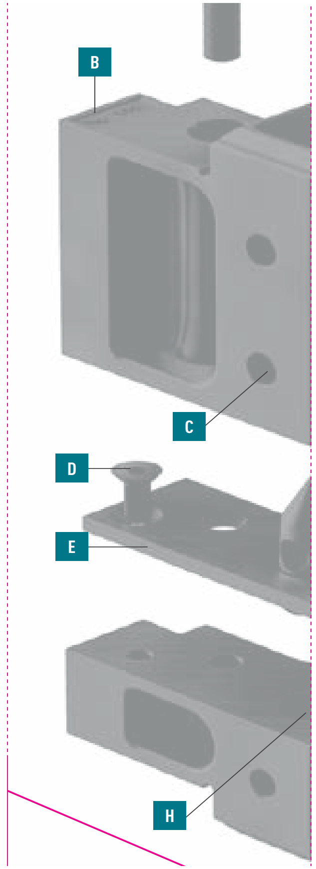
Modules connected on site with a connection plate at corner joints.

Reference for connection joints - Z MODULAR COMPANY



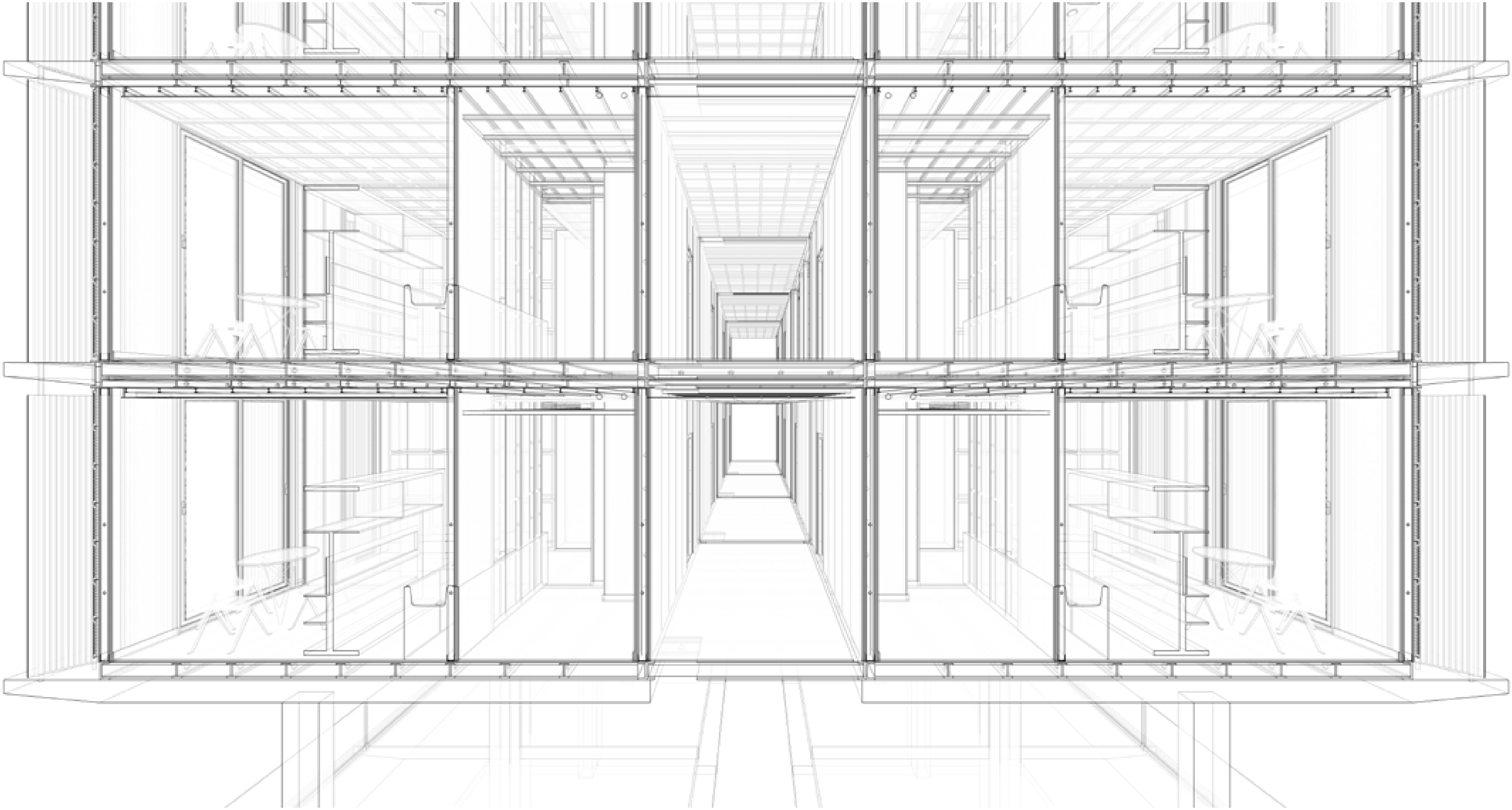
Vector Bloc

Modules are built with hollow structural sections (HSS) and cast steel connectors, then joined with bolts to form complete buildings. Tight tolerances (+0”, -116”) ensure even stacking — allowing you to create buildings of virtually any form factor.

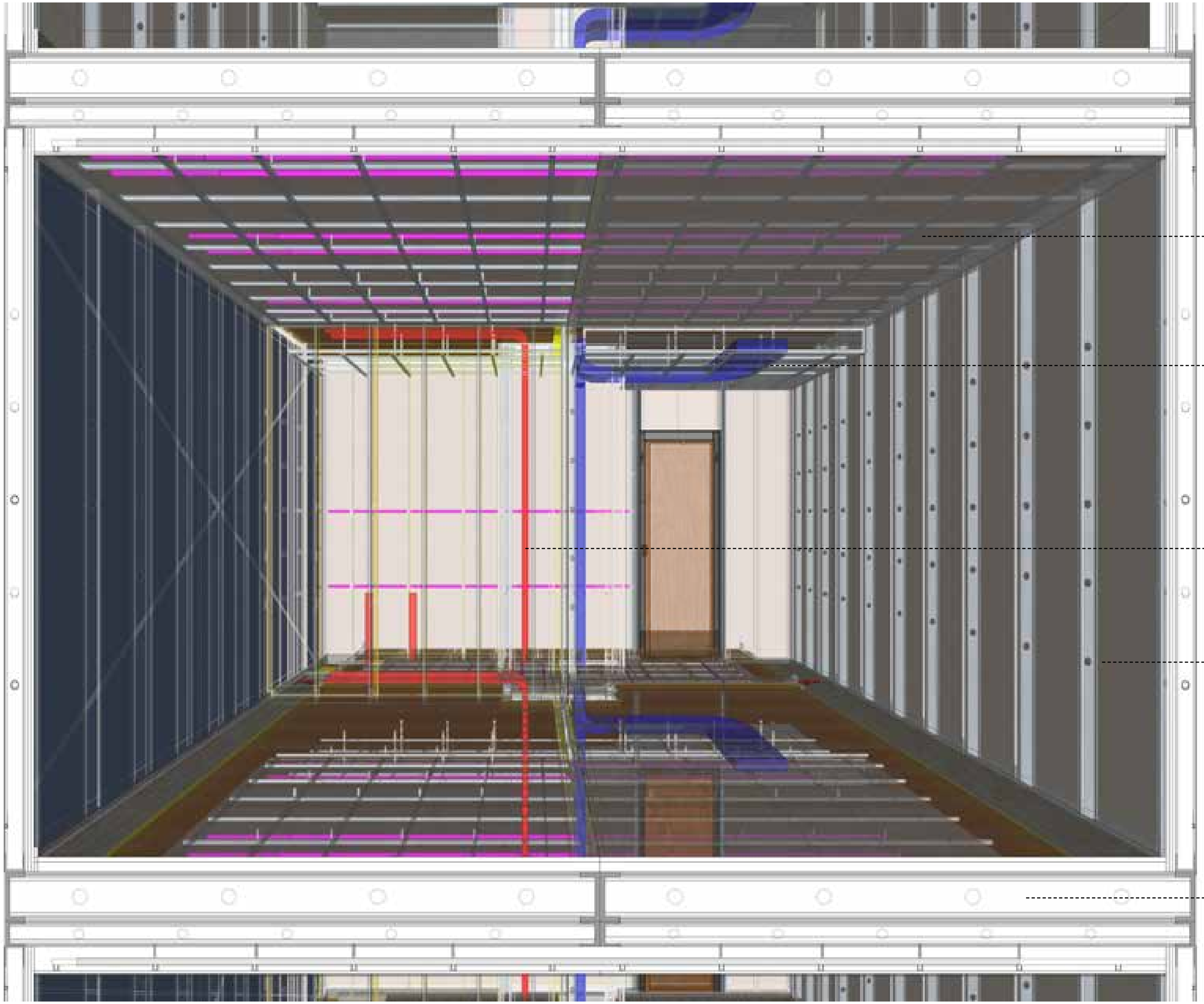


- **A** Tension bolt
- **B** Lower VectorBloc
- **C** Accessory connection point
- **D** Gusset plate bolt
- **E** Gusset plate
- **F** Tapered locating, shear and hoisting pin
- **G** Upper VectorBloc
- **H** Threaded hole

Source - Zmodular - VectorBloc



Perspective Sectional View of detailed construction model with interior fittings.



Intergerated Electrical lines in False Ceiling.

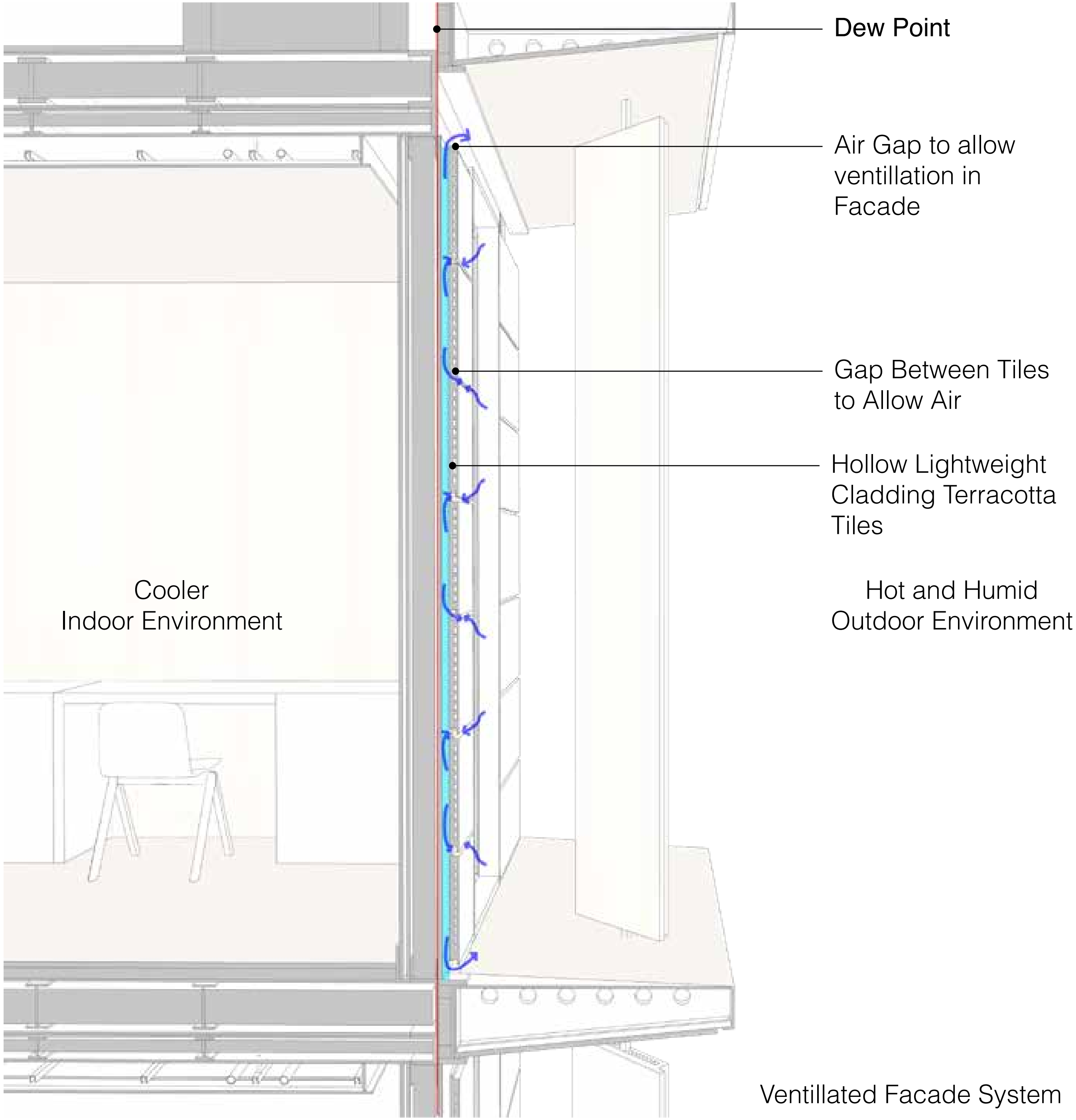
Pre-determined HVAC provision.

Water/ Sewage Pipelines pre-attached with possible service core connections.

Lightweight Alluminium framework with cutouts for electrical conduits.

Lightweight Structural Framework.

Perspective Sectional X-Ray View of detailed construction model with interior fittings.



Ventillated Facade System

TERRACLAD COMPANY

Used for Fins

SANDING FINISH

Size - 300*600*18mm
Surface Finish - Sanding
Material - Natural Clay

Source - Terraclad

Used for Wall Cladding

CARVED PANEL

Size - 300*900*18mm
Surface Finish - Natural Flat/Carved
Material - Natural Clay

Source - Terraclad

Due to higher humidity Levels in the outdoor environment, the Dew Point would be towards the exterior facade in the walls.

The Air Gap created due to the cladding system of the terracotta tiles, improves the ventillation on the facade to reduce condensation.

Hollow Terracotta Tiles as cladding material reduce direct heat gain and are a very efficient, low maintenance material largely available in the local market.

Ventillated Facade - Wall System

Site Top View

View from Courtyard


Terrace View

View from Courtyard

FLEXIBILITY & ADAPTIBILITY IN DESIGN

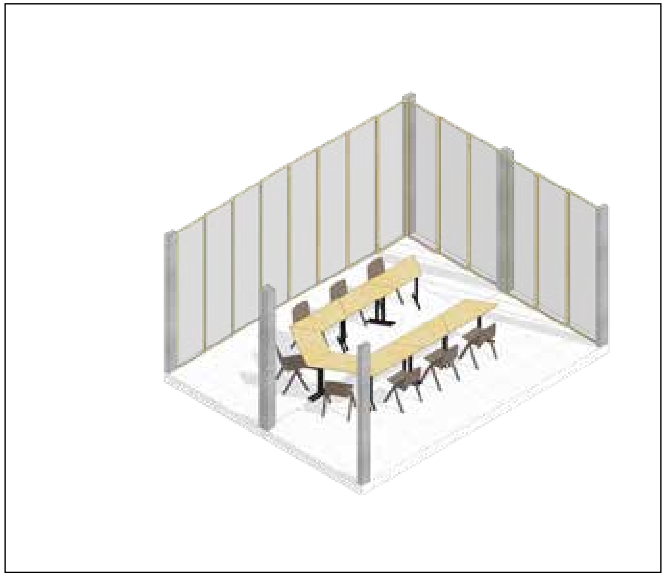
ONE MODULE - SEVERAL APPLICATIONS

Live

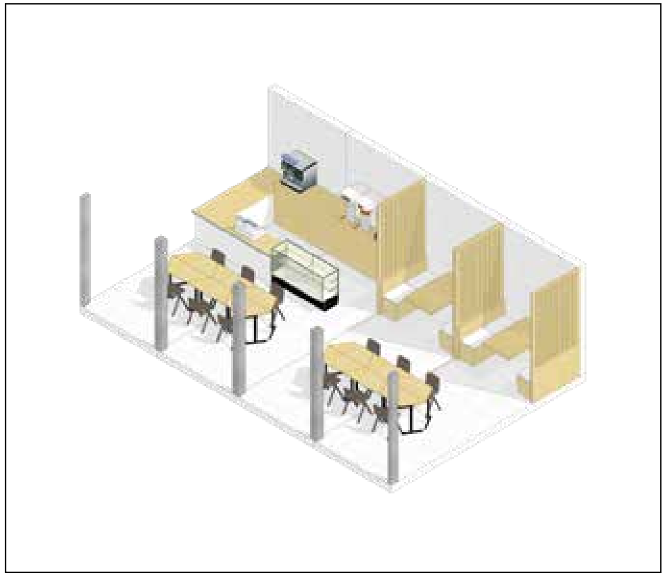
Work

Play

CO-LIVING

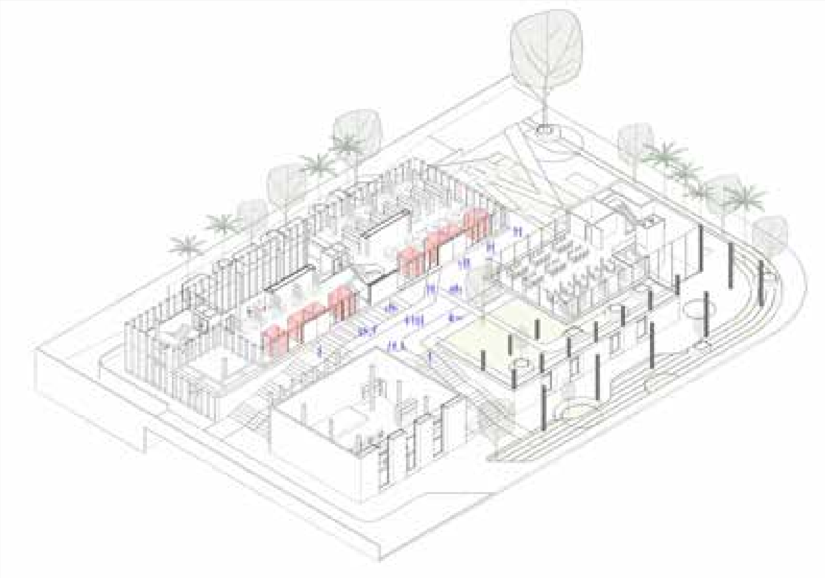


CO-WORKING

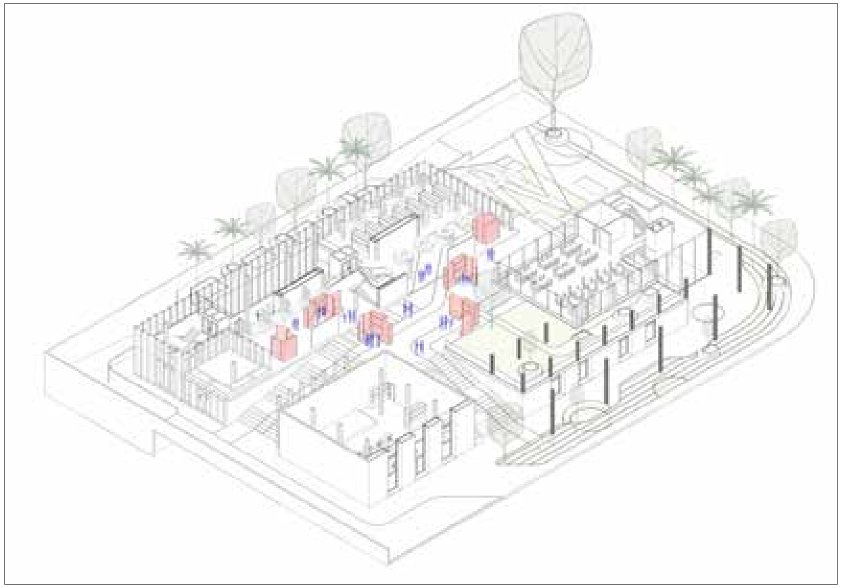


COMMUNAL AMENITIES

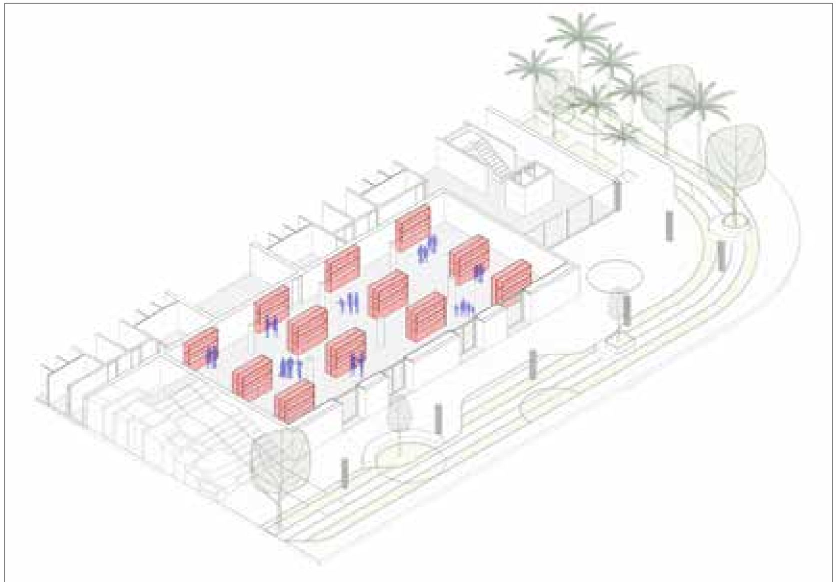
ONE SPACE - SEVERAL USES



Indoor Co Working & Outdoor Courtyard



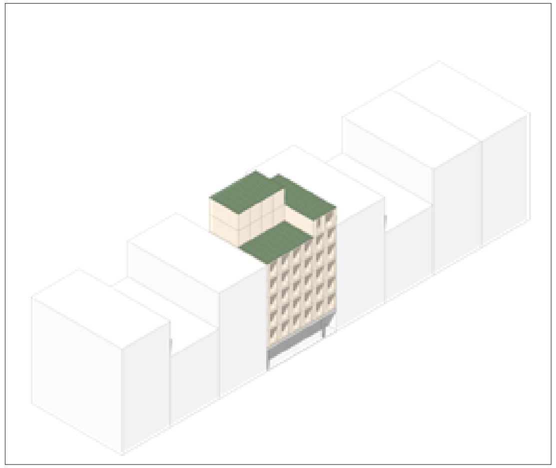
Extended Exhibition Space



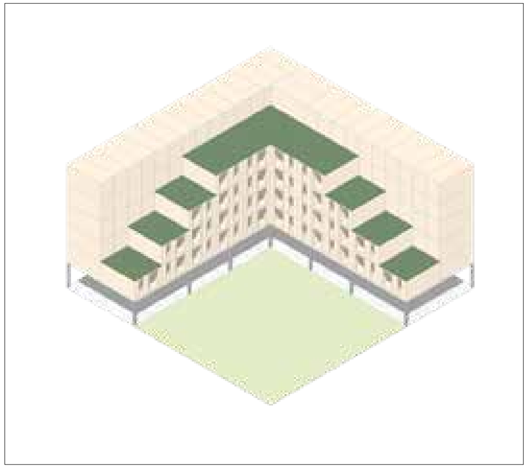
Market

Event Space

ONE SYSTEM - SEVERAL CONFIGURATIONS

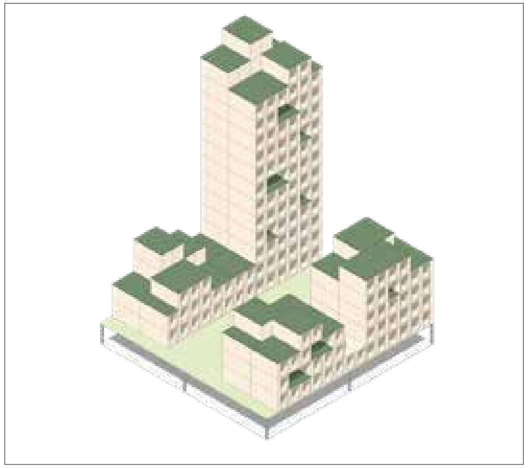


In Dense Urban Blocks



Mid Scale

Cluster Complex



High Rise

4. THESIS CONCLUSION

In the ever-changing world, factors like rapid urbanisation, constant social shifts and corresponding demands, technological advancements, climate emergencies, and economical instability many a times render the buildings and infrastructures obsolete.

- How can we leverage emerging construction methods to address the critical demand for flexible solutions in cities?

- How can we provide better infrastructure and living conditions without drastic disruption?

- How can we PRE-PLAN to increase the lifespan of buildings?

- How can Prefab Modular Construction be integerated with a sustainable flexible approach to adapt to unique urban needs?

- Can we devise a MODULAR RE- CONFIGURABLE PROTOTYPE to envision future of urban infrastructure?

1. Urban Density v/s Urban Adaptation

The growing concentration of population poses a fundamental challenge on urban tissues in order to provide economic opportunities, development of adequate infrastructure and healthy living environments. To address these issues, a model of prototypical urban development of shared economy and community living is devised which features flexible and adaptable multi-functional spaces as its core foundation.
The city of Chennai (15th highest population density in the world) in India is studied and selected as a site of intervention where there is a high inadequacy of planned urban growth in the older city centres. A model of co-living, co-working and shared public spaces is developed which can become a reference for development in various urban zones with high density where scarcity of land, open- green spaces and community infrastructure are common denominators of concern.

2. Prefabrication for Flexibility, Adaptability and Reusability

Having understood the complexities and nuances of a dense urban centre, this project proposes use of prefabricated architecture for smarter, sustainable and affordable built environments. A high degree of pre-fabrication can ensure high standards of quality as well as least intrusive construction methods. Pre-fabrication also provides scope of recycling, reusing or even displacing the building components with progression in the life cycle of the building, which proves to be of value in a high density fabric with constantly changing social and infrastructural needs. Moreover, in densely packed urban centres, it is preferable to obtain solutions that cause minimum disturbance and disruption to the inhabitants, which require shorter amount of time to be executed and are environment friendly. Thus, making prefab the ideal choice.

3. Offsite Construction as a Solution

Selection of pre-fabricated building modules provides opportunities of incrementality, interchangeability and reusability. These characteristics underpin the mission of flexibility in urban environments which are vital for rapidly and unpredictably changing tangible and intangible social and physical scenarios. The ultimate goal derived from the research is to design a prototype of modules which can be replicated in various high density urban fabrics with additional tweaks based on the local climatic and social conditions. Prefabrication ensures a uniform quality and technique of construction which is one of the most important feature for replication. This standardised approach aids in making the construction cost more affordable, thus providing opportunities to develop multiple urban centres in the same city or even different cities simultaneously.

4. Universal Design

Prefabrication and modular approach to execution can have a great impact from a micro level furniture scale to a macro building unit scale to achieve a level of maximum flexibility and adaptability of spaces for multiple functions. Technology driven execution and preplanned modular designs can open up new horizons to endless creative reconfigurations and add a dynamic image to the perception of spaces and cities.

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