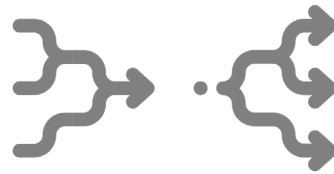


X IN ONE: MULTI-FUNCTIONAL ELEMENTS



—— Explore design strategies to extend life cycle of large-scale temporary architecture by breaking the barrier between scales

BO HAN
Master Thesis 2019 Spring
Material Turn Studio

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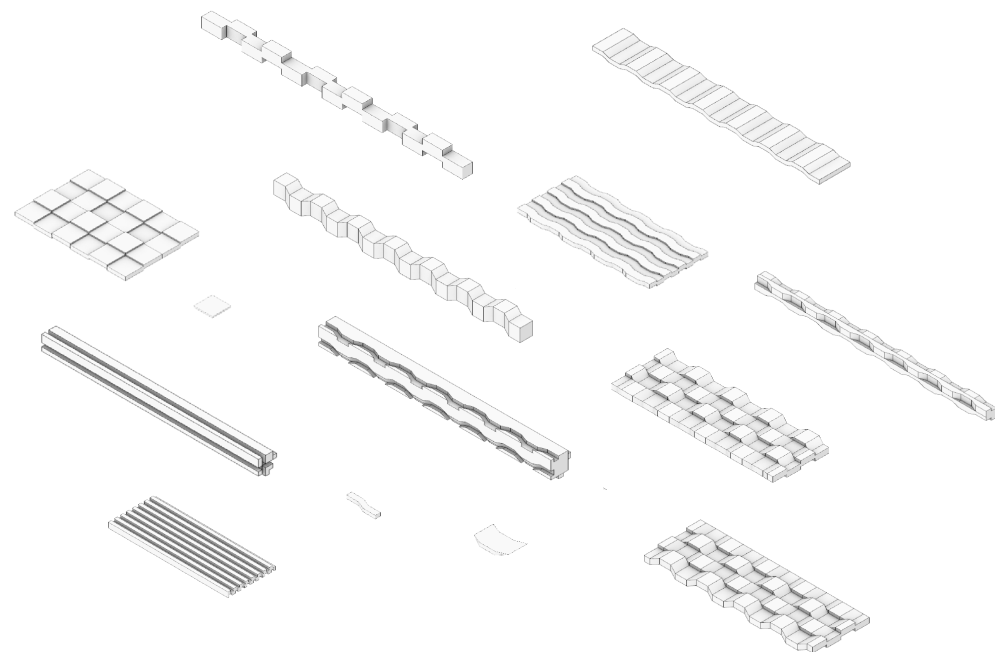
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CHALMERS

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ABSTRACT

With the globalizing within the world, there comes to be more and more big worldwide events which ask for amounts of large scale temporary buildings. For instance, there are quite a few exhibition buildings during every EXPO and lots of arenas during Olympics. Together with the rising awareness of sustainability, people start to step forward on recycling and reusing rather than just leaving the buildings abandoned. There are various attempts about this, such as design for disassembly, recycling materials, renovation and so on.

This thesis project tries to look for a new design strategy and architectural language. It appears to be more economic-friendly if the initial design of large scale structure and the re-assembly could be more related instead of finding solutions of reusing afterwards. The new strategy performs better in both technology and economy aspects by providing the opportunity of no leftovers and no destruction on elements compared to having a material bank of recycled building components and materials.

The project starts at subdividing large-scale building components and rethink them, then ends at multi-functional elements which can serve different scales. It asks for the design strategy of giving elements different meanings in different scales and leave the consciousness and identity of another scale in the architecture. For instance, furniture function, texture and joints can be expressed in different scales by one element. It is free to build up various buildings when just following the instruction of elements installation. Compared to current practice, this strategy provides more design opportunities and free outcomes when breaking the barrier between scales, since these elements can be assembled without following regular grids.

In this project, a kit of basic elements are designed to build up various structure and space. "X in one" not only means there can be X proposals of different scales built from one kit of elements, but also means there can be X scales in one proposal using the same elements.

INTRODUCTION



*Background, Current Practice,
Thesis question & Methods*

BACKGROUND

With the raising of people's awareness of environmental problems and sustainability, there is a tendency of not just leaving the event building as original and there are some attempts till now. Taking Olympics and EXPO as examples, the situation of stadiums and exhibition buildings is becoming better. During the earlier times, like what happened after Beijing Olympics, few of the stadiums became main public buildings later while many of them were abandoned for years.

Then people got to consider about the strategy called "design for disassembly", which brought the consciousness of sustainability. Practices such as Slow Food Pavillion (2015 Milano) appeared in EXPO that some exhibition pavilions were disassembled after the event and re-assembled back in other cities and even other countries. Another kind of attempt is to recycle materials from the same type of buildings. For example, 2016 Olympic in Brazil took lots of building materials from London which were used for 2012 Olympic. But this process was also from stadium to

stadium, much same as re-assembly.

However, there is a larger need of small scale daily-use buildings especially housing and schools for everyone. People have tried to recycle the materials from these temporary buildings to redesign them into some other buildings but the cost of transportation and transformation keeps this strategy hard to be widely used. Also it seems difficult to just reuse large components or materials from a large scale building into a small scale one. Actually, all these kinds of reusing and recycling happen after the use of large scale temporary buildings, which means the initial design and the re-assembly later are two separate process.

Being inspired from an intention to build up four schools using recycled external walls from 2016 Olympic Handball Arena, which showed that it was possible to reuse building components from large scale structure to small scale buildings if it is designed in advance.

REUSABILITY

Disassemble buildings
then reassemble



Reassembled Serpentine Pavilion
London - Toronto

Reuse elements after
reproduced



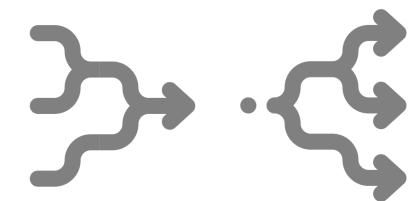
Reused containers - reading center
Tianjin University, China

Reuse proper elements
without reforming

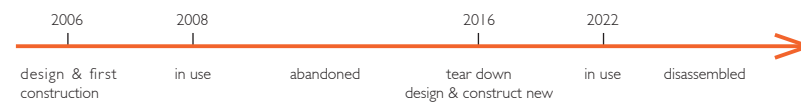
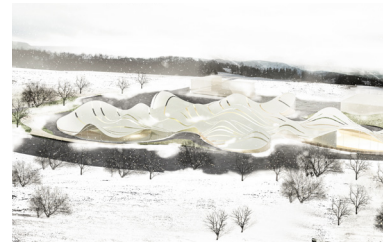


Reusing steel and concrete from Big
Dig - apartment
Boston

Multi-functional elements
designed for various functions
and scales



This thesis project



Laoshan Bicycle Moto Cross (BMX) Venue

Place: Beijing, China
For: 2008 Olympics

- the old venue was abandoned and torn down
- new project is designed for disassembly but not related to the old one
- make no sense of reusing building materials or components



Oil Pavilion

Place: Shanghai, China ---- Daqing, China
For: 2010 EXPO

- design for disassembly firstly
- reassembled as original function in another city



The three structures were supposed to be disassembled and transported to a selection of Italian schools, where they will be rebuilt and used as garden sheds.



Slow Food Pavilion

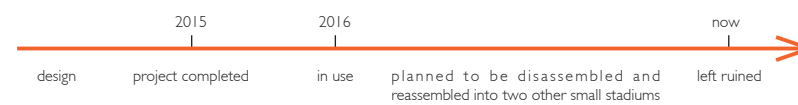
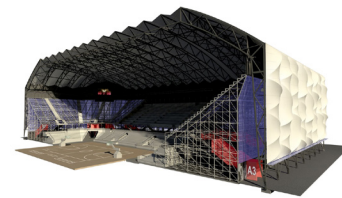
Place: Milano, Italy
For: 2015 EXPO

- design for disassembly firstly
- reassembled as original design in another city
- garden sheds are not something strongly needed



Materials donated from a number of Expo pavilions will be re-used in YK Pao School's new Secondary School boarding campus.

staircases, flooring, signage, and doors



2010 Shanghai EXPO

Place: Shanghai, China
For: 2008 Olympics

- design for disassembly firstly
- consider about the possibility of reusing materials to build up a school
- the safety and quality of materials cannot reach the requirements

Basketball Arena

Place: London, UK
For: 2012 London Olympics

- design for disassembly firstly
- over 2/3 materials and components were sold to Brazil for next Olympics
- reuse within same scale and function

Olympic Aquatics Stadium

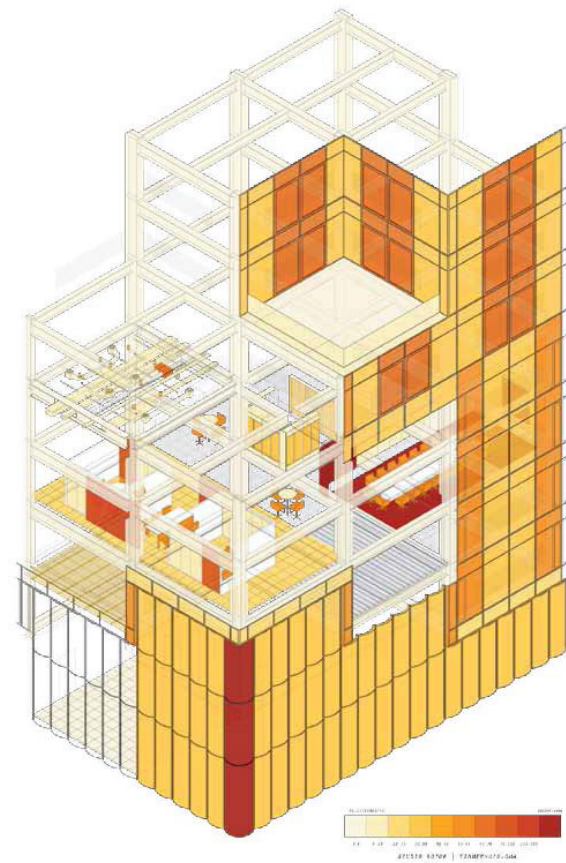
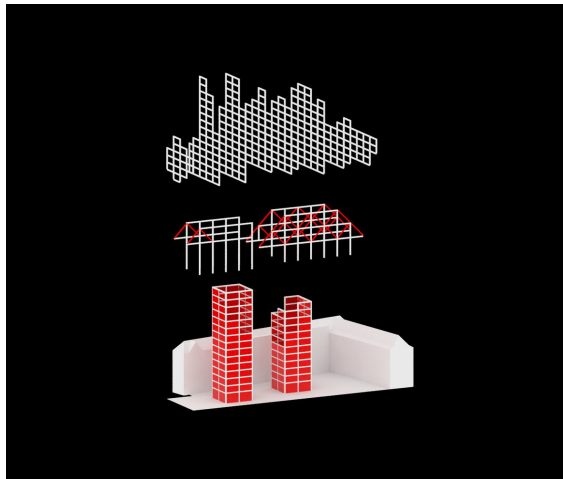
Place : Rio de Janeiro
For: 2016 Rio Olympics

- designed for disassembly
- supposed to be reconstructed into two smaller aquatics facilities
- the aquatics center now rests empty and in a state of disrepair

CURRENT PRACTICE

With the increasing consciousness of sustainability, architects have tried to reuse building components from existing architecture. Inspired by reusing, they also start to design for disassembly which means the lifespan of building is longer than that of initial use. There are various strategies:

- Evaluate building elements and components of existing/abandoned buildings if they can be used and how, then redesign;
- Make full use of recycled building elements and components from material bank;
- Redesign from building elements and components which are designed for reusing.

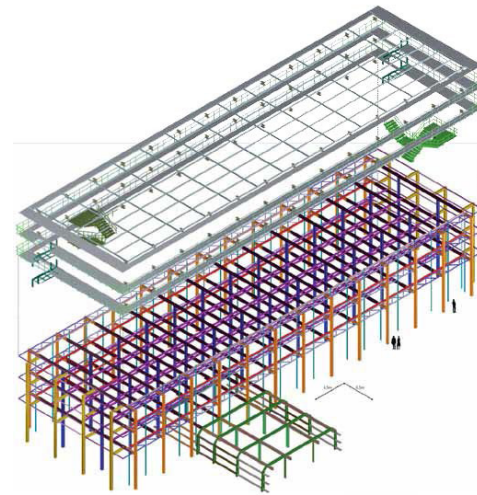


DECONSTRUCTION AND REUSE /STUDIO ROTOR

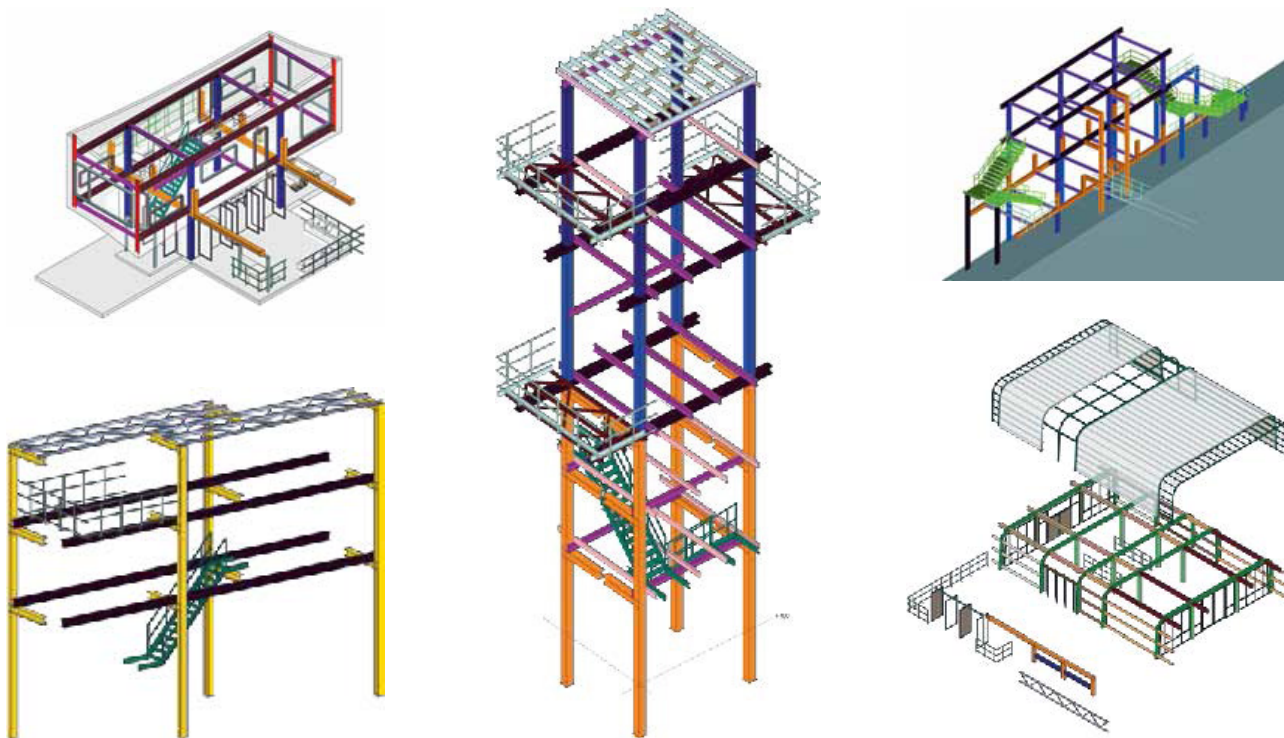
Timmerhuis in Rotterdam / OMA

Studio Rotor was carried out by TU Delft and visiting professors from office Rotor which focus on deconstruction and reuse. The Timmerhuis in Rotterdam designed by OMA considered "the full lifespan of the building - from construction to manipulation to reuse". They achieved by a cellular and flexible structural system that would allow units to be added or 'dismounted'.

The studio had the assignment to assess the reuse value of the Timmerhuis building components through a cost and embodied CO₂ study of the building's structure, mechanical systems, facade, and interior finishes. The axonometric drawings represent an estimation of the reusable elements of OMA's Timmerhuis as built, taking into account all these criteria. The steel structure of the building, for example, is shaded in very light yellow as it is heavy and difficult to dismantle. Similarly, some of the facade glazing is not reusable due to thermal leaks. In contrast, some of the interior furnishings, which are the work of renowned designers - for example, Petra Blaisse's curtains and carpets - are shaded in a dark orange tone, denoting their high reuse value.



Original distribution of steel components



Designs using the available steel components

DECONSTRUCTION AND REUSE /STUDIO ROTOR

Youth Hostel in Ockenburgh / Frank van Klingereren

The extension to the Ockenburgh youth hostel in The Hague was designed between 1971 and 1973 by Frank van Klingereren, and built throughout 1974. In 1997 the building was left vacant, and shortly after, the municipality of The Hague began to plan transformation of the hostel into a conference hotel. In 2010, its steel structure was dismantled and stored. While its rebuilding was planned for a year later, today the rusty steel beams and columns remain outdoors in the same location, awaiting their reassembly.

In this exercise, studio designs made use of the available steel components from the dismantled Van Klingereren building. An equitable split of the available components was planned, and then these were distributed among the groups following fair rules. Components were allocated to a group; the ones that were not being used were put in a common materials bank and made available to the other groups. At the end of the day, the designs used all available components of the original building.

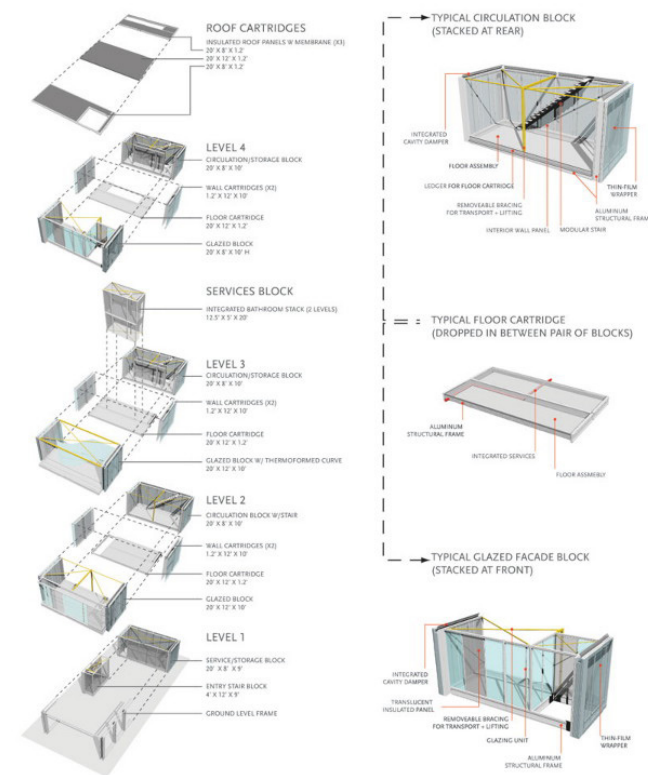
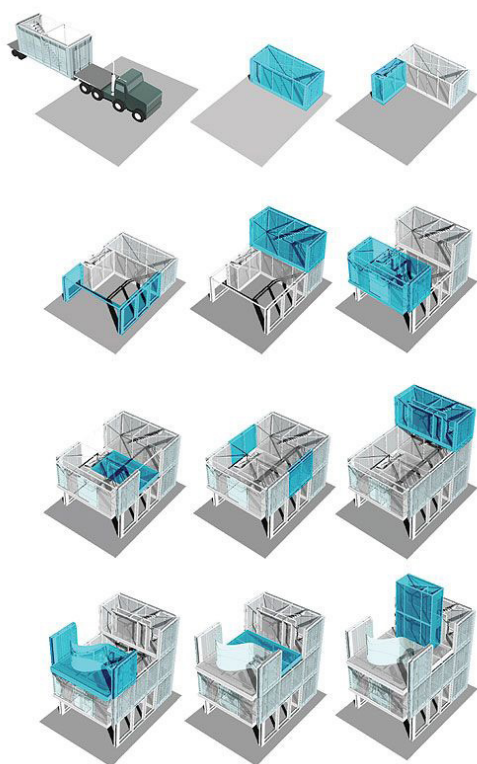


CELLOPHANE HOUSE /KIERAN TIMBERLAKE ARCHITECTS

Cellophane House demonstrates a holistic approach to off-site fabrication. It is designed to preserve all energy embodied in the house materials through rapid disassembly and recovery of all components for reassembly, helping to offset the millions of tons of construction and demolition debris generated each year.

Due to the nature of its connections, the house can be built or taken apart in pieces that range from large to small. For this prototype, integrated component assemblies—or chunks—were constructed on a factory over the course of three months, and simply stacked together on-site in sixteen days. A 3D BIM model was used to achieve a high level of precision, procure materials and plan assembly sequencing.

Cellophane house is a practice focusing on design for disassembly which means the whole house can be disassembled into building components and the components can then be used for reassembly. But without an exactly redesign, it may be a bit hard to reuse all these components for another building.

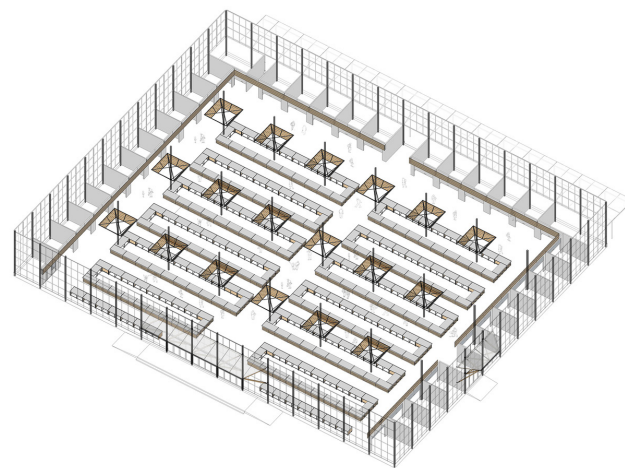
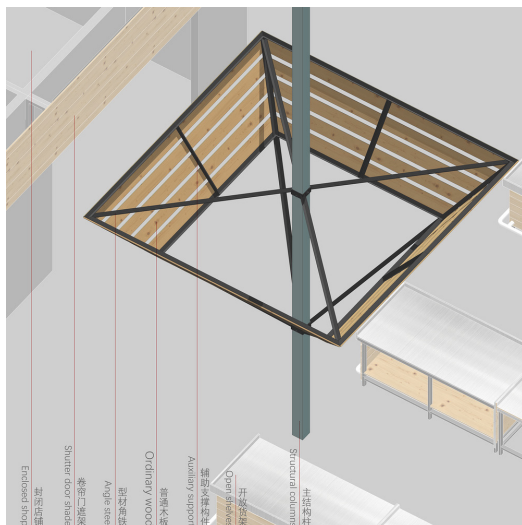




TEMPORARY SITE OF SHENGLI MARKET /LUO STUDIO

The project is the temporary site of an old market, located in Puyang City, China. The client requested a rapid construction process and low cost, while as designers we attached great importance to sustainability, hoping the architecture can be used for other purposes or recycled and reused after it completes its role as a temporary market. Taking those into consideration, the studio tried to figure out a solution to create a low-cost, multifunctional and sustainable architecture on the square plane in a short term. Eventually, they decided to adopt a fully industrialized vegetable shed-like architectural structure, built with standardized component sets. All the components are lightweight, modular and prefabricated, which ensured rapid construction, reduced cost and obtained a relatively expansive architectural space. Those construction elements including standardized rods can be dismantled, recycled, or reused for other constructions.

Since the market is a temporary site, building components are designed for reusing afterwards, the market itself can be seen as a material bank later.



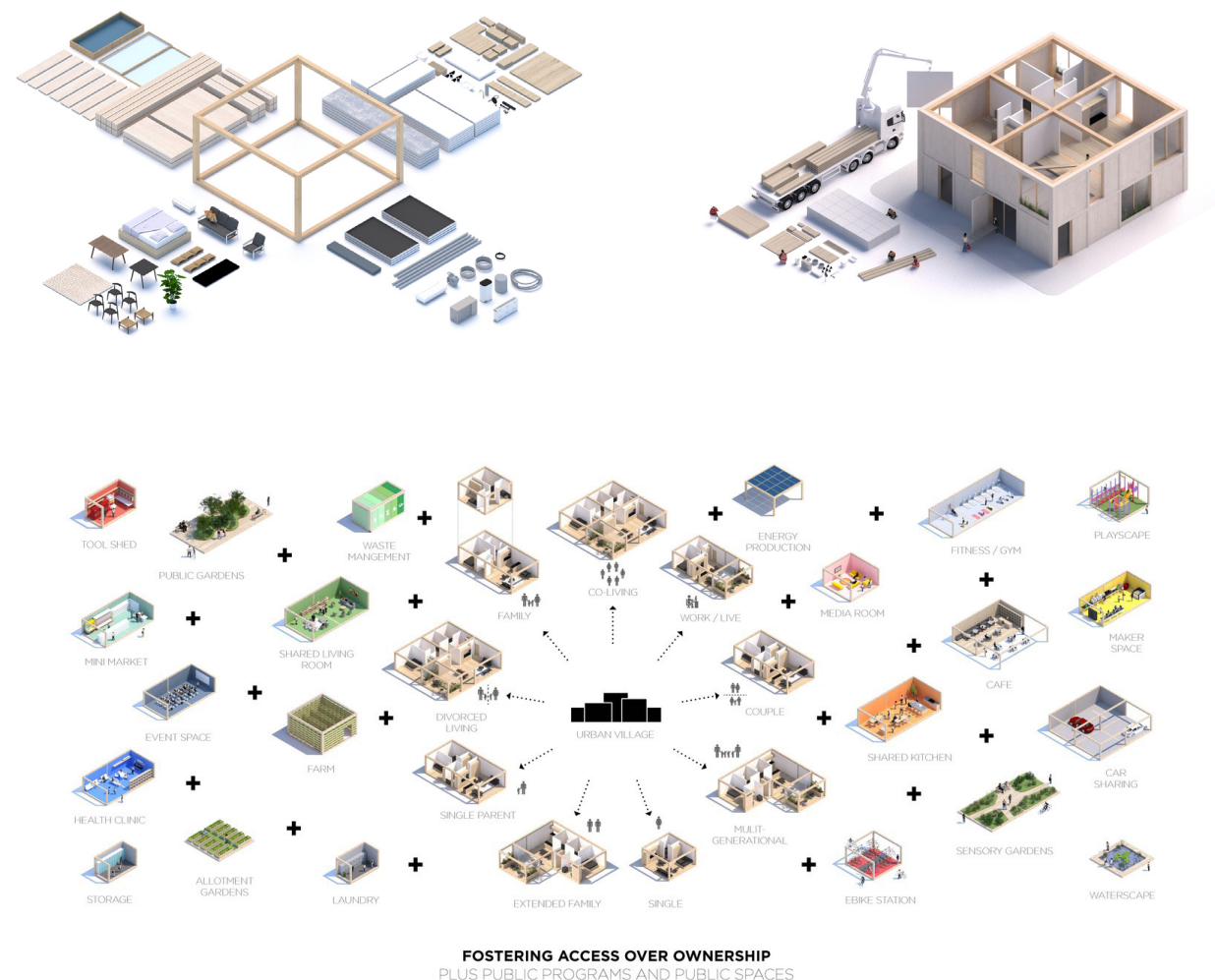


THE URBAN VILLAGE PROJECT //IKEA SPACE 10 & EFFEKT ARCHITECTS

Some assembly required for this vision of future urban living. Known for simple, well-designed, flat-pack furniture, IKEA is proposing expanding their DIY-model to a much larger scale: entire city centers. With an overarching goal of improving our quality of life, The Urban Village Project includes a multi-faceted approach. The housing is designed to be adaptable within a modular building system. Taking the trademark IKEA route of prefabricated, flat-packed kits, the homes are even designed to be disassembled for future reuse and recycling.

“Urban Villages is based on a modular building system which allows us to configure a wide range of different housing typologies for different urban settings. The system is designed for disassembly, unlocking a truly circular material loop where building components and materials can be reused and replaced rather than wasted. This could be a game changer for the building industry,” says Sinus Lynge, partner, EFFEKT Architects.

IKEA's assembly set concludes not only construction components but also things like furniture. All these components can be reused and they are also designed for various scales, for example, medium-scale public space and small-scale room. The design makes it possible to assemble and reassemble buildings of different scales but only within regular grids.



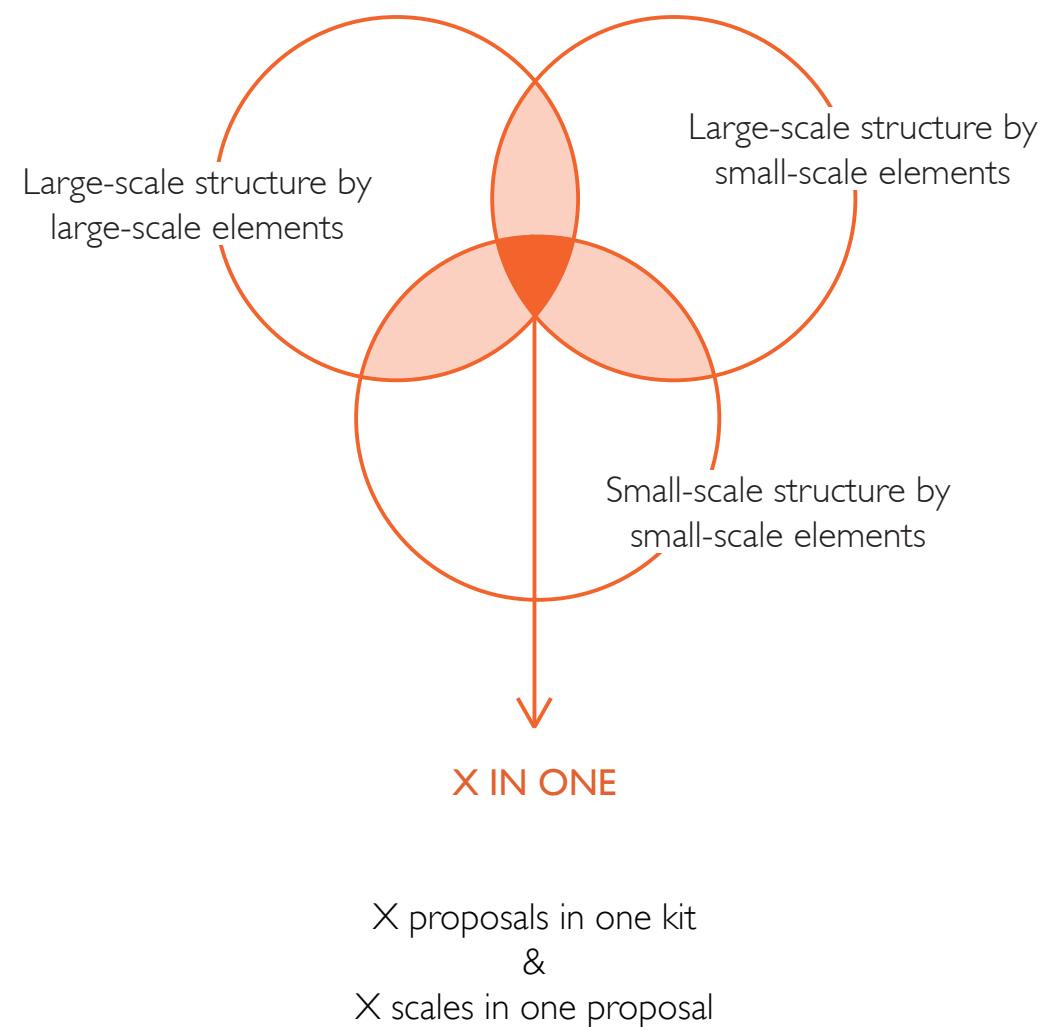
THESIS QUESTION

Building elements << Building components << Buildings

- Which design strategies are most potential for the design of a large scale temporary event building later to be transformed into modular housing with the same elements but without leftovers?
- How should the elements be to serve different scales and function demands?

AIMS

- Identify what needs to be improved from current situation of design for disassembly and reusing.
- Search for the principles for subdividing and dismantling large scale components.
- Define relationships among furniture function, joints and texture on one element.
- Define rules for elements forming.
- Develop a design strategy for this kind of designing process which ask for a multi-proposal based on one package of multi-functional elements.
- Provide more design oppotunities by introducing the new strategy.



X IN ONE

- "X in One" is the core concept of the design strategy and project.
- To extend the life cycle of large -scale temporary architecture, which asks the elements can be used in both large and small scales, it is necessary to break through the barrier between scales. It should be able to build up both large-scale structure and small-scale structure from one kit of elements.
- X design proposals from one kit of elements:
elements --- components (large / small scale)
components --- structure / architecture (large / small scale)
- X scales in one proposal:
The project is a large-scale exhibition pavilion, there are spaces of different scales inside, which shows the elements can build up various scale -structures. The pavilion itself is also an exhibition, showing how elements can serve all scales.

METHODS

- **Vocabulary :**

element - small-scale building blocks which are seen as basic units to compose building components

component - made up of elements; multi-scale components which are used to build up both large-scale temporary buildings and small-scale daily-use buildings

- **Research :**

The project started with researching the current situation of the using of large scale temporary events building, and finding out the problems and difficulties of reusing materials and assembly-disassembly-reassembly process.

- **Practice & Experiment :**

Doing practice and experiments on selected case studies to get the sense of contrast between scales and relationship between elements and components.

Get conclusion of subdivision and dismantling, then define rules for elements forming.

METHODS

- **Design Study :**

"Practice & Experiment" is a process from top to bottom, "Design Study" is a process from bottom to top. Combine simple element forming and space design together to define relationships among furniture function, joints and texture on one element. Building up spaces of various scales by basic elements provides different space characters. It is convincing to create multi-functional elements.

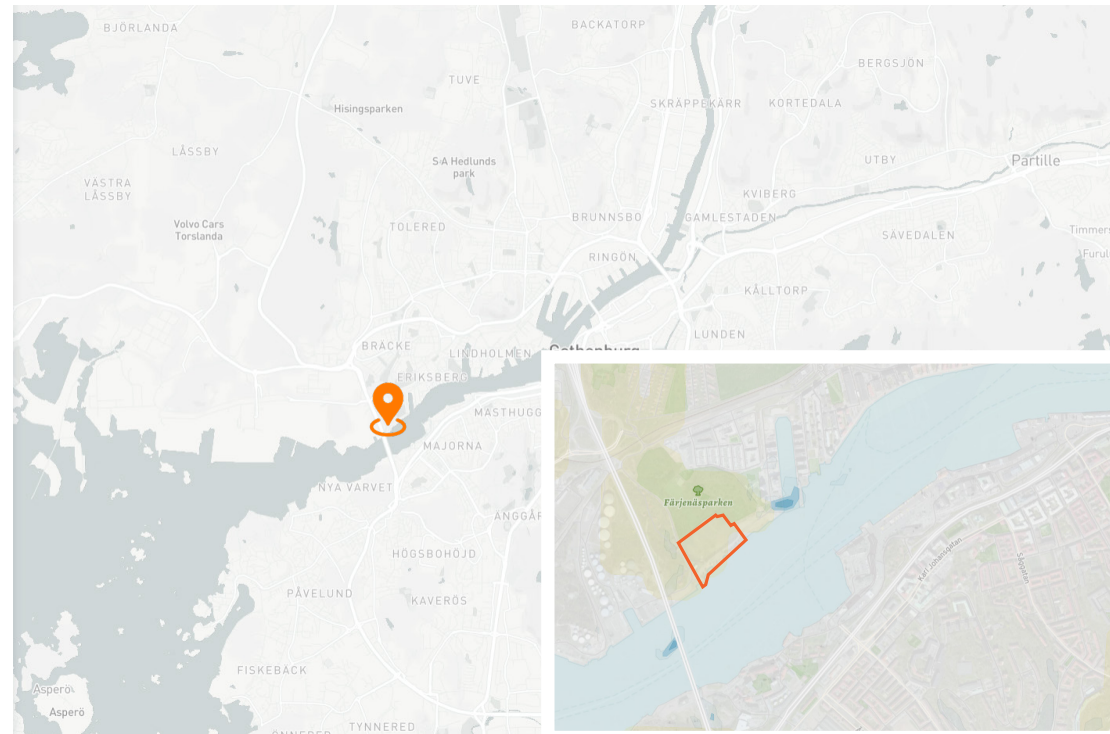
- **Design :**

After getting categories of optional materials and structures, there comes attempts of applications. And together with articulating themes into actual building designs, the strategy of X in one should be tested to see whether it works or not. This is also in a circular way.

- **Modelling :**

The reusability in this project is more about materials and building components rather than the entire building. Defined elements are 3D printed for physical experiments, which show how elements serve various scales and space.

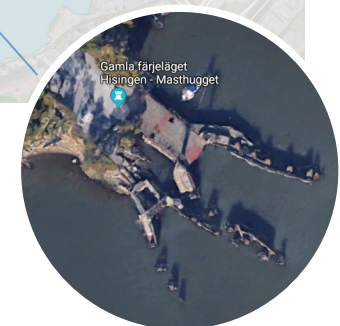
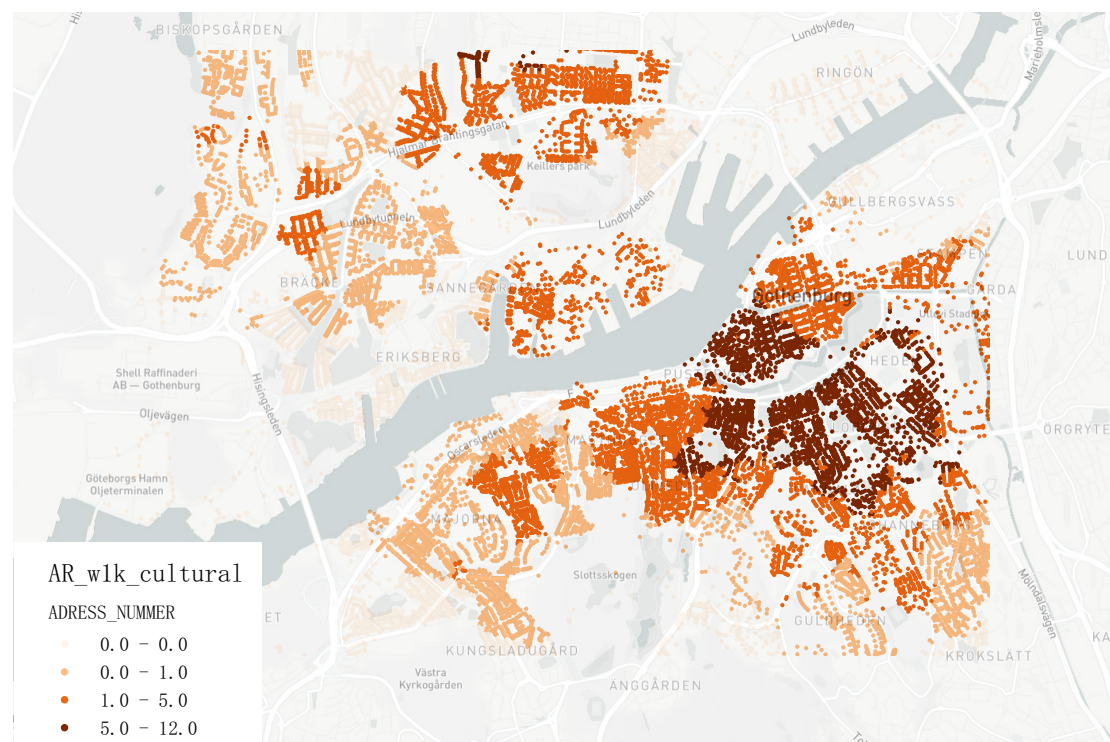
Digital models should also be used as test tools to understand how elements should be and if the reassembly works as imagine.



SITE

Västra Eriksberg, Göteborg, Sweden

- The area has a good connection with water and green area (parks, forests, etc.) which is suitable for exhibition pavillion.
- Due to the QGIS data analysis, it is on the direction of expansion of residential areas, there is more need for cultural and event places.
- If this area need more dwellings according to the area development, then the pavilion can be reassembled into housings.



DESIGN



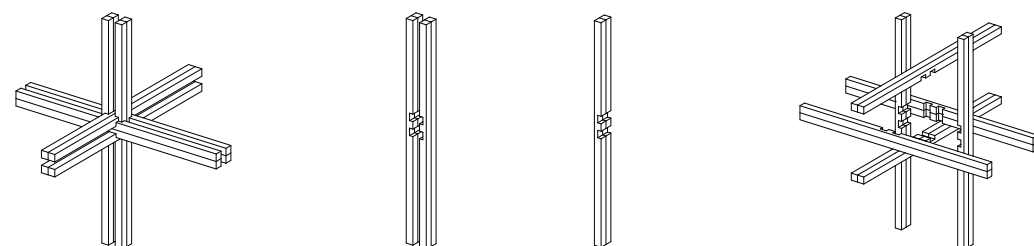
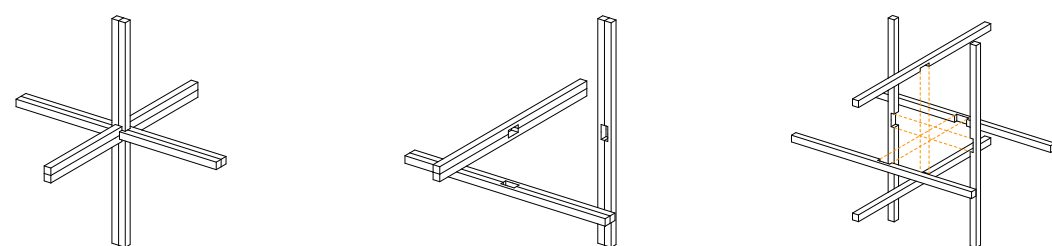
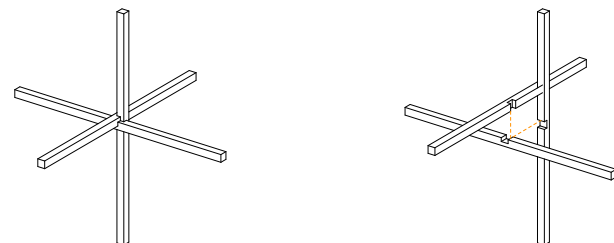
*Design Study, Multi-functional elements
& Design Proposal*

DESIGN STUDY

Due to series of researches on elements and modular housing, it eventually comes to the stage of designing. When applying the principle of dismantling and subdividing to exhibition pavilion design, a question appears. How can I take the advantage of this design strategy in terms of architectural design. It should not be only the simple subdivision of building components, but also related to space and function.

The design study starts with looking deeper into consequences of subdivision and assembly. There are micro-spaces created by combination of elements. There are also different results when meeting the needs of functions.

In this stage, elements start to be multi-functional, which means it is not only a structural component, but also treated as, for instance, functioned furniture and unique joints.

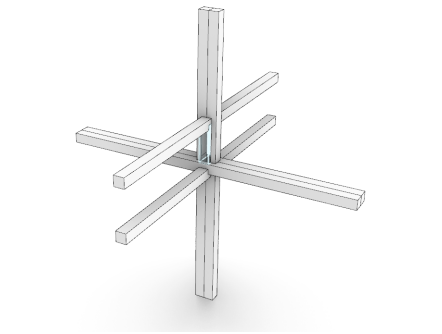


DESIGN STUDY

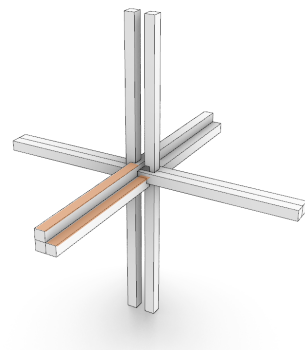
1.1 Element accumulation

When researching subdivision of large scale frame structure, I only tried with entire components, but there is another situation that there is possibility of combining small scale components to build up large scale buildings. The amount of components in each direction can be multiplied every time to make up a larger structure to carry heavier load.

For example, it is possible to have one element in each direction to make up a small structure maybe for modular houses. And when it is doubled even four-fold, it will be enough to act as a large-scale structural component.

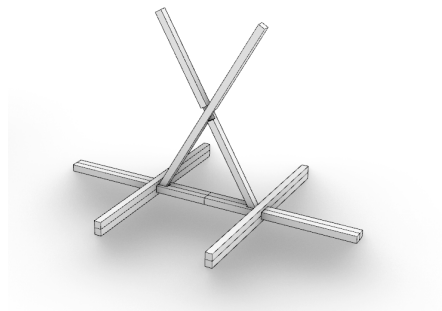


micro-space can be used for random exhibiting



steps created by elements

can be used as seating/stairs



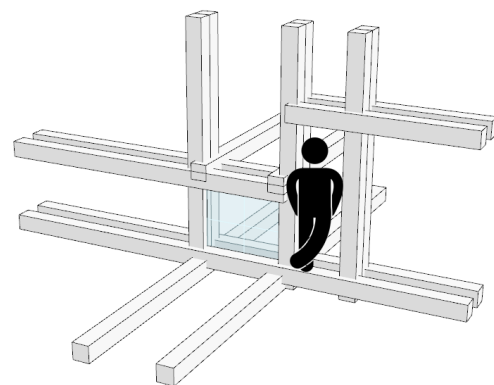
more possibilities of shapes of structure

DESIGN STUDY

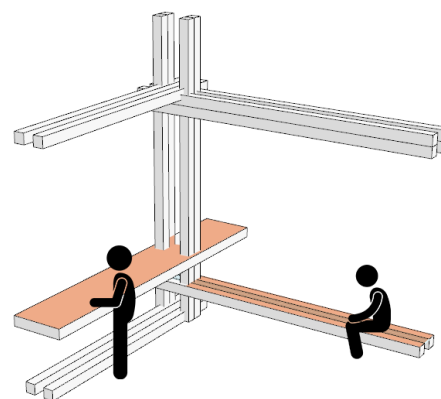
1.2 Space and Function

There are different kinds of spaces created by the structure, mico-space in between, potential furnitures due to the different height of the elements and also various exhibition spaces.

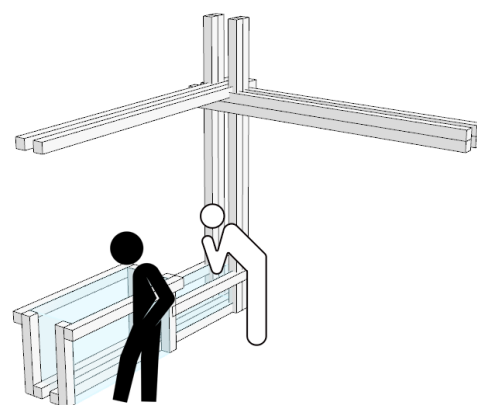
And when the scale of the structure becomes larger, the combination of elements shows more possibilities of space and its using. For example, seating, leaning, walking (steps), exhibiting, etc.



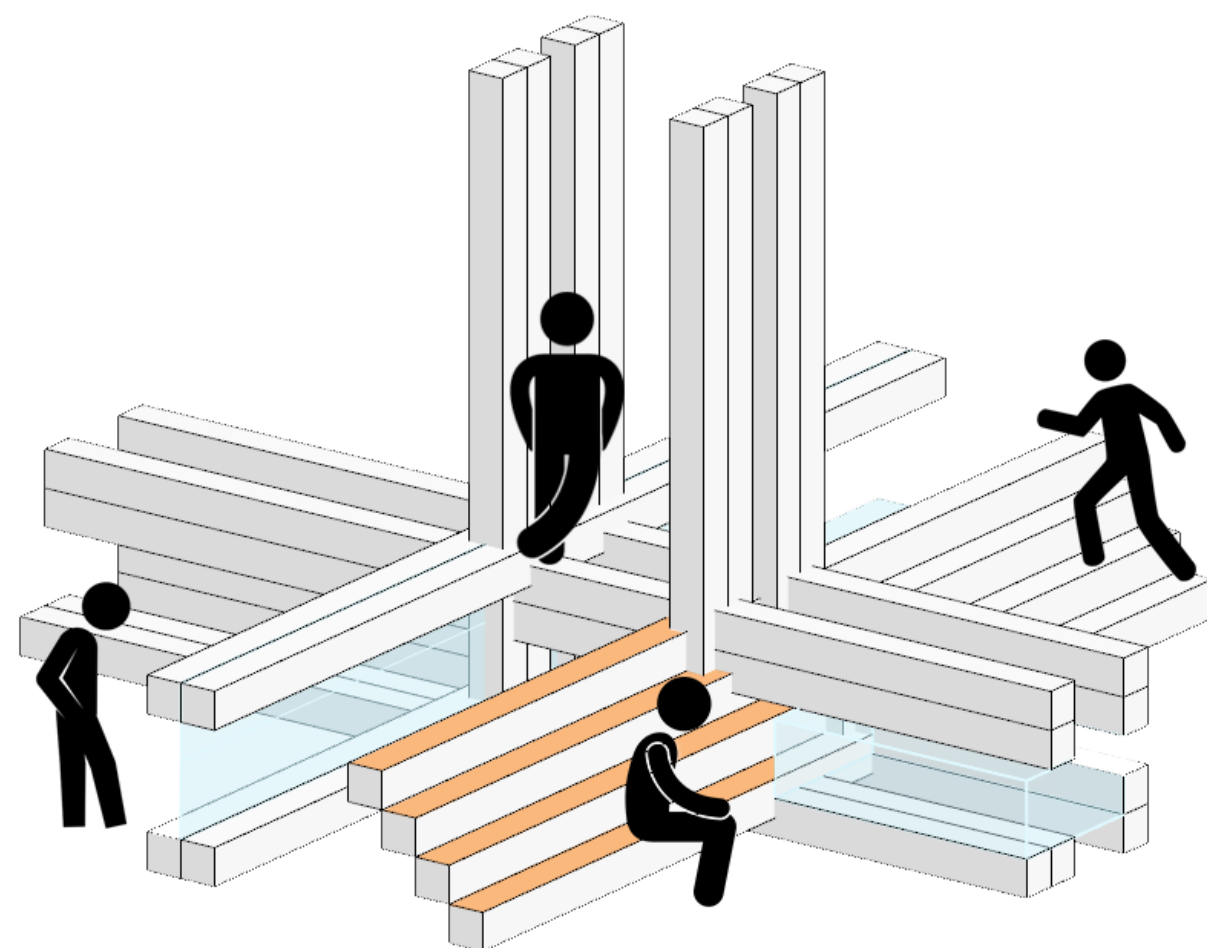
different scales of micro-spaces

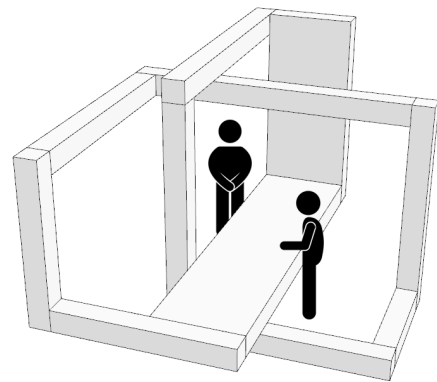


different height - different function
(seating / table)

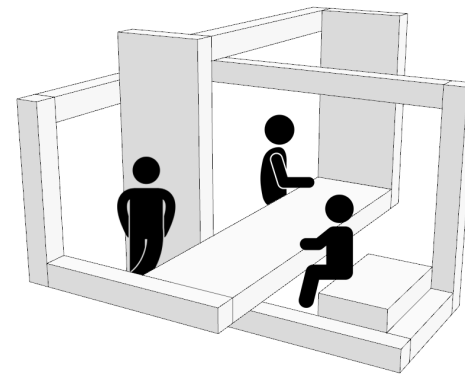


different height - different function
(for exhibition)

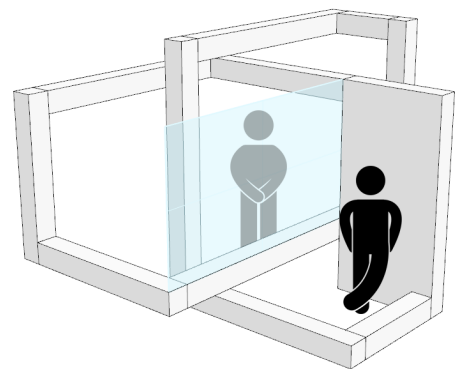




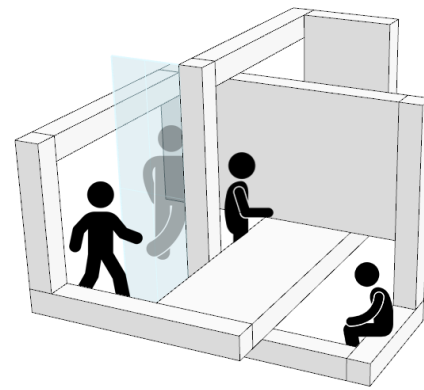
space separate by furniture
direct communication



furniture & space division



see through but not accessible



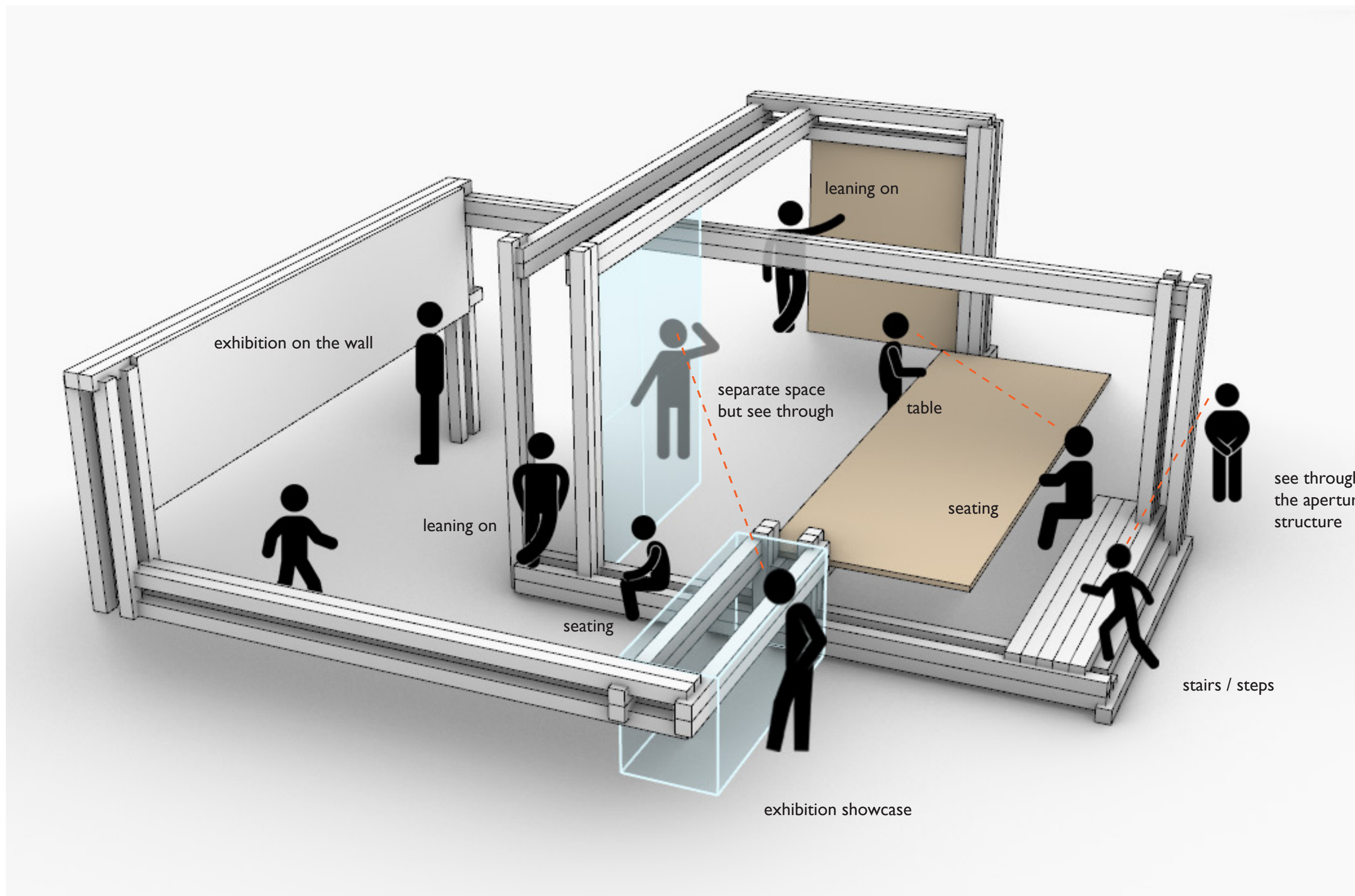
mixed space division

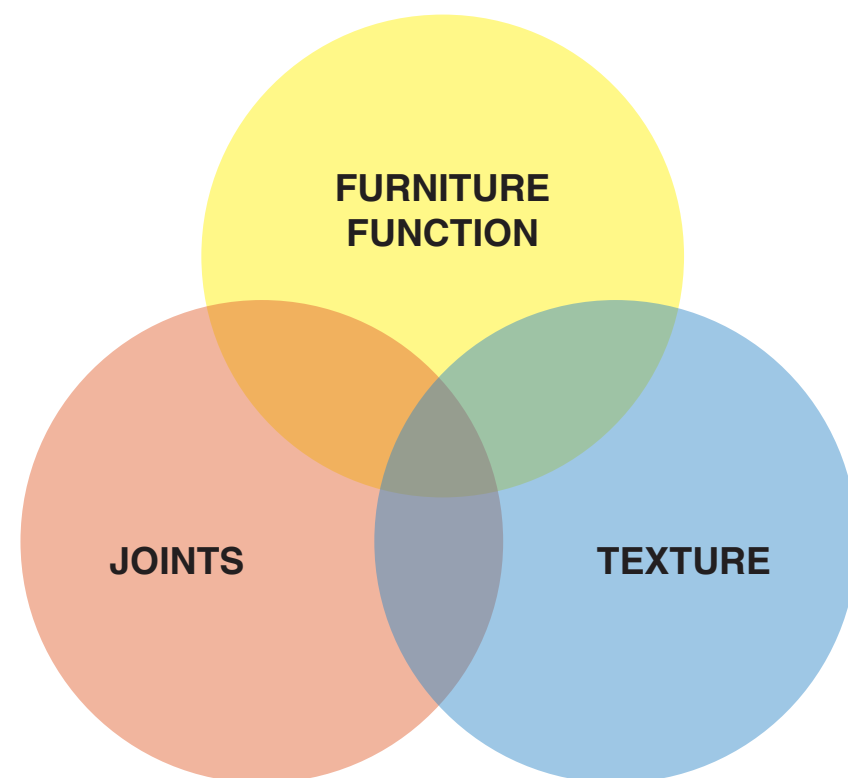
DESIGN STUDY

2.1 Space and Function by Mixed Elements

Picking up a typology built up by both linear and panel elements and doing iterations on spaces and functions formed by them provides more possibilities of how to take advantage of using small scale elements to build up large scale structure.

The few design studies on the left show the space formed by elements : seating, leaning on, placing things, seeing through but not accessible, etc.





MULTI-FUNCTIONAL ELEMENTS

Multi-functional Elements:

Basic elements which can be used to compose building components for various scales, combine joints, furniture function and texture into one.

Joints:

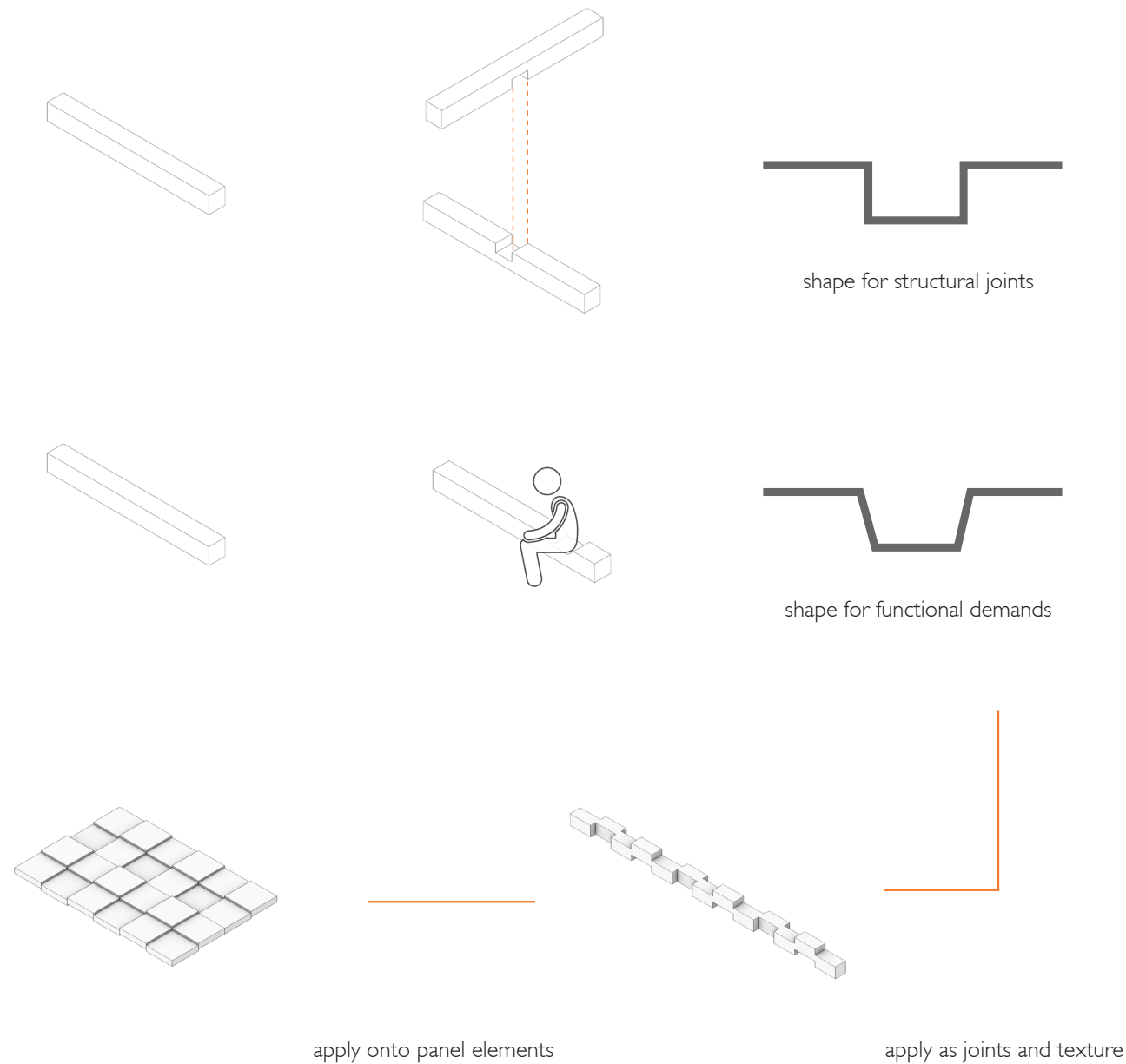
All elements are able to work as a part of large components, which build up large-scale structure. They are also able to build up small-scale structure themselves or build up large-scale structure by accumulation. There should be proper and enough joints on the elements to enable all these aspects.

Furniture Function:

The joints, on the other hand, can be seen as furniture when the shapes and characters are also considered for human behaviour. When the elements work as structural components, other idle parts can then act as furniture (seat, table, etc.).

Texture:

When there is no need of furniture function, the elements then have texture on surface which can be seen as unique ornament. This gives a unique identity to the design strategy and the architecture following the strategy.


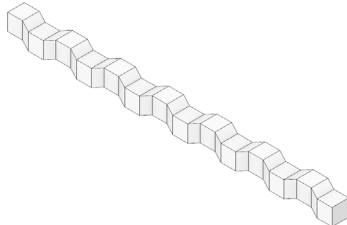
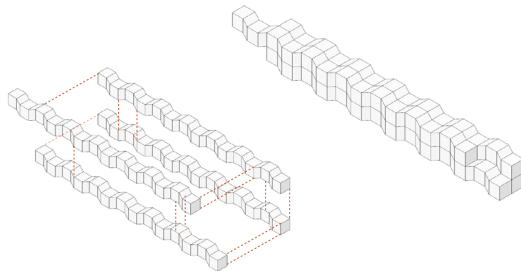
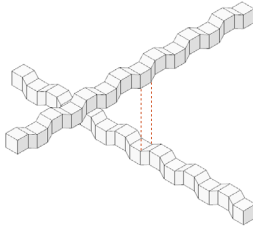
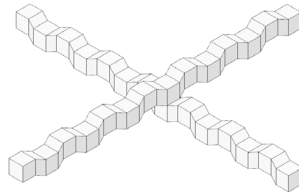
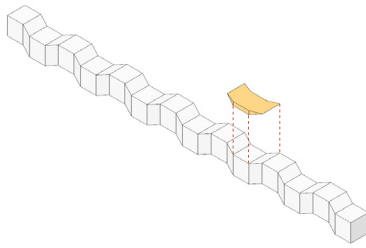
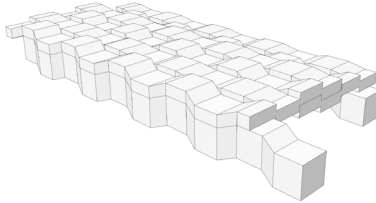

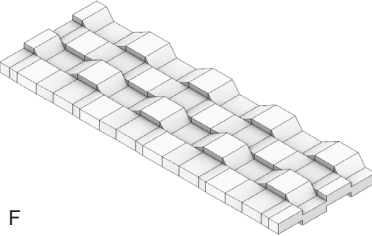
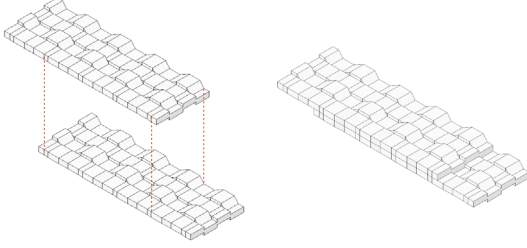
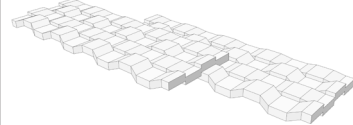
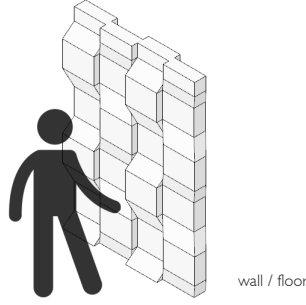
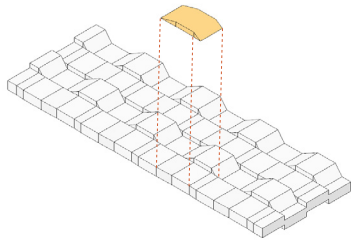
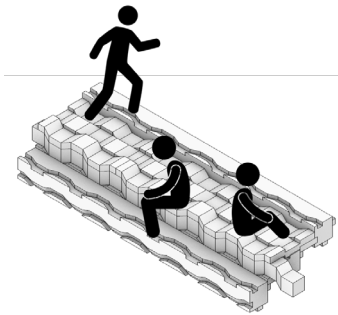

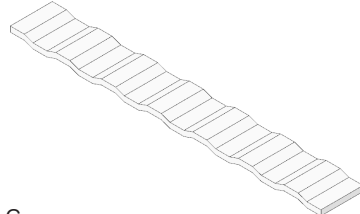
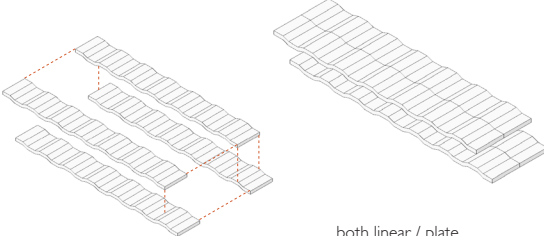

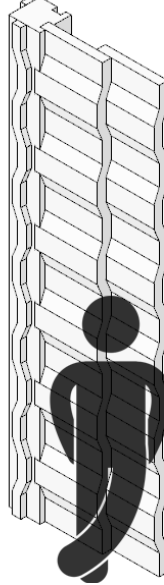
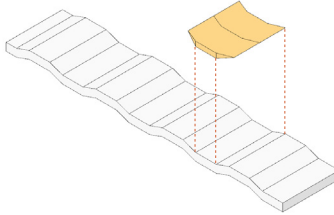
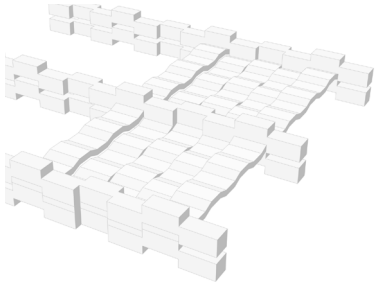

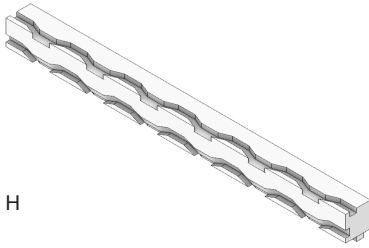
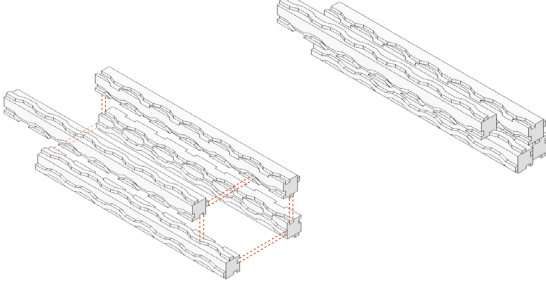
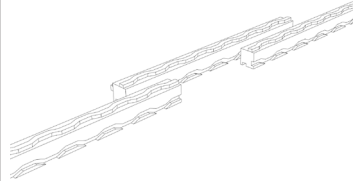
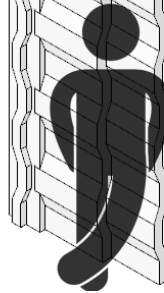
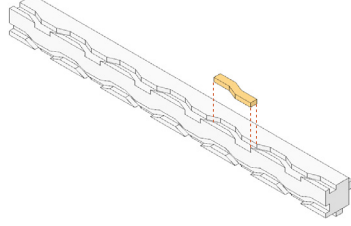
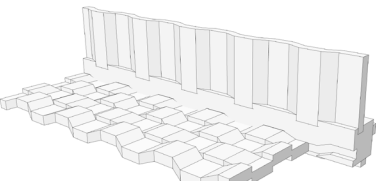


FORM ELEMENTS

Basic shaping relies on the demands of both joints and furniture function. There are plenty of possibilities of elements forming based on simple joint shapes. In this thesis project, two most simple shapes are selected. One is regular rectangular concave based on structural joints, another is concave with a bevel based on functional demands - concave as seat. Both are used to show this multi-function concept can fit any aspects.

After defining these basic shapes, they can be applied all over elements, both linear structural elements and panel elements. Joints everywhere provide freedom for people to build up whatever they want, it is free to combine elements into various large components or assemble either small or large scale structure. The architecture can be always seen as underconstruction which becomes a unique character. Furniture everywhere makes it more free for people to interact with the structure and space. Texture everywhere works as natural but special ornament.

JOINTS (SHAPE)	ELEMENTS (SINGLE)	COMPONENTS			ADDITIONAL ELEMENT	COMBINATION BETWEEN EACH OTHER
		large-large	large-small	small-small		
	 A					 can act as support structure for other elements
	 B					 insert into channels act as floor / wall
	 C					 more complete module can act as a room
	 D					 related as wall and column

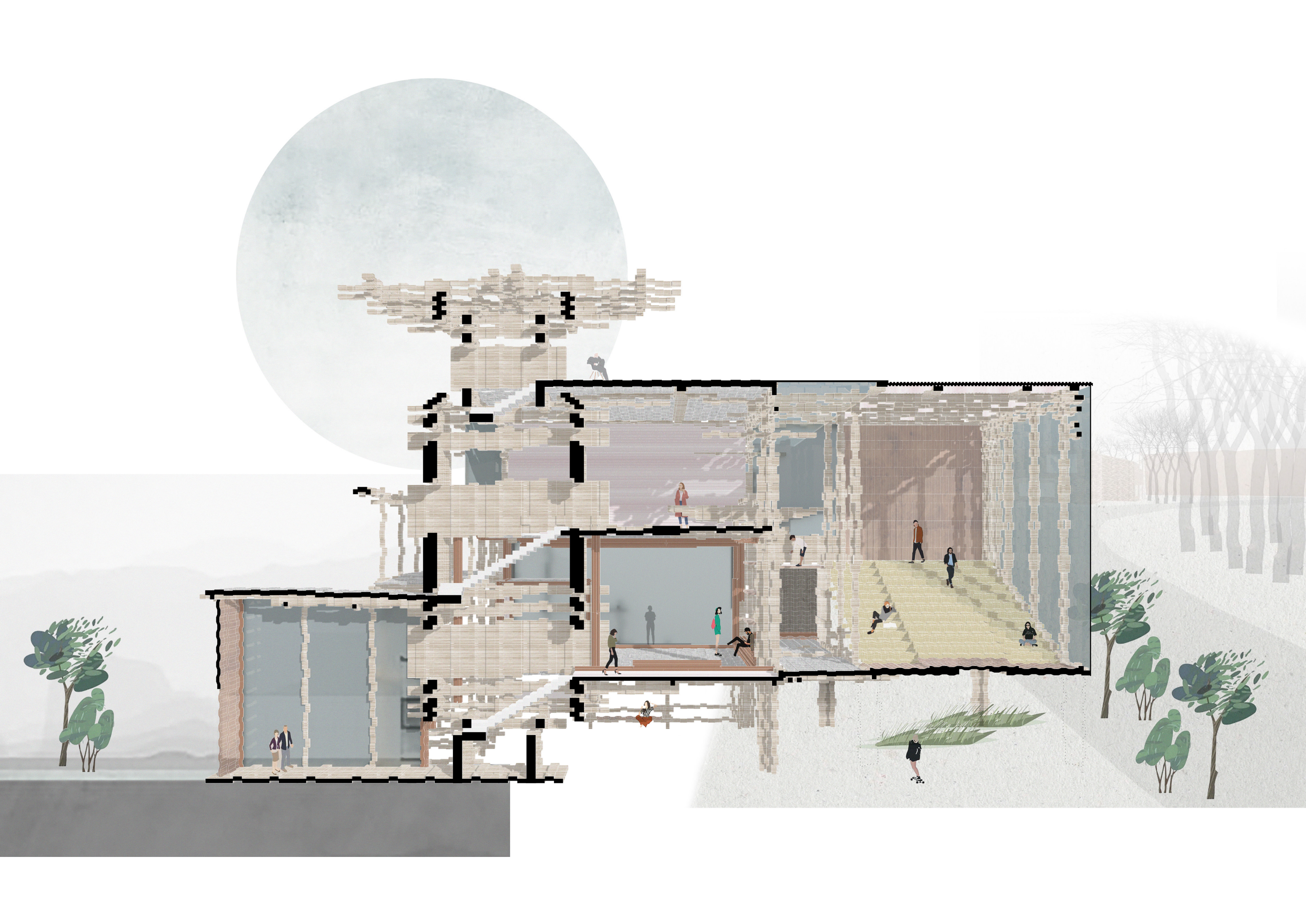
JOINTS (SHAPE)	ELEMENTS (SINGLE)	COMPONENTS			ADDITIONAL ELEMENT	COMBINATION BETWEEN EACH OTHER
		large-large	large-small	small-small		
	 E		 			
	 F		 textured surface (wall / floor)	 wall / floor		
	 G	 both linear / plate				
	 H		 long span without tough combination			 can insert panels in two directions

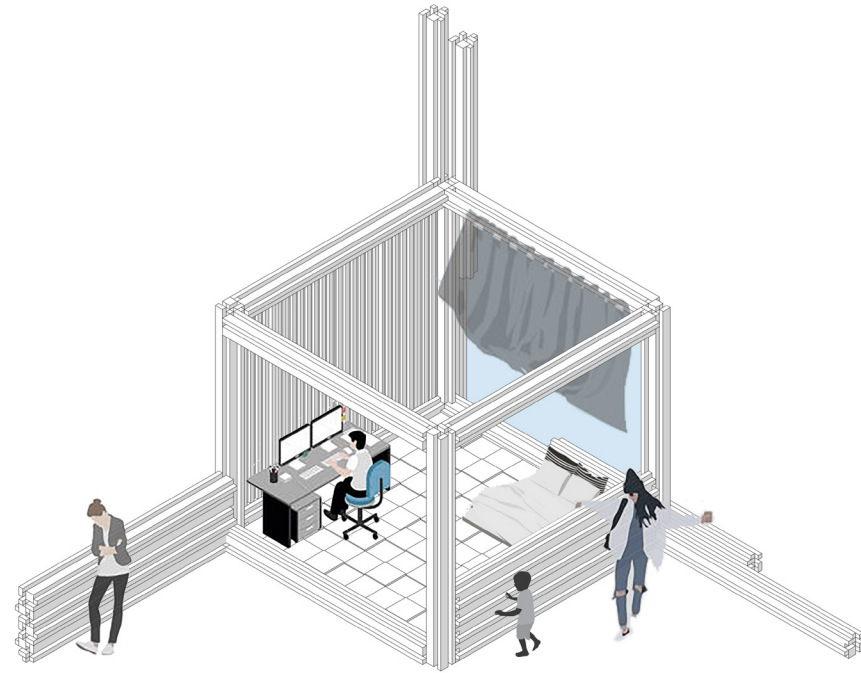
	A	B	C	D	E	F	G	H
A	●		●		●			●
B		●	●	●				
C	●	●	●	●				
D		●	●	●		●		
E	●				●	●	●	
F				●	●	●	●	
G					●	●	●	●
H	●						●	●

ASSEMBLY INSTRUCTION

The design proposal in this theis project shows limited options of using the elements. There can be a large number of possibilities to make full use of the eight designed elements. The assembly instruction shows all the possible combination among them. The design strategy can provide lots of novel proposals than imagine.

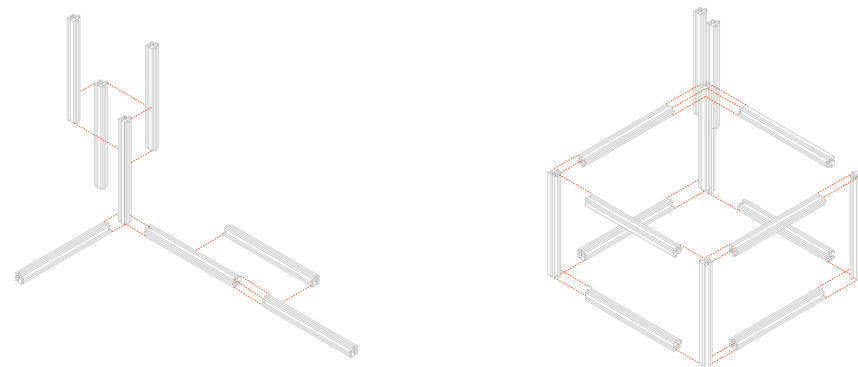
DESIGN PROPOSAL





MULTI-SCALED CORNER

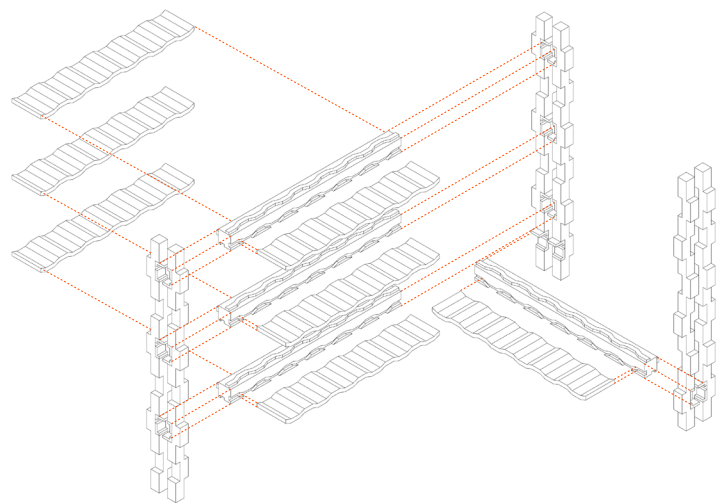
This is a small area in the exhibition pavilion, which can be called multi-scaled corner. This corner serves at least two different scales, one is the large-scale structure, another is the small-scale module. The main structure is built up by series of elements showing how these elements can work for large-scale structure. At the same time, one of the elements of the large-scale component can also be used for small-scale module. This corner combines both scales and shows that these elements can build up various scales structure. The module is exactly a housing module and that is how the exhibition pavilion itself is also an exhibition.

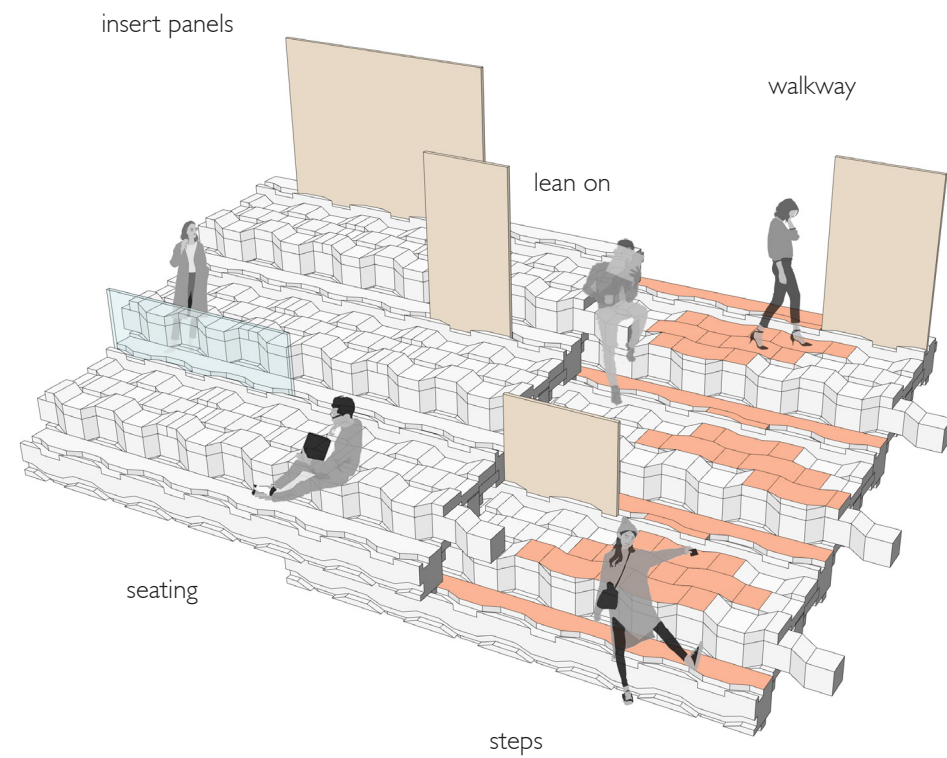




MULTI-FURNITURED CORNER

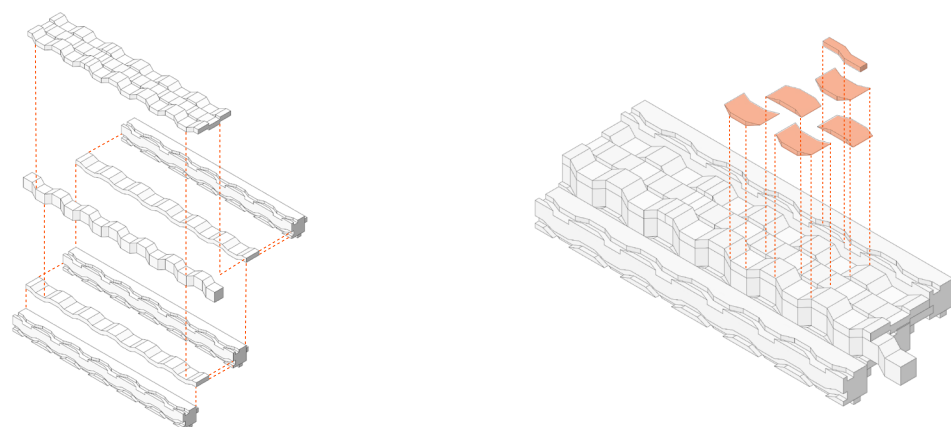
This is a corner who combines structure and furniture together. By assembling linear elements and related panel elements, the structure extends as a shelf and seating place for people. This corner shows how structure and furniture function can be combined. For example, the panel elements can be seen as ceiling or floor panels when building up an architecture, they can also be seen as shelf panels or some other similar furniture panels. The elements can be used for different scales and also different functions.

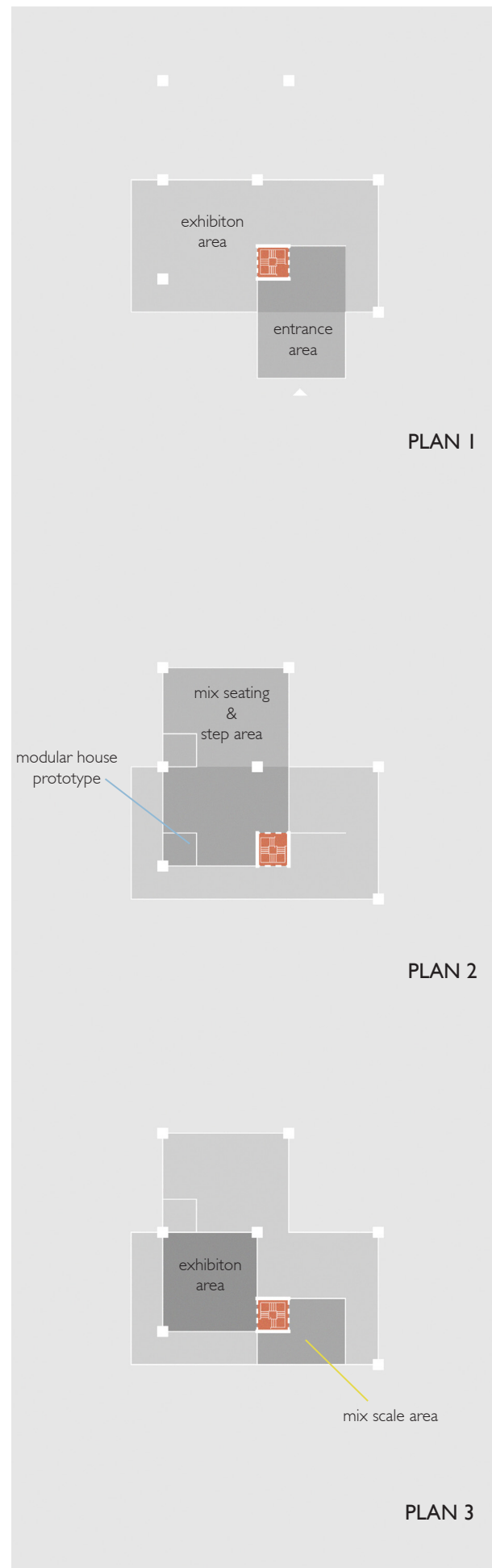




MULTI-FUNCTIONAL AREA

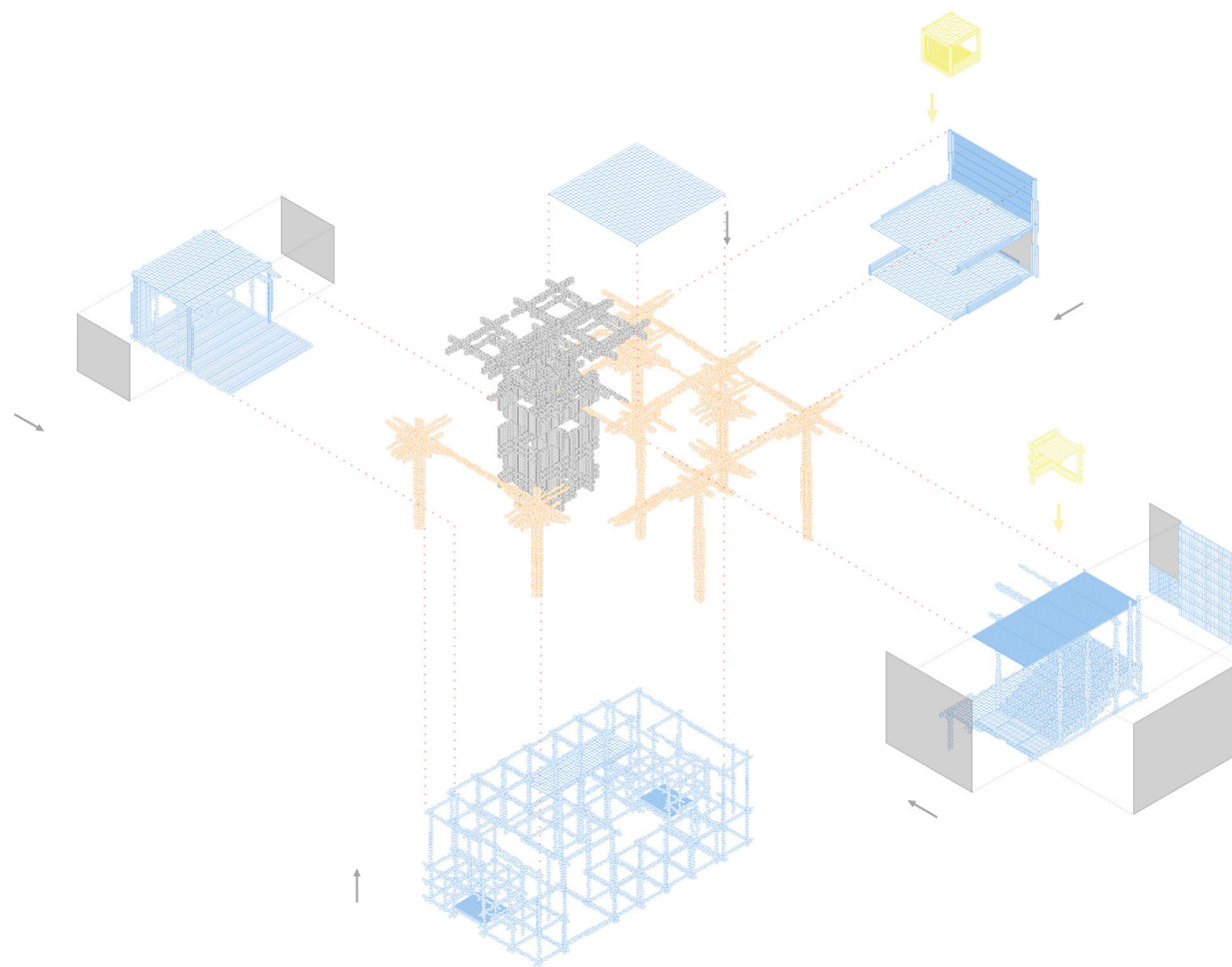
This multi-functional area acts as a flexible public area in the exhibition pavilion. By assembling this part from different kinds of elements, it combines different functions together. The concaves can be used as joints, but also can be used for seating. The height difference created by elements acts as stairs. The channels are free to be filled by exhibition panels. Also the additional elements can be put anywhere it needs to provide a flat path for people to walk through. The area shows architecture assembled by these multi-functional elements are super free to edit and have their own unique identity. It also provides an active space.





FUNCTION PLAN

The plan is function plan with colors showing different function areas in the pavilion. The orange square is the main staircase which has interface with floors in different directions. Light grey areas are atriums which do not coinciding with each other.

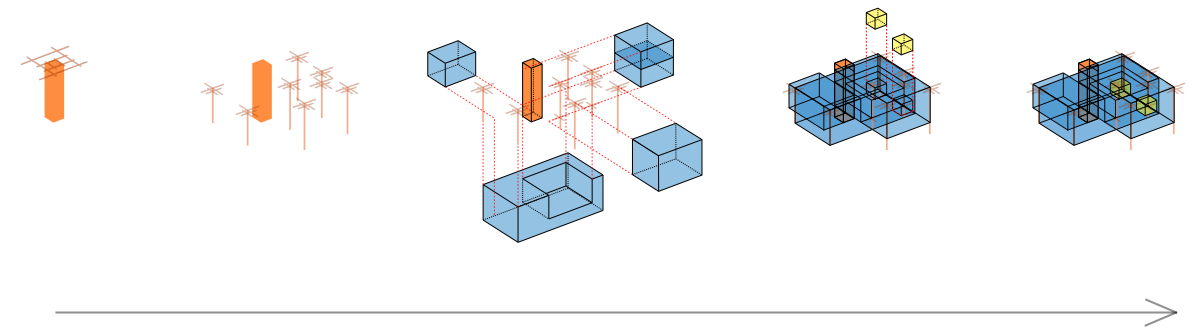


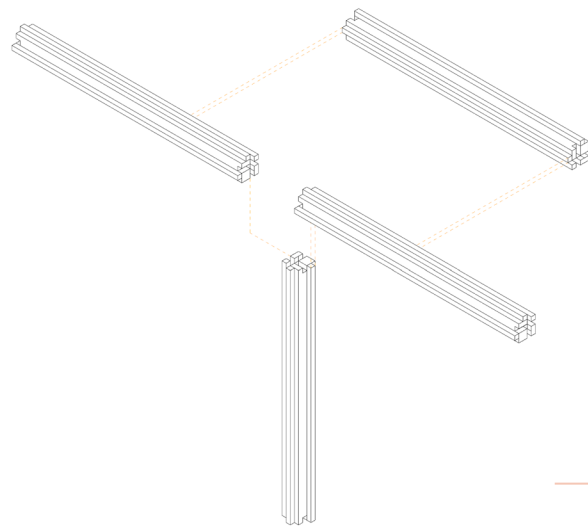
ASSEMBLY

To build up large-scale structure by these multi-functional elements, there is a principle of assembly to follow.

Firstly, use abundant elements to build up a core structure; combine the elements into large-scale structural components.
 Secondly, use various elements to assemble space of multi-scale which are able to be assembled onto main structures.
 Finally, take advantage of some corners to assemble small-scale modules with single elements.

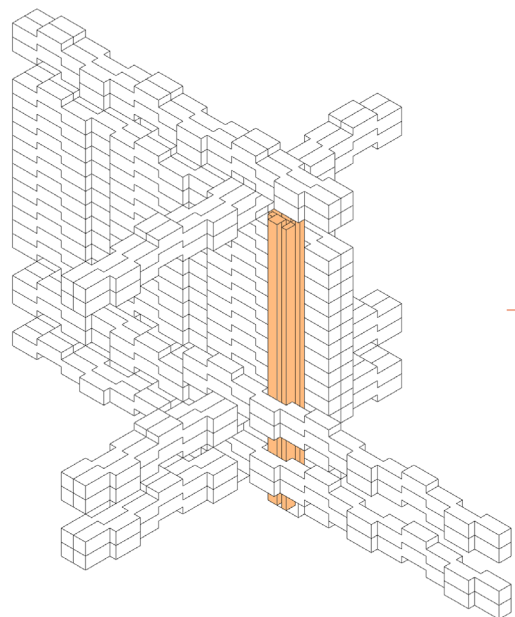
Then here comes out an X in one pavilion by multi-functional elements.





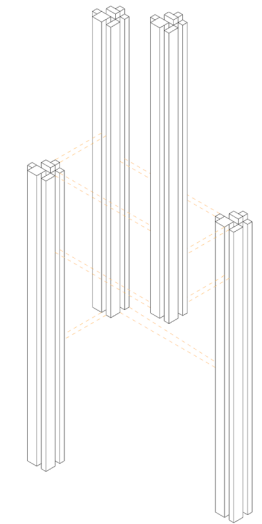
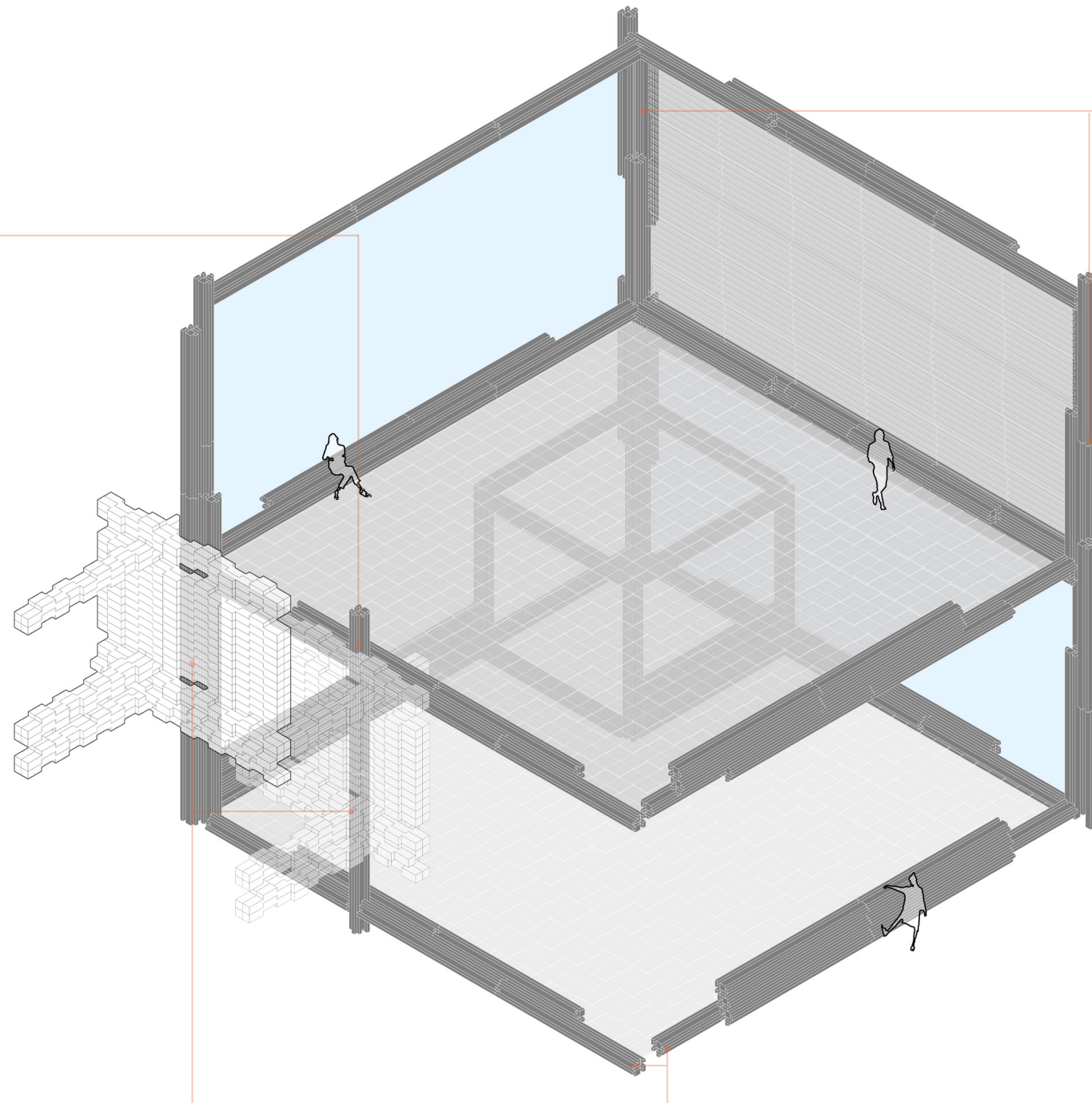
Support more directions

The elements are divided into linear elements and panel elements while all scale structures are mainly built up by linear elements. To build up space and architecture, the linear elements need to be able to extend into 3D directions (xyz).



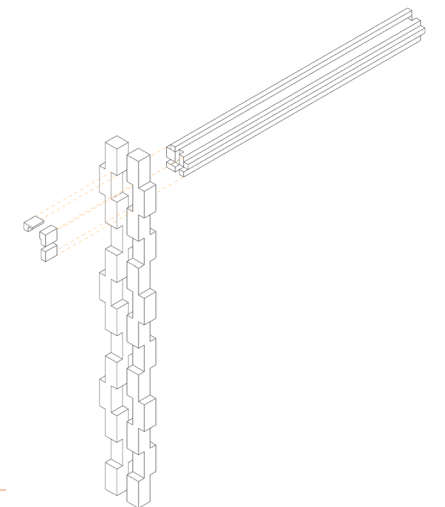
Assemble onto core tube

The core structure of the pavilion is assembled by abundant A type elements and there are channels for structural components of "box" to be inserted into.



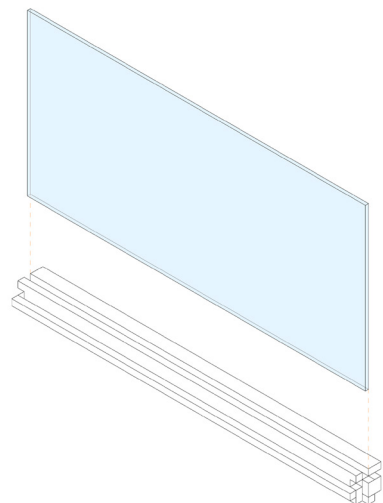
Assemble into large-scale component

Different scales of structures need different scales of building components. All components can be assembled by basic elements and the scales depend on the amount of elements.



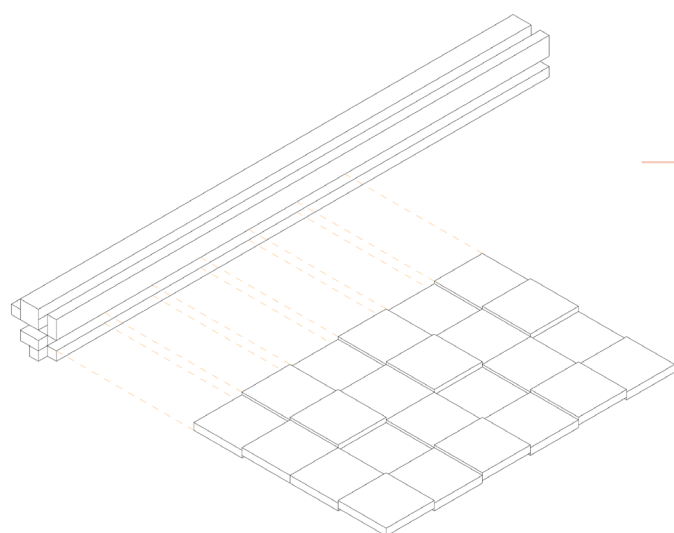
Assemble onto main structure

The "boxes" are supposed to be supported by being assembled onto main structures. All main structures in the project are built up by A type elements and there are channels and portals to be inserted into.



Linear element <-----> Glass

There are channels on linear elements where glass can be inserted into. The glass can work as window or handrail depending on position and need.

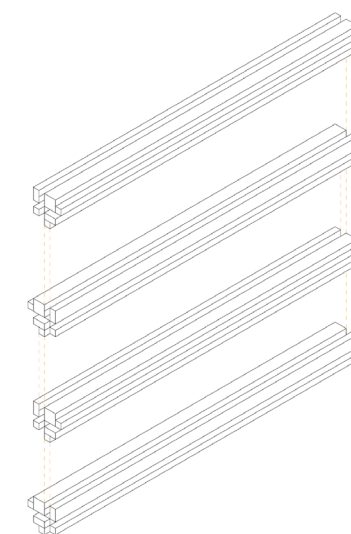
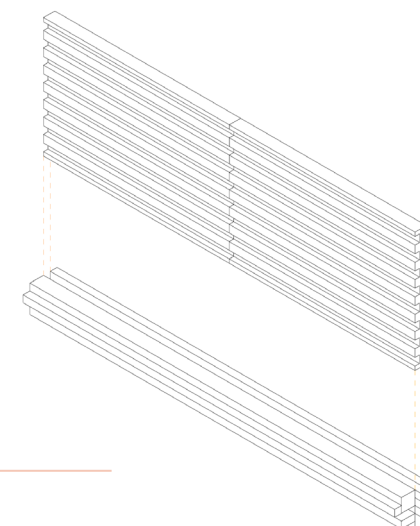


Linear element <-----> Panels

Panels elements can act as walls, floors, ceilings and even furnitures (table, exhibition panels, etc.). They are always able to be inserted into channels on linear elements which build up the frame of architecture.

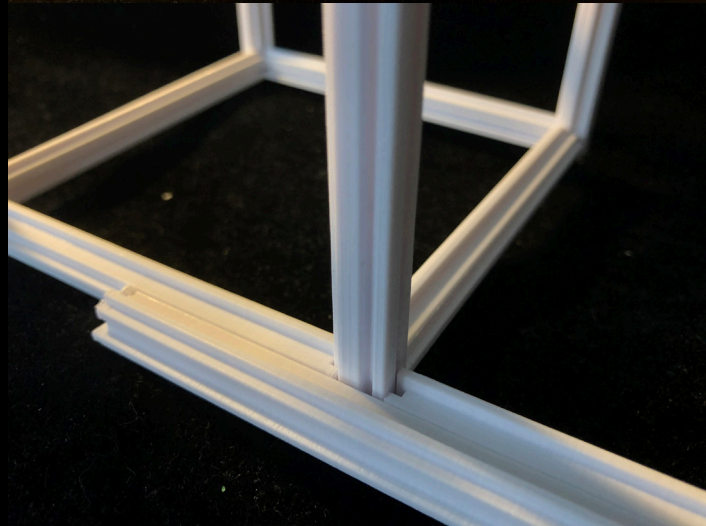
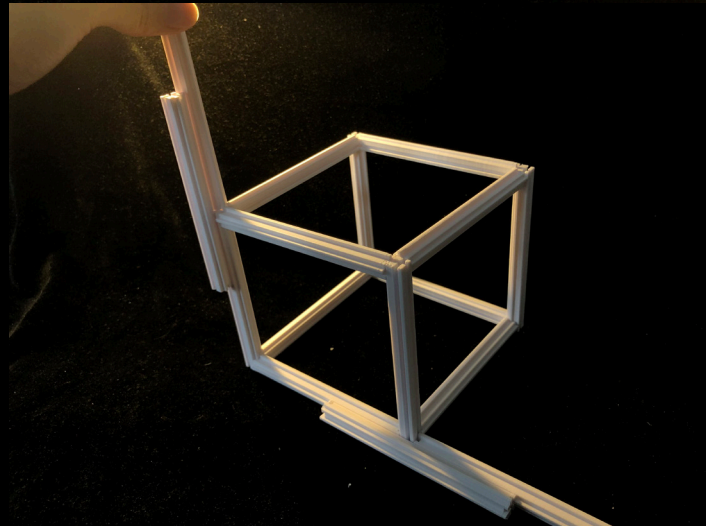
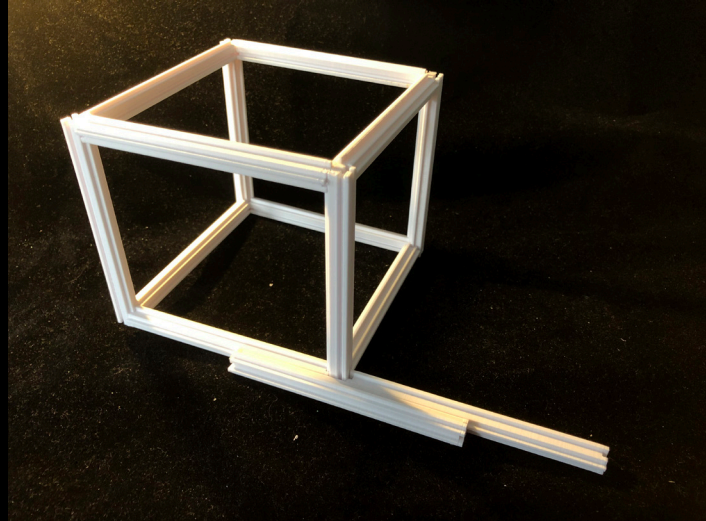
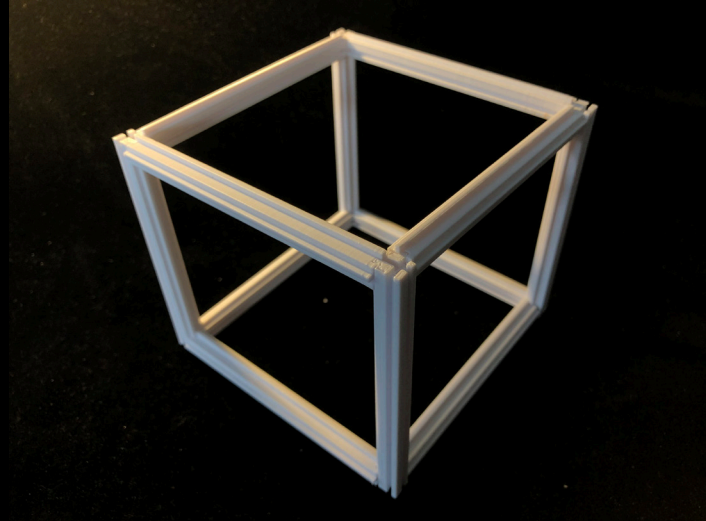
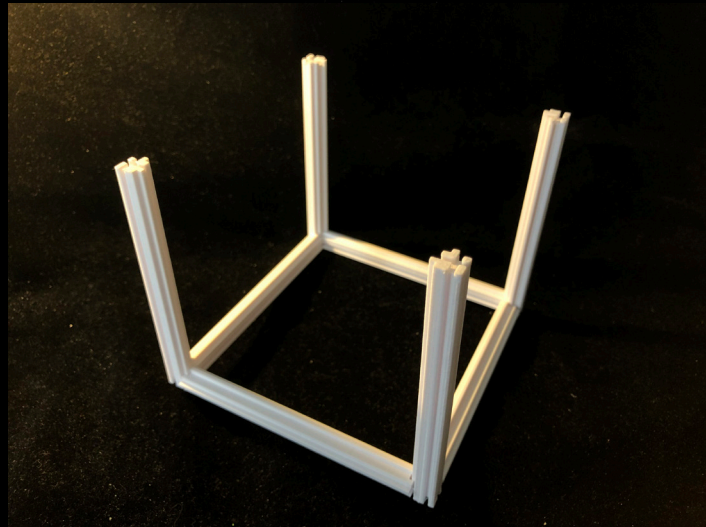
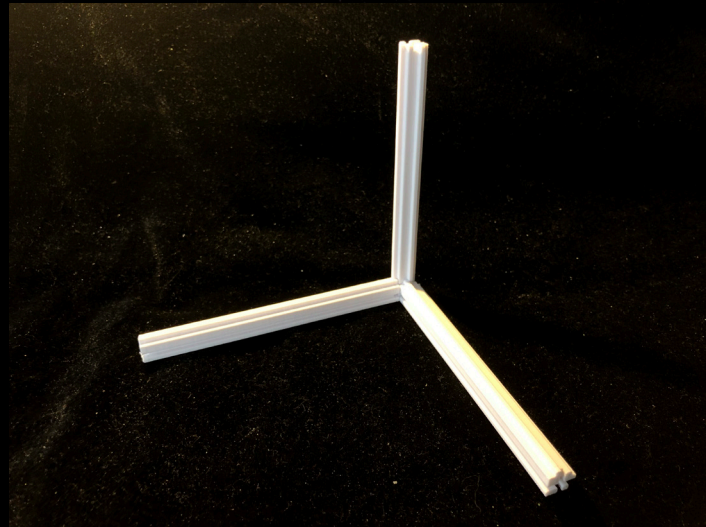
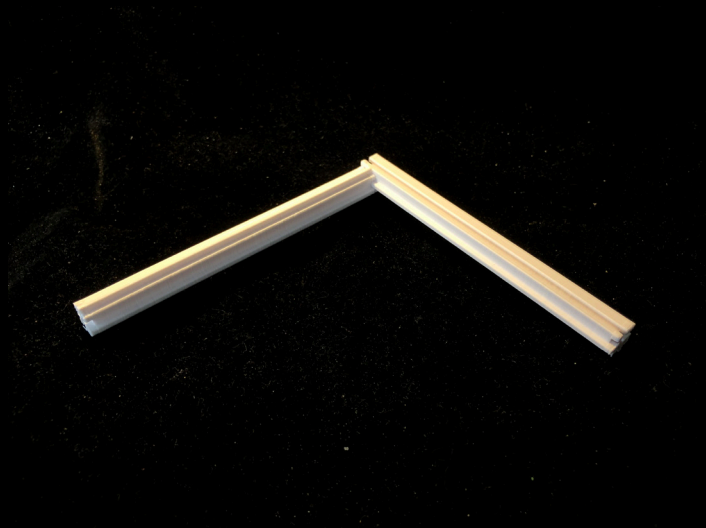
Linear elements <-----> Panels

Channels on linear elements are also prepared for inserting panels which can work as walls and exhibition panels.



Assemble as furniture

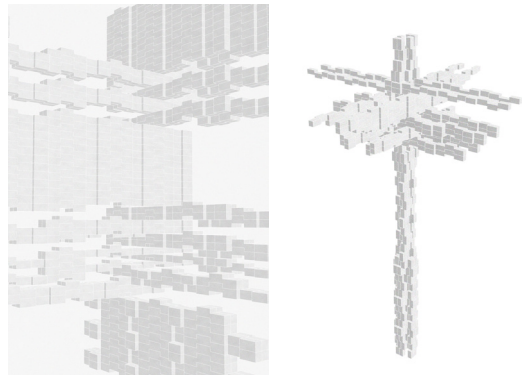
The elements can be used for building up structures but can also be assembled into furniture following a different principle. For instance, when stacking some linear elements (type C) in z direction, there comes out a place to sit on and lean on and it can also be seen as a handrail.



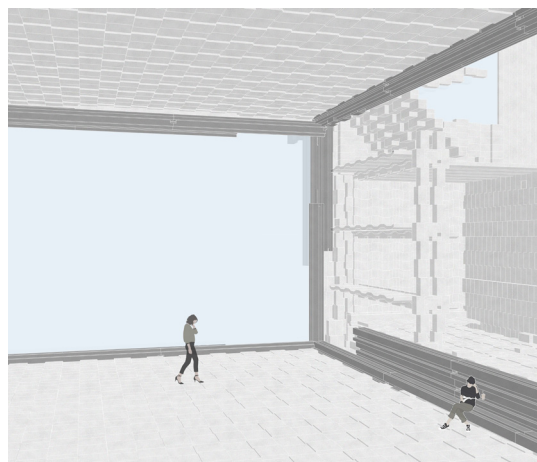
PHYSICAL MODEL

The elements were 3D-printed to show the assembly principle and process from physical models. The print process proves that this kind of elements can be easily go in production. Assembling these elements physically can not only test the design strategy but also provide a chance of building freely.

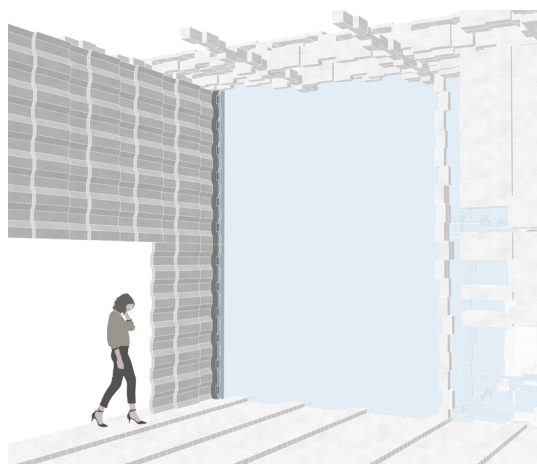
LARGE-SCALE



Exhibition Space

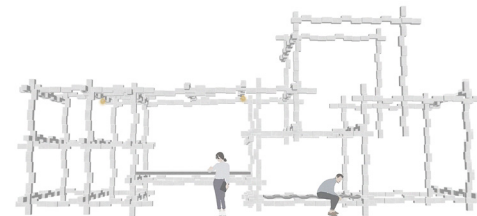


Exhibition Space

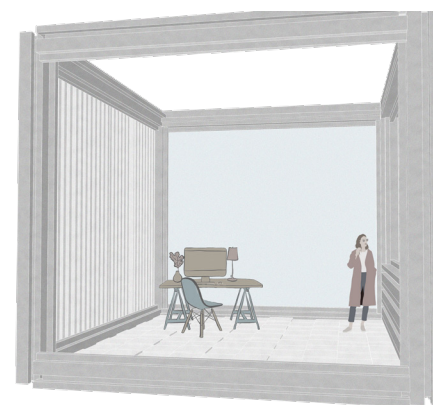


Pavilion Entrance Space

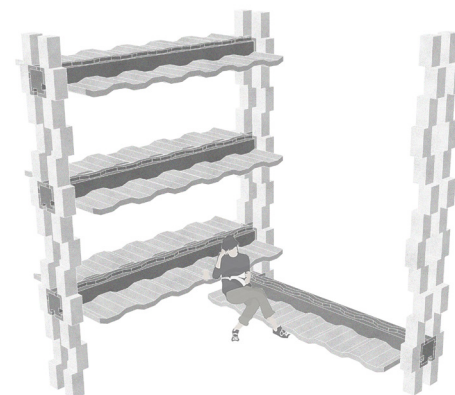
SMALL-SCALE



Small-scale Module



Small-scale Module



Assembled Furniture

BETWEEN SCALES

One of the main points of this thesis project is to break the barrier between scales when using same elements. The pavilion mixes various scales into one which shows the principle of how to assemble X proposals of X scales with one set of elements. So in this project, different scales of structure and space are mixed. The comparison between scales shows diverse possibilities of this multi-functional element concept. In the pavilion, there are some moments showing how some elements can serve different scales.

RESEARCH



Case Study, Practice & Experiments

CASE STUDY



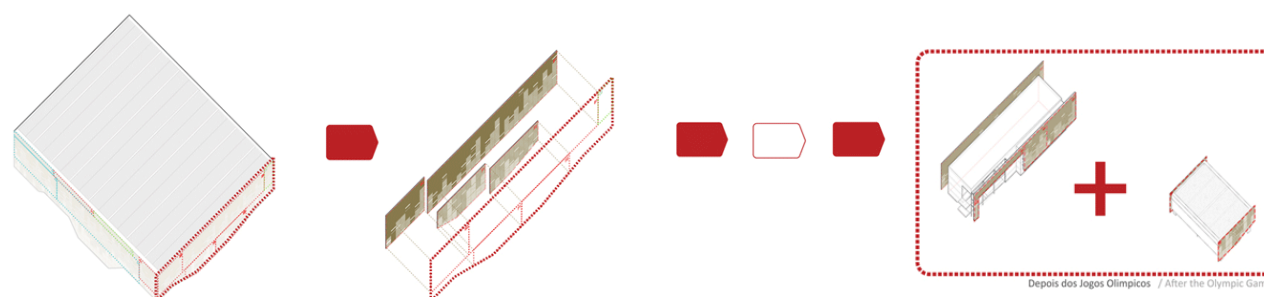
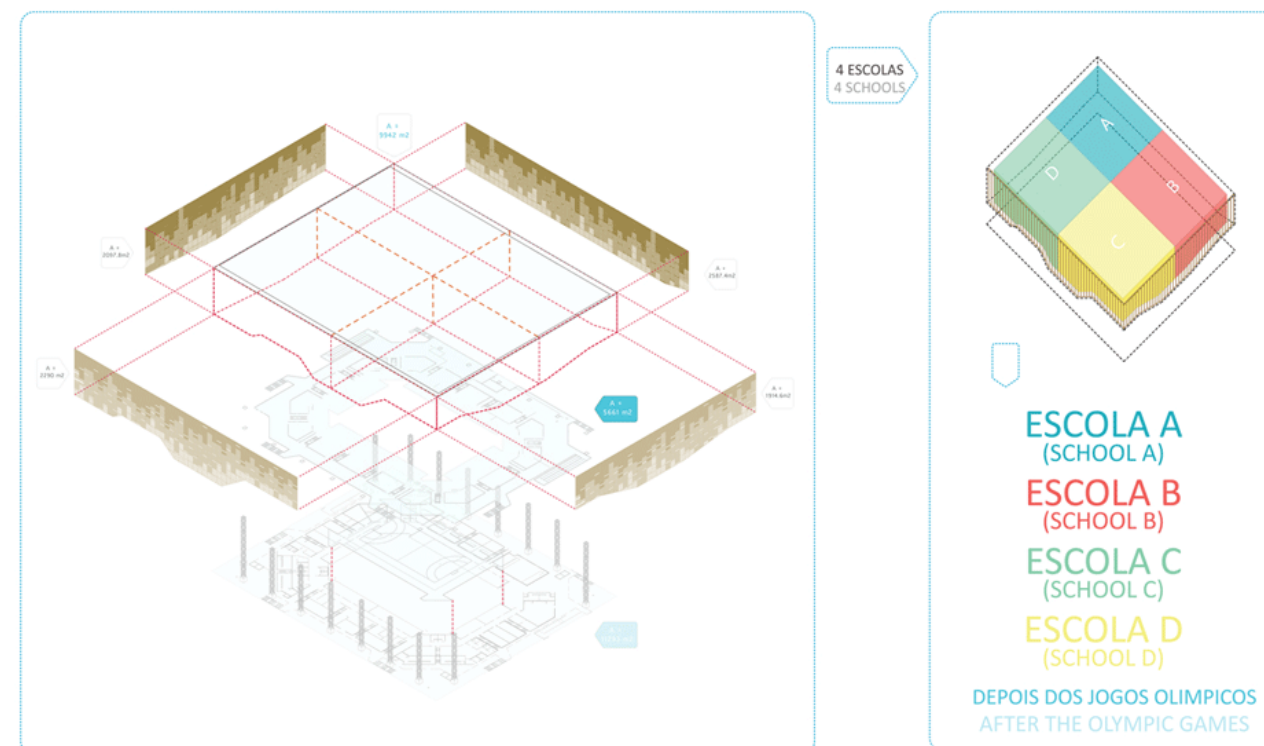
RIO 2016 OLYMPICS HANDBALL ARENA /ANDARCHITECTS

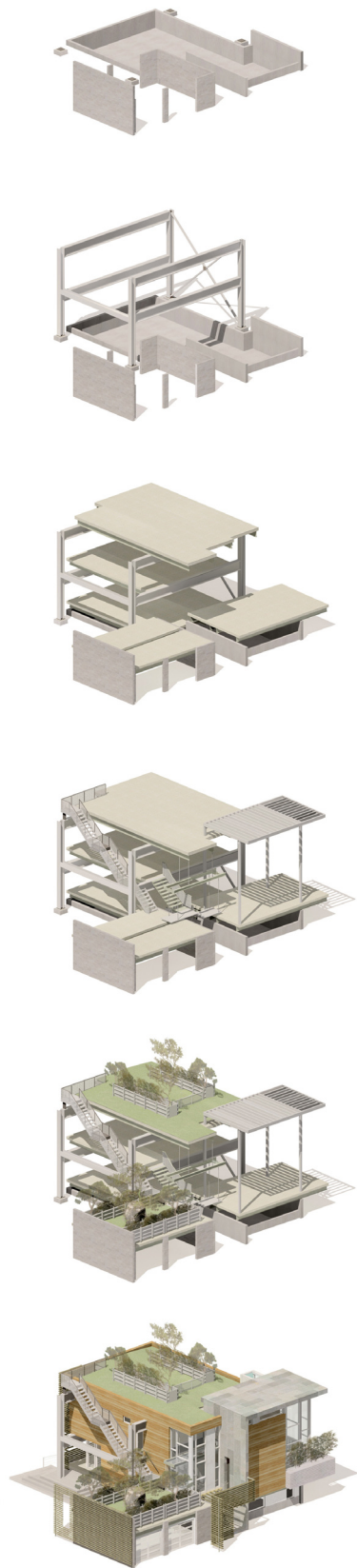
From the 2012 London Olympics, there have been more and more practices of design for disassembly on arenas. For example, more than half of the arenas were temporary and disassembled after the event, some were reassembled somewhere else and some materials were sold for reusing. The arenas for 2016 Rio Olympics were also designed under this kind of sustainable strategy and improved to dismantling and subdividing.

Rio Olympics Handball Arena by AndArchitects and Rio's Olympic Aquatic Centre are both examples for this.

The handball arena is supposed to be reassembled as four schools :

- dismantle and subdivide external walls
- subdivision principles in advance
- walls for schools fit directly and perfectly
- no remaining parts / material





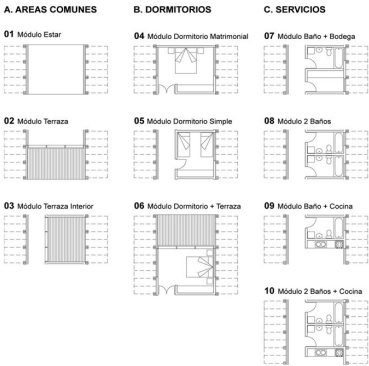
BIG DIG HOUSE */SINGLE SPEED DESIGN*

The Big Dig House by Single Speed Design reutilizes materials from the Big Dig. In that aspect, it's a remarkable example of recycling in architecture.

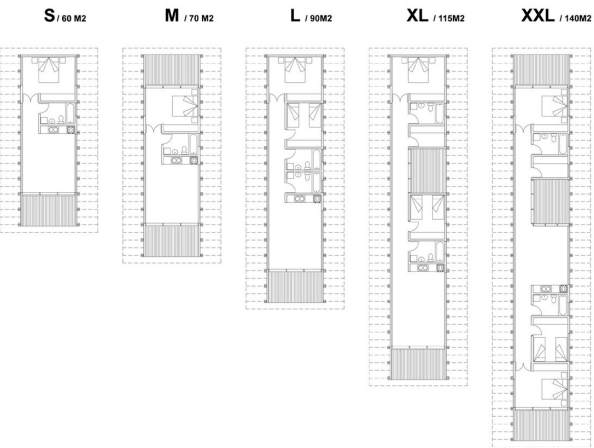
The Big Dig is the most expensive highway project in the history of the US. Part of the material of the house was from the removed structure in the Big Dig.

- salvage and reuse infrastructural refuse
- material of steel and concrete
- pre-fab system
- subtle spatial arrangements are created from the large-scale highway components
- the components are capable of carrying much higher loads than standard building materials, thus easily allowing the integration of large scale planted roof gardens (make it possible to create a lively housing)

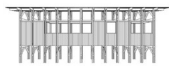
MODULOS



COMBINACIONES



S / 60 M2



MODULAR HOUSE PROPOSA
/FRANCISCO ABARCA AND CAMILO PALMA

This modular house proposal is made up of 10 different types of module, capable of forming 5 different house layouts. The 10 spatial modules correspond to living spaces with a specific use which can be combined according to the requirements of each inhabitant. These modules include bedrooms, living rooms, terraces, bathrooms, and kitchens, among others. The modules also vary in their finishes using natural wood, wood painted in carboline oil, corrugated zinc, smooth zinc, and other materials.

- various modules forming different layouts
- modules vary from each other according to functions
- modules vary in materials (can be related to functions)

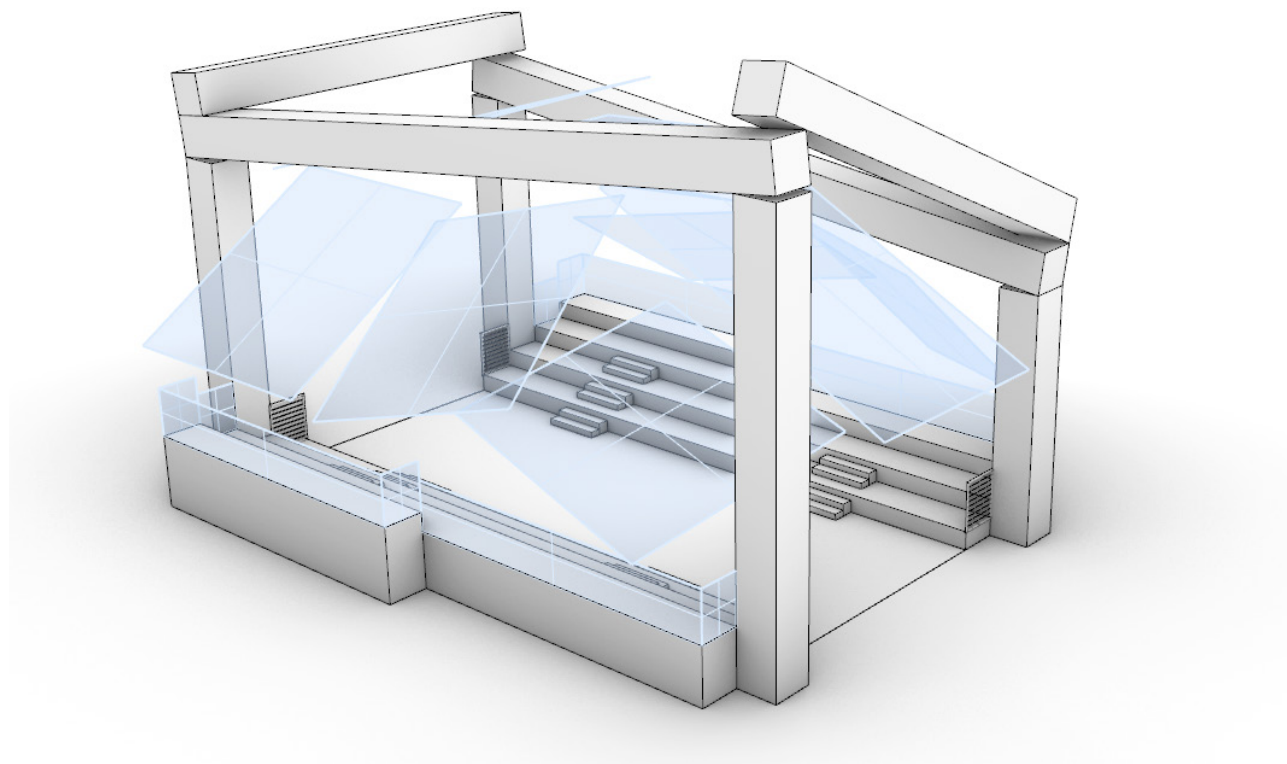
PRACTICE & EXPERIMENT

Different types of buildings ask for different structures, to achieve the aim of this thesis project, it means in the building there should be enough flexible and adaptable elements of various materials to go along the process of assembly, disassembly and reassembly into another scale and usage.

Nowadays, most structures chosen for large scale temporary buildings are longspan spatial structures with large elements or even entire structure such as membrane. However small scale daily-use buildings like housing and schools always need small scale structures. So there is a need of doing research about different types of building structures and finding out some decisions how to adapt both demands.

The following researches (including practice and experiments) show the possible solutions for various structure. They lead to the following situations by taking exhibition pavilion and modular housing as examples:

- combine small scale elements into large scale components for large scale structure
- use small scale elements as components to build up large scale structure
- use small scale elements as components to build up small scale modular housing



PRACTICE

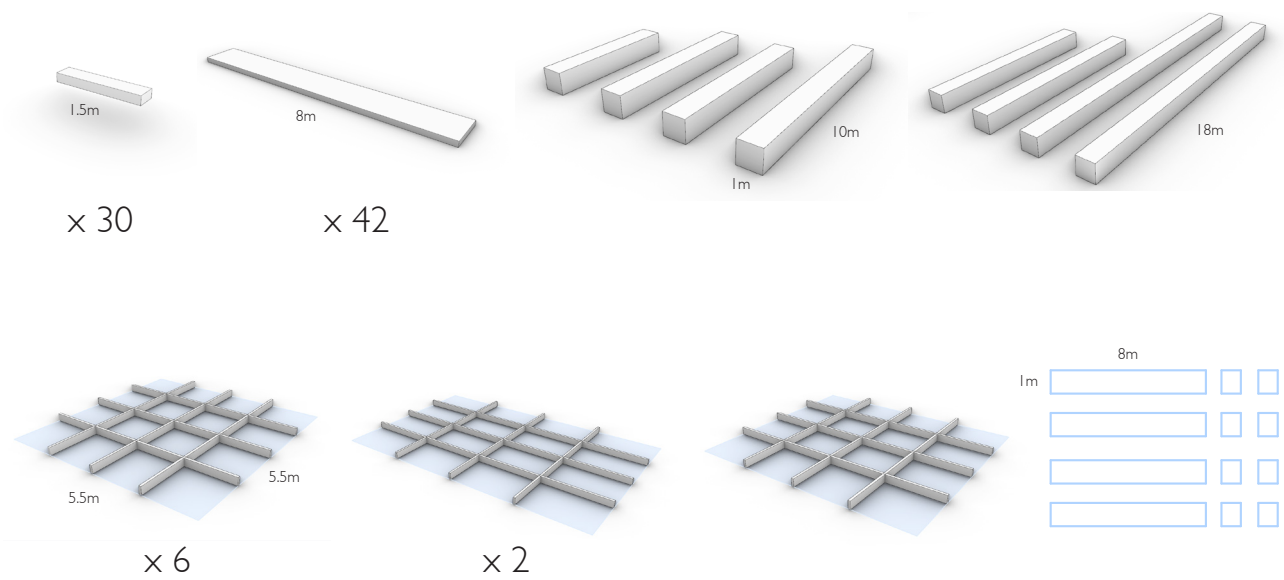
Serpentine Pavilion 2008 / Frank Gehry

Practicing with dismantling and subdividing an existing exhibition pavilion makes it easier to get the sense of large scale components and small scale elements. Take Frank Gehry's Serpentine Pavilion 2008 as an example, the large columns and beams are approximately 1.0 meter wide and 6-18 meters long which means they can be subdivided into four even more smaller ones. There are also timber sheets and glass panels in the project which can be used as walls, floors, windows and some other components in modular housing. So this pavilion contains most of the necessary components of a building / exhibition pavilion, and it is potential to be dismantled and subdivided into small elements to build up modular housings.

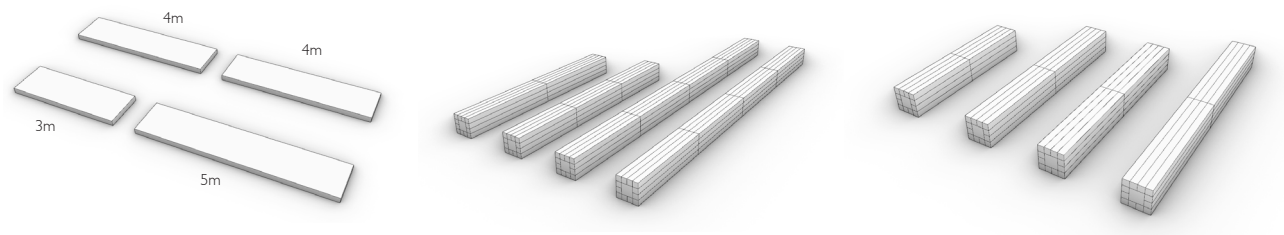
Regardless of joints and fabrication, this practice focus more on understanding how scales of building components can be transferred from one to another. What's more, it introduces the process transferring between scales which stands for the core design strategy in this thesis.



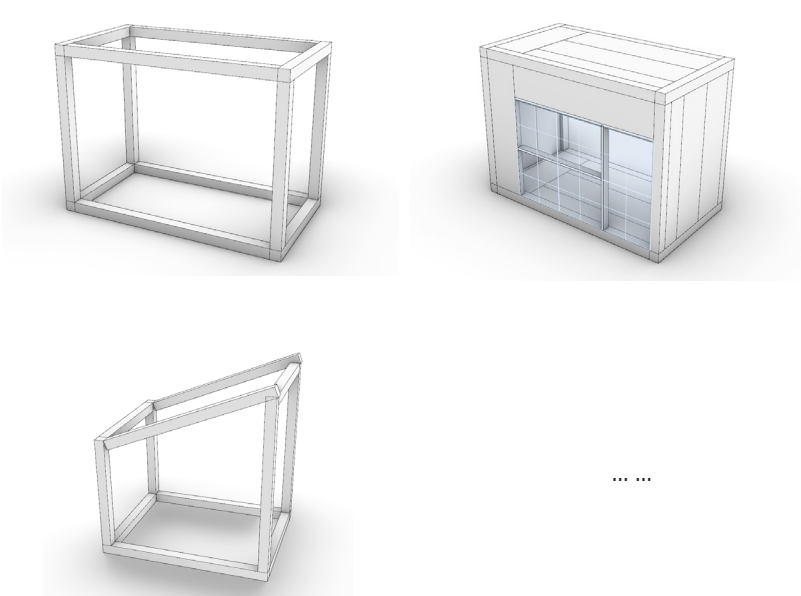
Components :



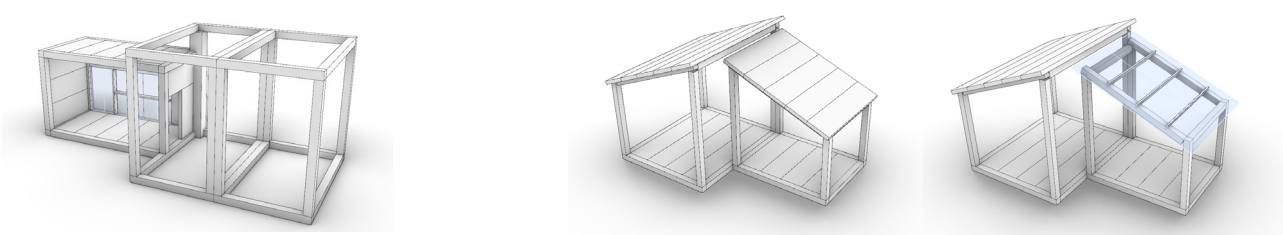
Subdivision :



Modules :



Houses :



Using linear elements to frame the module, then finish the module by adding walls, floors, roofs and windows

... ..

how one element/component/material can be different things

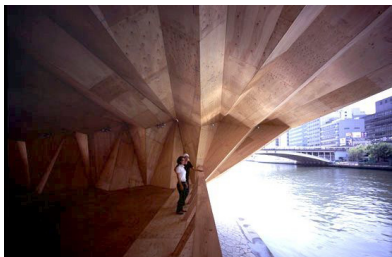
- Frame and grids



- Vaults



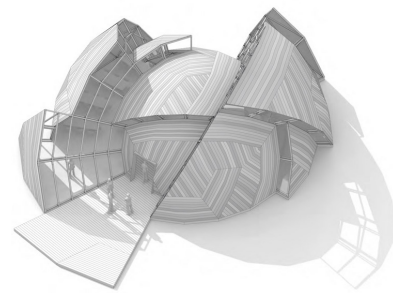
- Folded Plates



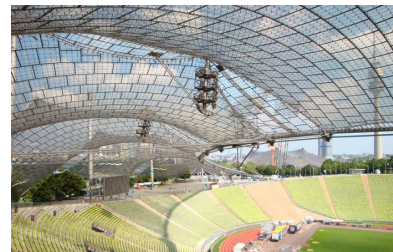
- Shells



- Domes



- Tensile Membranes



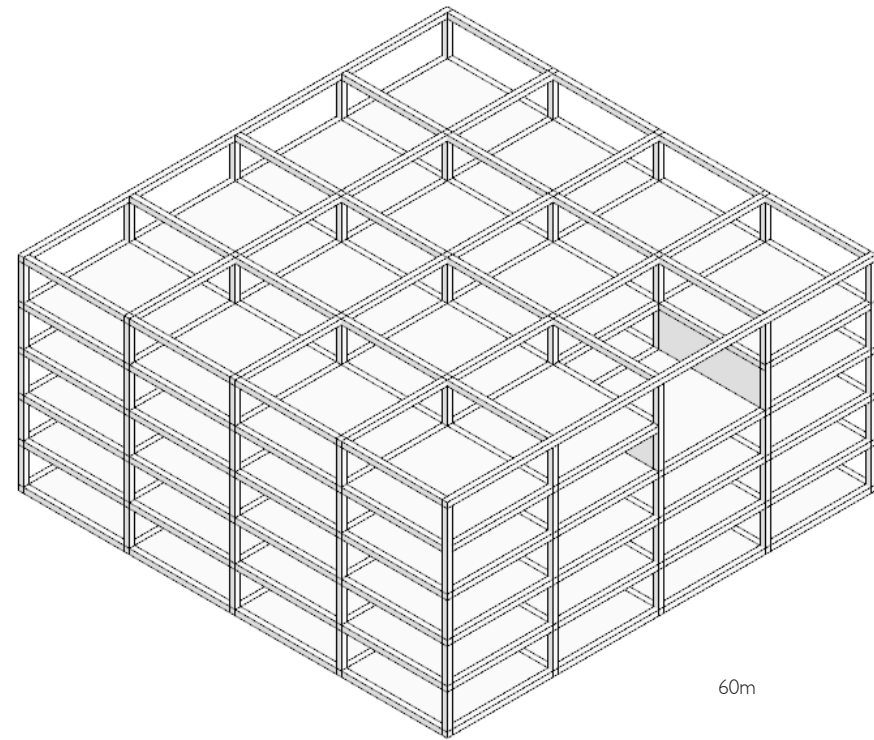
- Pneumatic Membranes



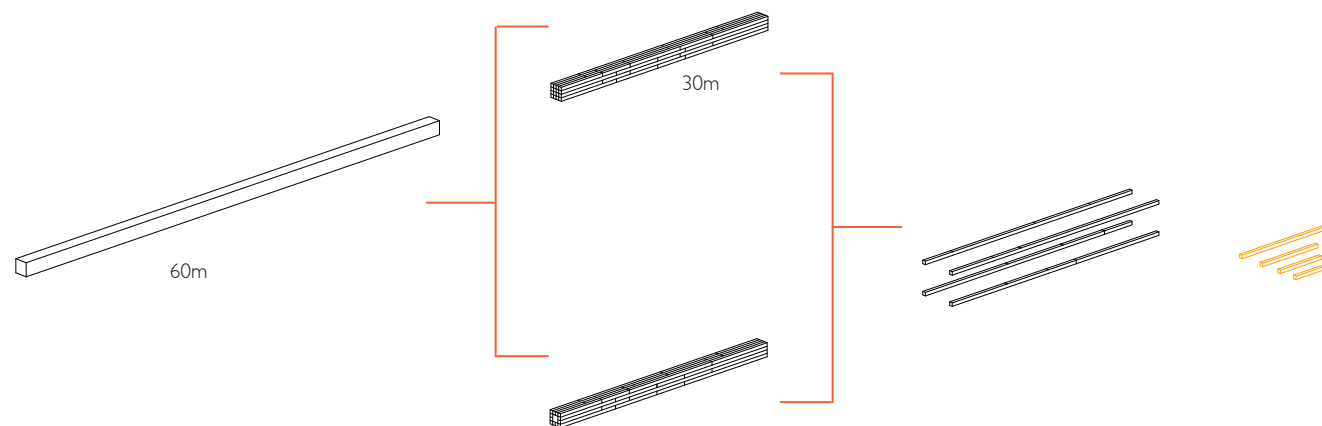
EXPERIMENT

Structure system overview

The concept asks for knowledge of structure system to make use of the designed elements. Doing research and experiments on disassembling and subdividing different types of structure system helps to develop the concept. The ideal condition for multi-functional elements could be that it can serve various structures. The core point of the concept is to assemble architecture/structure of both large-scale and small-scale by basic elements. To do practice and experiments on diverse structure systems helps to figure out principles of forming and assembling.



60m



EXPERIMENT

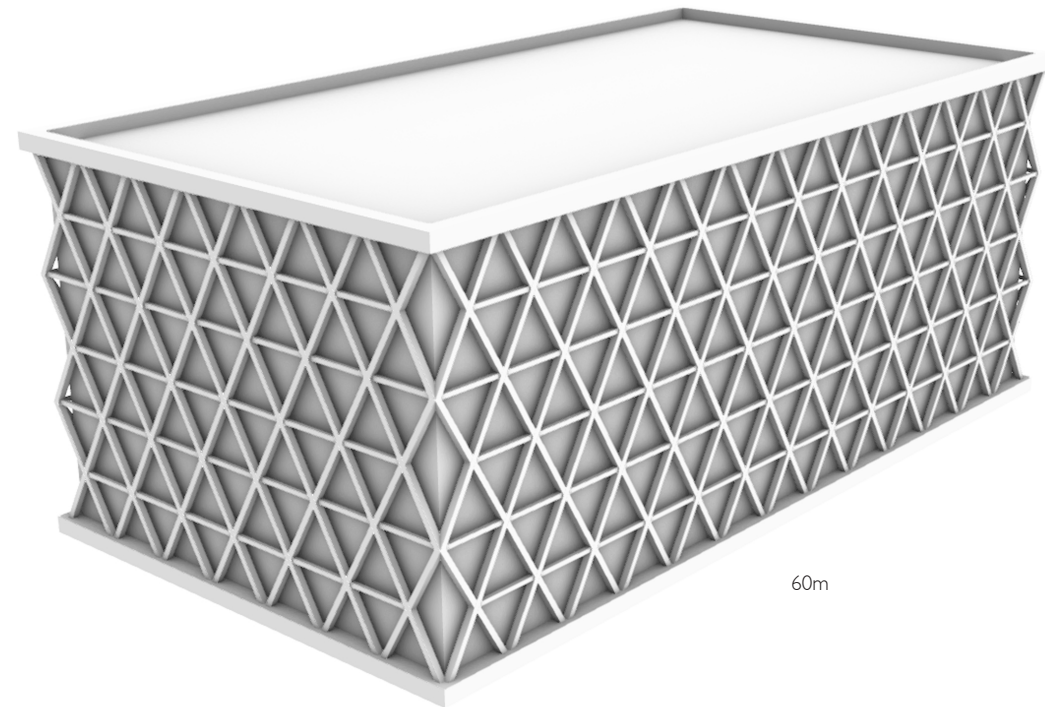
I.1 Regular Frame Structure

In regular frame large scale structure, the most common building components are large scale columns and beams. So the most simple way to subdivide them is dividing directly to end at smaller columns and beams. These small elements with certain dimensions then can be used in housing modules.

large-scale structure : regular frame

subdivision principle : linear elements --- linear elements
subdivide directly

housing module : regular frame



EXPERIMENT

1.2 Diagrid Frame Structure

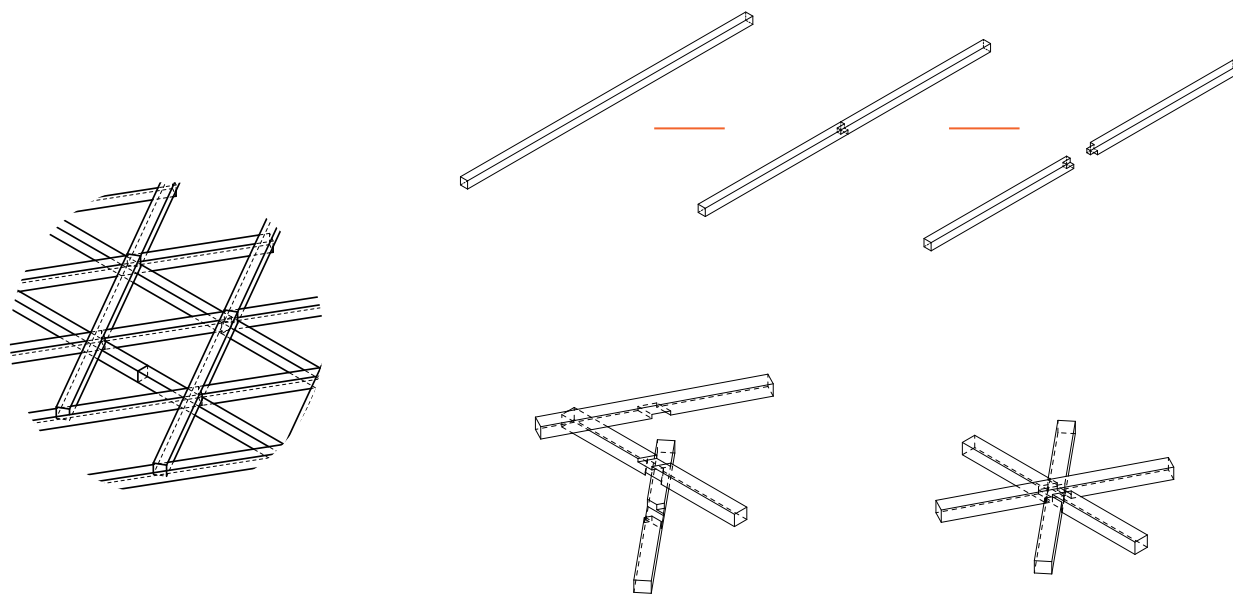
In diagrid frame large scale structure, the building components usually are linear elements which are large in length but maybe not in width. So the most simple way to subdivide them is dividing directly to end at smaller smaller linear elements. These small elements with certain dimensions then can be used in housing modules.

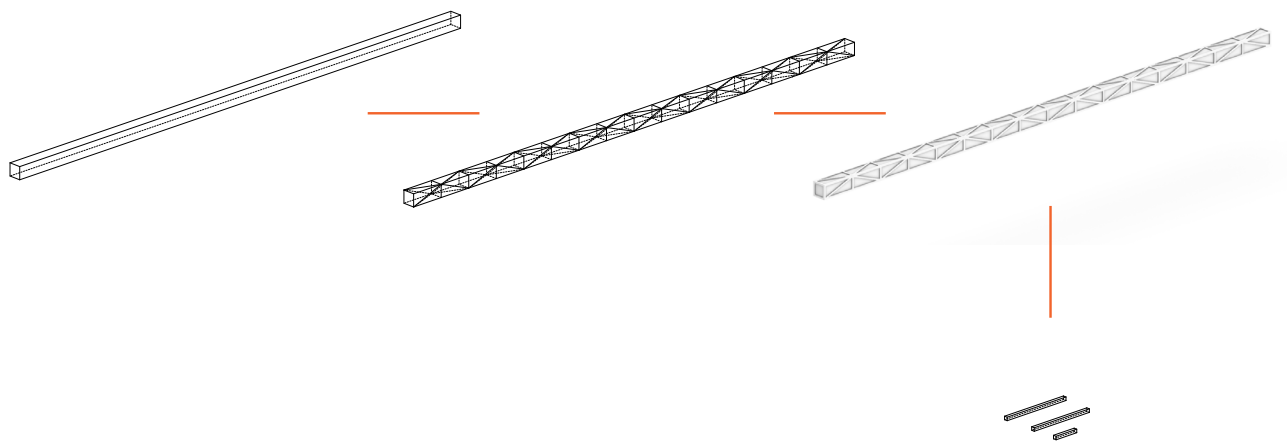
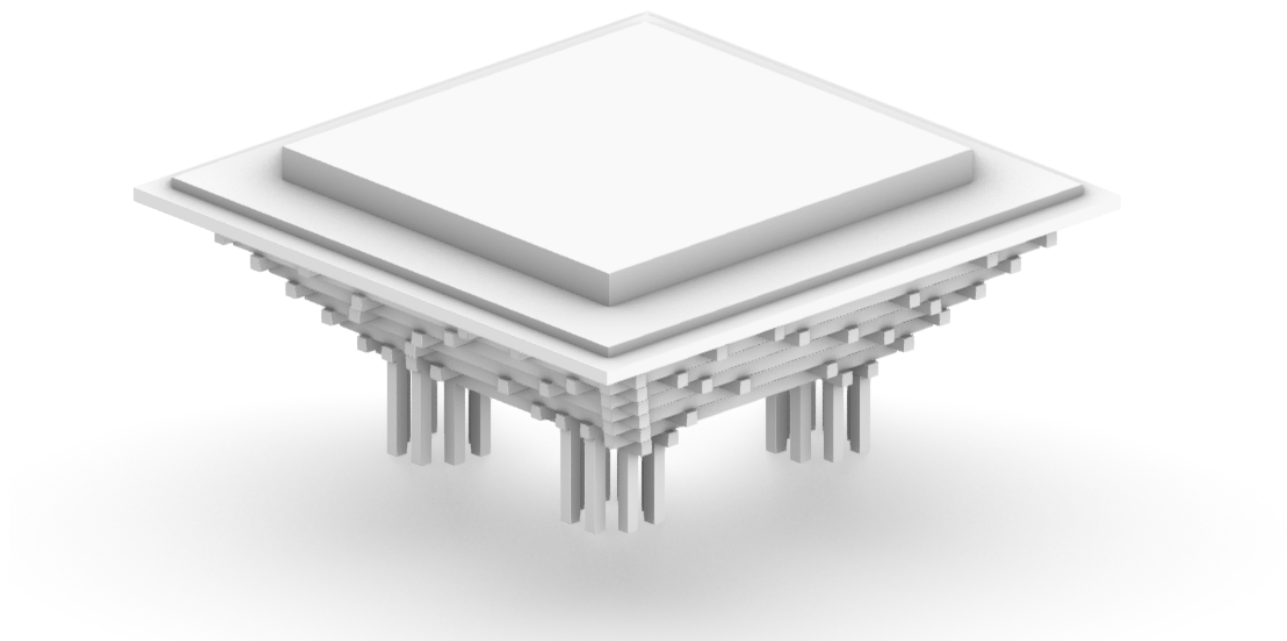
large-scale structure : diagrid frame

a

subdivision principle : linear elements --- linear elements
subdivide directly

housing module : regular frame





EXPERIMENT

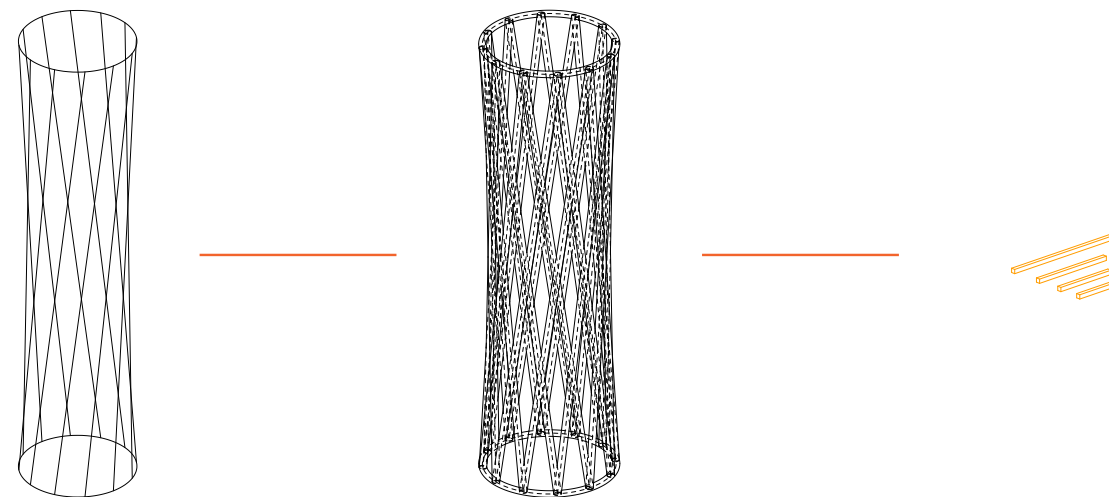
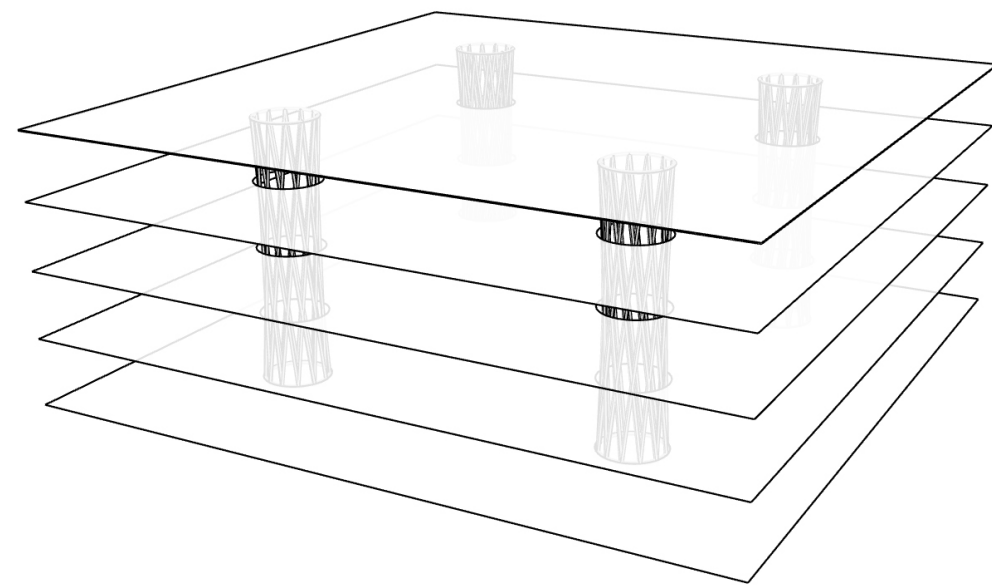
1.3 Bracket Frame Structure

Bracket system is one of the traditional ancient Chinese structure which works stably by inserting and overlapping linear elements. Actually in this kind of form, large-span structure can be built from small scale components which will be discussed later. In this experiment, the large scale structure is supposed to be built up by large scale components. And they can be subdivided as trusses which means the visible large beams are not solid inside. These small elements with certain dimensions then can be used in housing modules.

large-scale structure : bracket system

subdivision principle : linear elements --- linear elements
subdivide as truss structure

housing module : regular frame



EXPERIMENT

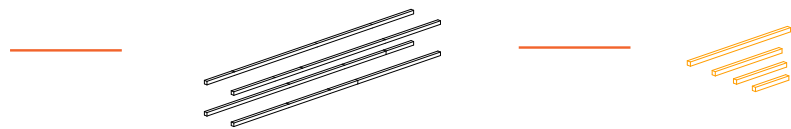
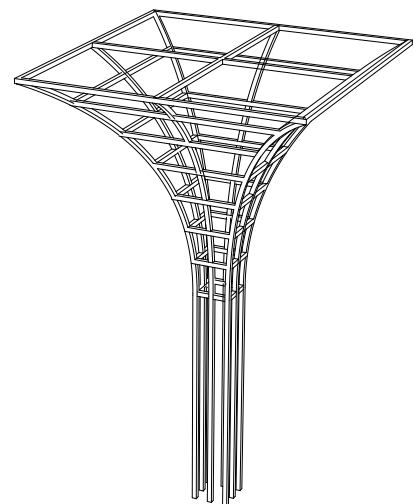
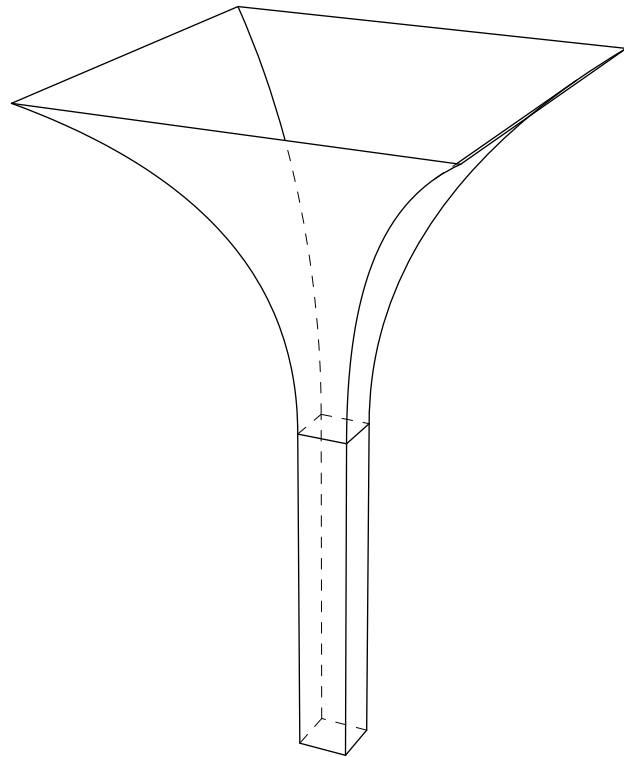
1.4.1 Free-form Frame Structure

Taking Sendai Mediatheque as an example, there are some new structural systems which makes it possible to have free-form architecture but still remain some characters of frame structure. In this experiment it is a structure system of independent structural steel-ribbed columns which can be subdivided as truss structure. These small elements with certain dimensions then can be used in housing modules.

large-scale structure : independent structural steel-ribbed column
free plan, free facade

subdivision principle : linear elements --- linear elements
subdivide as truss structure

housing module : regular frame



EXPERIMENT

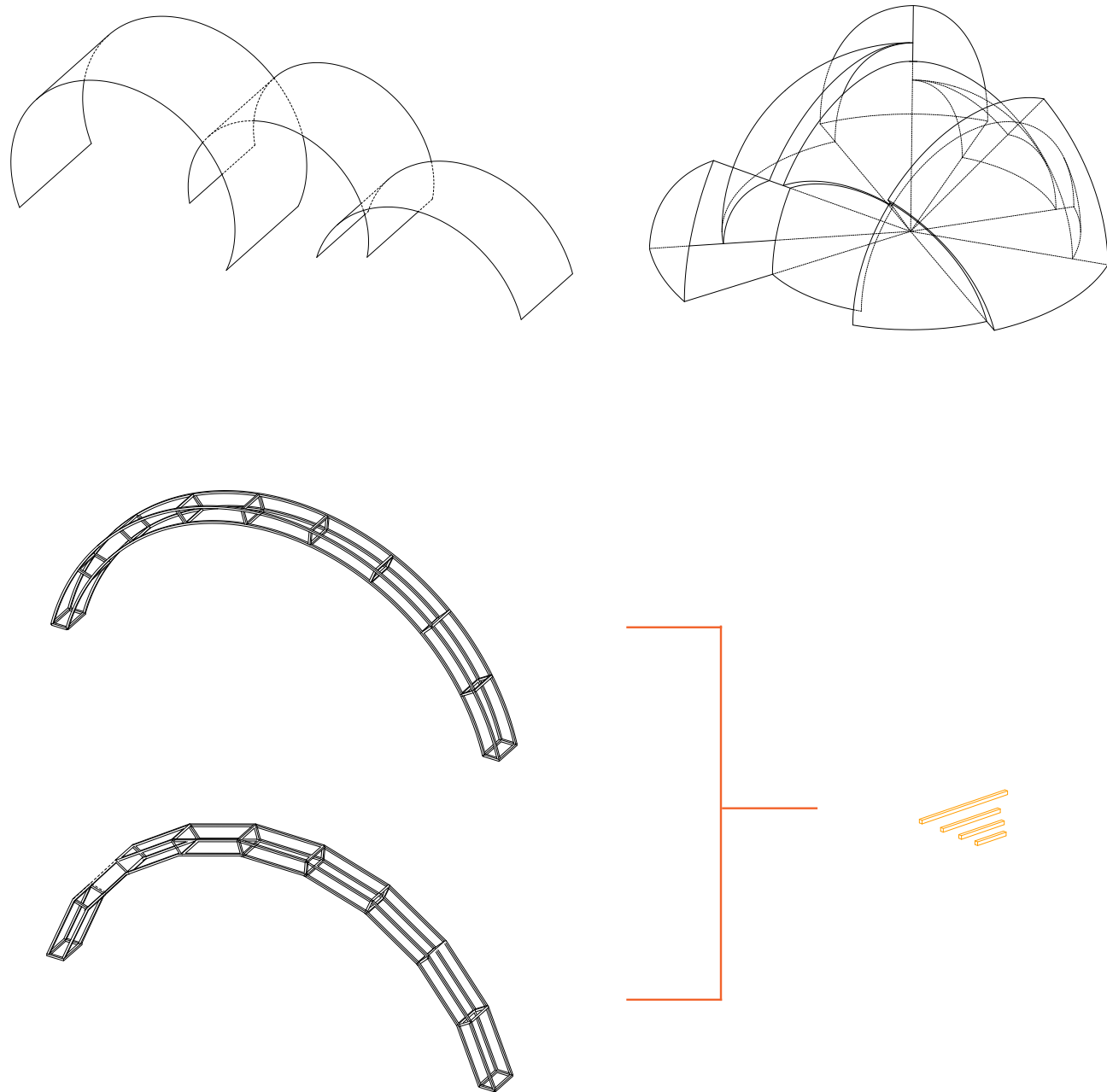
1.4.2 Free-form Frame Structure

This experiment is kind of similar to the previous one. The main part of the structure is the independent column/tube which can be divided directly according to the form. The small elements can also be used in modular housing as frames.

large-scale structure : umbrella structure / tree structure
free-form frame structure

subdivision principle : linear elements --- linear elements
(can be curvy)
divide directly

housing module : regular frame



EXPERIMENT

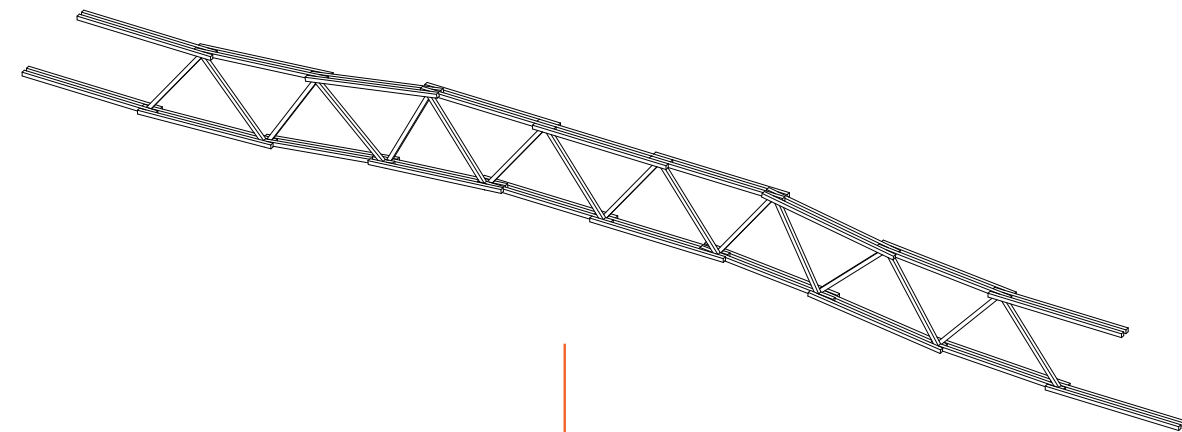
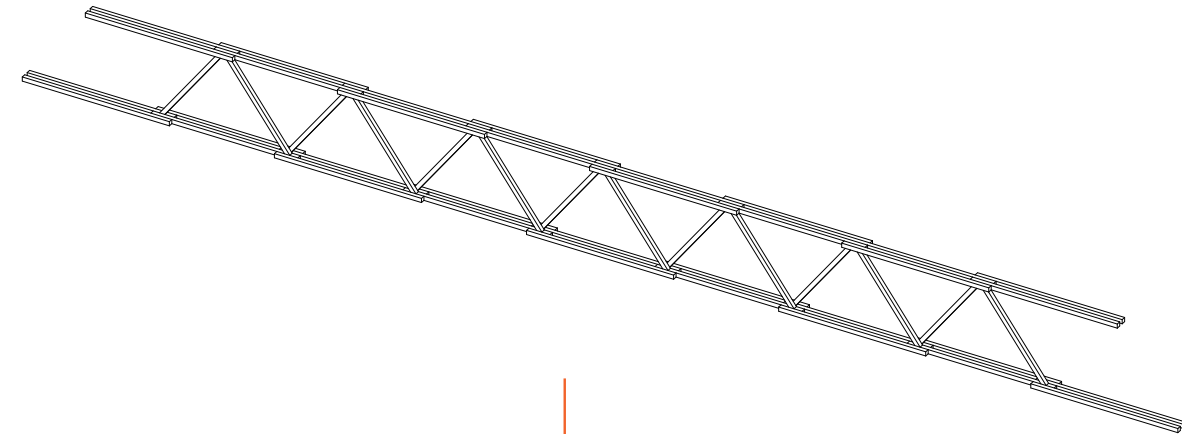
2.1 Curvy Shape Formed by Truss Structure

In this experiment, it shows the possibility of forming curvy structures like vaults and domes by truss structure. It then leads to the principle of subdividing directly. Trusses make it possible to build up large scale structure with small scale elements. This kind of principle can be applied in vaults structure and dome structure.

large-scale structure : arch / dome
truss formed

subdivision principle : curvy shapes --- linear elements
divide as truss structure

housing module : regular frame



... ..

EXPERIMENT

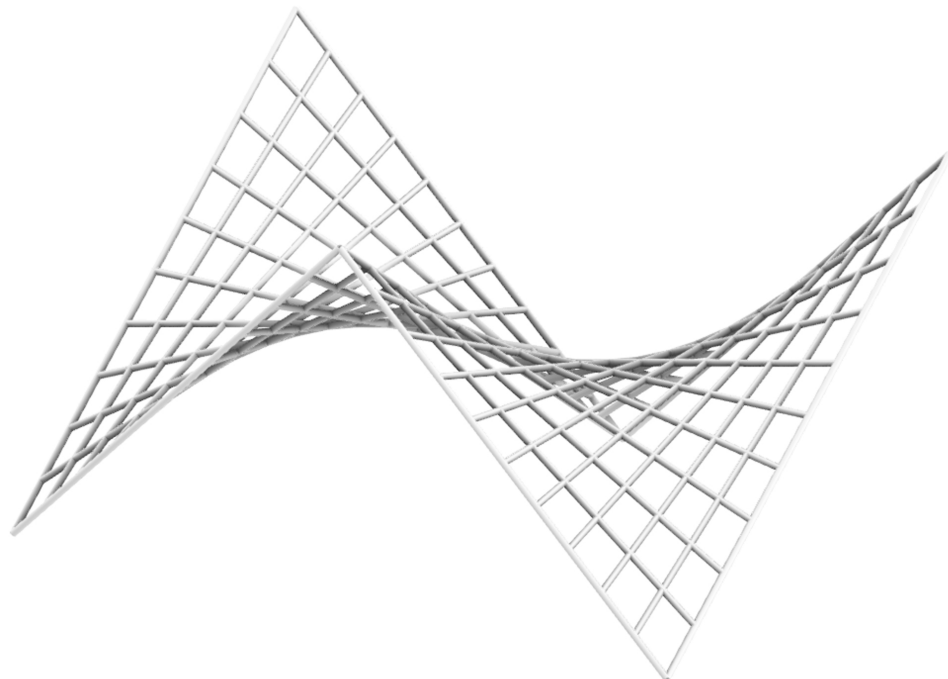
2.2 Free-form by Truss Structure

This experiment goes a bit deeper into truss structure from the former one. When the trusses are built up by small scale elements, it is possible to have the connection nodes flexible. Then the angles at nodes and the layers of trusses are both flexible enough to create free-form architecture.

large-scale structure : long-span truss
free-form

subdivision principle : linear elements
divide as truss structure

housing module : regular frame



EXPERIMENT

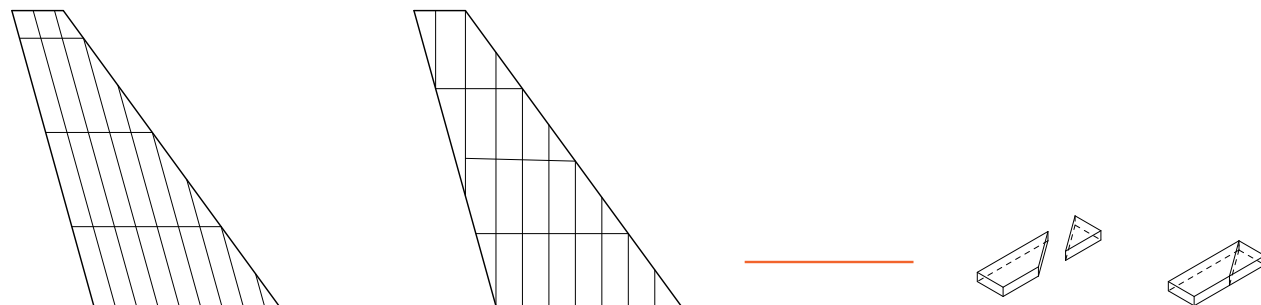
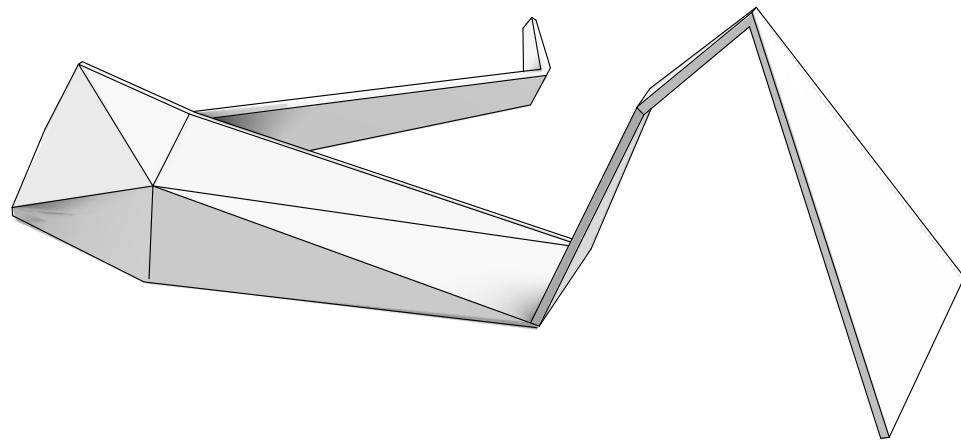
2.3 Curvy Structure Formed by Linear Elements

Curvy building components sometimes become one of the obstruction of adaptable reusing after disassembly. This experiment suggests one solution as ruled surface which forms curvy plates by linear elements. It comes to the conclusion that it is easier for reusing if structure of any form can be composed of linear elements. It can be applied in shell structure, folded plates structure.

large-scale structure : linear elements
ruled surface

subdivision principle : linear elements --- linear elements
divide directly

housing module : regular frame



EXPERIMENT

3.1 Plate/Slab Structure

Except for frame structures, slab / panel structures are also one of the common structure system in architecture. Subdividing these panels on the surface shows the possibility of scale-transfer of components like this. This principle can also be applied on the solution of other components in frame structure, such as walls, floors, ceilings and so on. The small scale elements can be used in housing modules for both panel structure and non-structural components.

large-scale structure : long-span panels
free-form

subdivision principle : slab --- panles
divide on the surface

housing module : panel structure & non-structural components

CONCLUSION



Reflection, Conclusion & Reference

REFLECTION & CONCLUSION

This thesis project is trying to make architecture more sustainable which is a necessary tendency of society development. As we know there are more and more events around the world which means there is a slight conflict between globalization and a sustainable future. The events are usually temporary so there is a need of low-cost reusable event place and architecture.

Large-scale temporary structure can be built up by both large-scale and small-scale components while some permanent daily-used small-scale structure can only be built up by small-scale components. Being inspired by this traditional construction principle, there is a potential found to assemble structure of various scales from really basic and small-scale elements. These multi-functional elements can work not only as structural elements, but also as furniture and ornament when they are used independently. They also avoid only modular system but provide more design opportunities. This strategy suggests a new way of extending temporary architecture's lifespan and make full use of them after the events.

The project just provides one possible development of sustainable architecture and this multi-functional elements can be developed more into digital design due to the current trend of technology. As people can imagine, if the assembly principle of elements is imported into computer, then there would be abundant proposals coming out which gives great freedom to design.

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