

Rebirth of The Arch

Controlling clarity of direction and movements by semi-circle arches intersecting level

Challenging the economy driven hidden structure architecture
for the lost qualities of structural space

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ABSTRACT

In ancient Rome, the arch plays a major role as an organizer of the space and as a means for expression. This is originally a constructive moment when structure has both a technological as well as spacial and expressive purpose. With the advent of modernism, the structure has virtually been emptied of any meaning except the purely technical, and eventually, the structure is hidden under other ornamental components. Thus, in this master thesis, the arch is going to challenge the economy driven hidden structure architecture for the lost qualities of structural space.

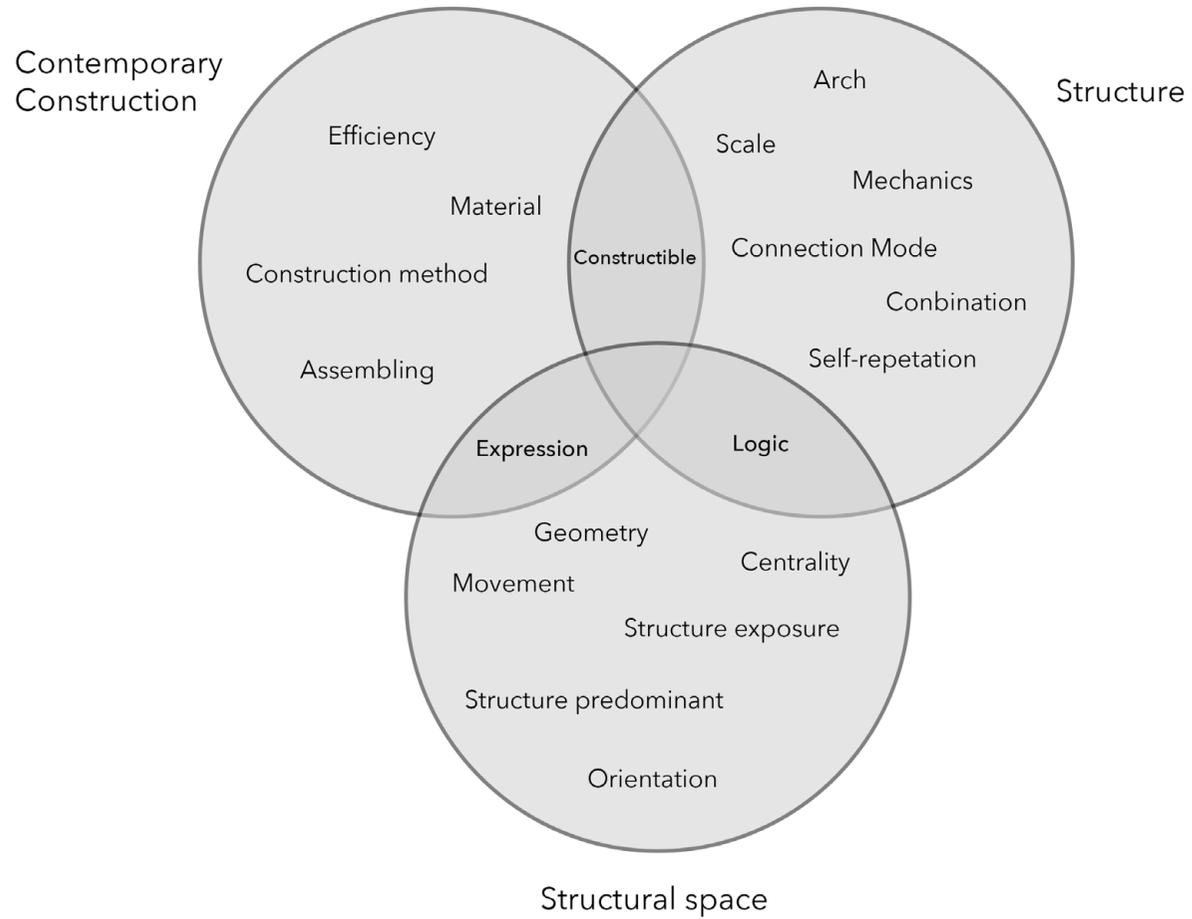
The purpose of master thesis is by doing the mechanical property study and reference study to refine semi-circle arches and find the relationship between people's movement, clarity of direction, duration of stay and organization of arch. By analysing the logic of network and centers in Musee du Louvre, the logic of controlling people's focused move and non-focused move has been found.

The relevant methods of this master thesis will be literature and case studies about the history and development of arch. Hang chain models will show the difference of semi-circle arch and parabolic arch on forces inside of them and also clarify the function of side mass. 3D models and physical models test the

spacial qualities.

The result of this master thesis will be a market on the bridge at Slottesberget. By apply the logic of controlling people's focused move and non-focused move, the system of network that contains centers, main paths and cells are created on the site. The perpendicular multi-intersecting arches are applied at centers for people to gather. The intersecting arches are applied at the main paths for people to get shortcuts and quick pass. The independent arches are applied at the cells to create non-focused move and provide space for market activities. The floor is designed as a landscape to create the circulation gradient and encourage people move freely on vertical direction.

1.1 Relevant field



1.2.1 Reference project

Christ Church- Carlos Mijares

This christ church is designed by Mexico architect - Carlos Mijares for one of the oldest zones of Las Lomas.

As his most recent work, the enormous interior space is generated by double arches. At their juncture, splayed vaults provide vertical light in the form of a cross upon the alter.

The second space is composed by smaller half arches. These half arches structurally work as flying buttress supporting the main structure. Meanwhile, these arches also become multiple curtains which transform daylight into something diffused and profound.



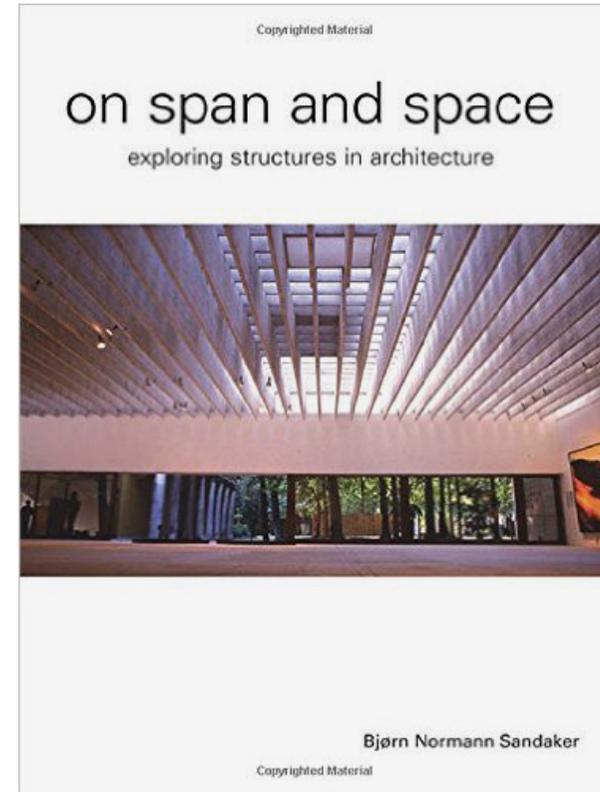
Interior scene of christ church shows that it is a structure dominate space. The double arches cross with each other and sketch the outline of interior space. Half arches hold the main structure and diffuse the daylight.

1.2.2 Reference literature



CARLOS MIJARES: TIEMPO OTRAS CONSTRUCCIONES

This book records Carlos Mijares entire career life. It not only shows all the projects of this Mexico architect, but also try to search the root of Carlos's creation. From this book, the reader can get through the logic of structure and space that is hidden behind his project.



On Span and Space: Exploring structure in architecture

This book provides readers with a better understanding of the relationship between structure and architecture. It offers a well-founded aesthetic theory to support the understanding and evaluation of a structure's form and design, examining concepts and viewpoints from both engineering and architecture

1.2.3 Reference-problematic precedence

The Heydar Aliyev Cultural Center

The reason why I choose Zaha Hadid's the Heydar Aliyev Culture Center as a problematic precedence is because this project represent a certain type of architecture which is seen structure only as a technical problem solver. After spend tons and tons of material, money and time, the building decides to hide the structure. Zaha Hadid pursues volume and figure in this project and decides to sacrifice the relationship between spce and structure. Therefore, I think this project is a problematic precedence.

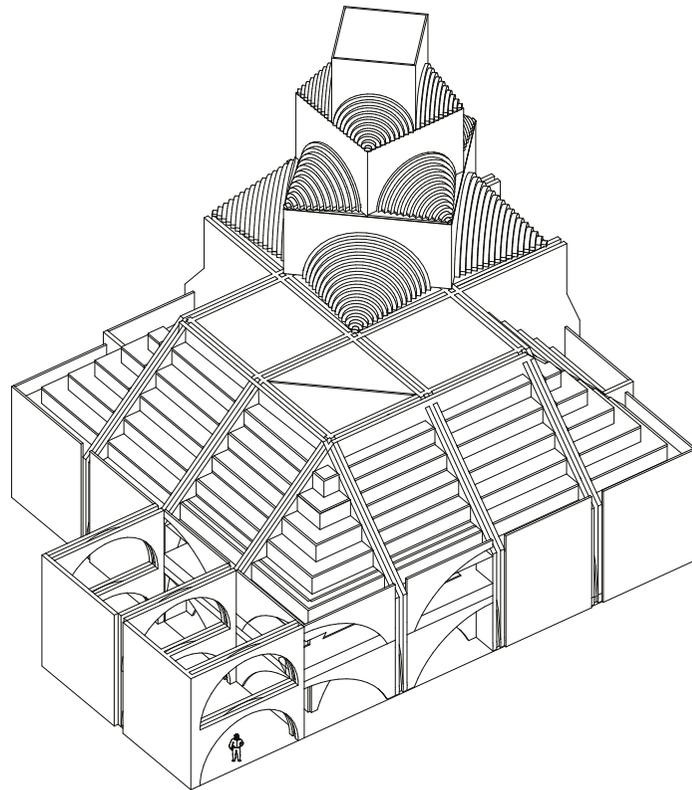


Structure is exposed when the building is under construction.

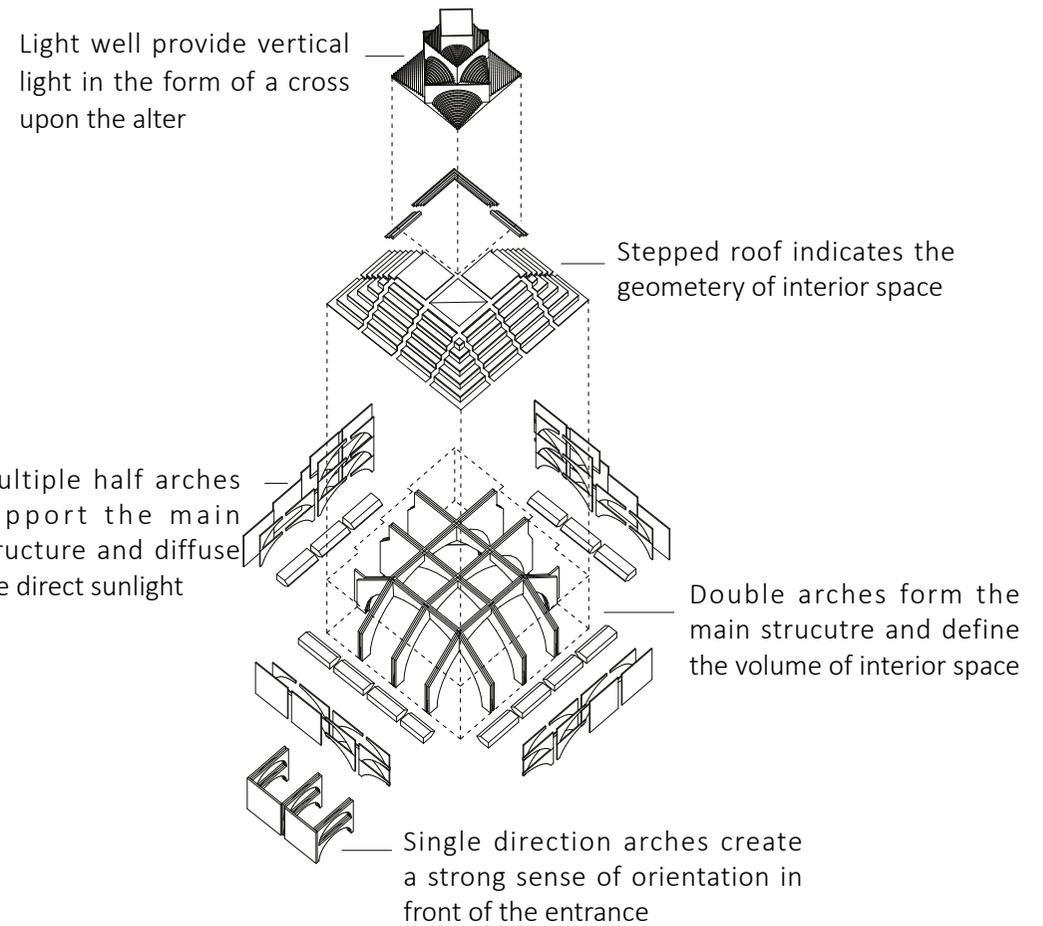


Structure is totally hidden under the curved plate when the building is completed.

2.1 Context argument

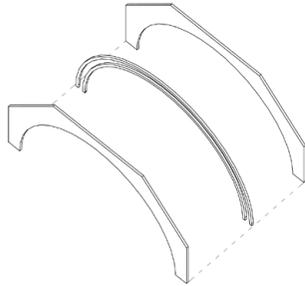


The Christ Church contains five parts - entrance aisle, enclosure walls, main structure, roof and light well. Arches as the main structure system have both structural and spacial roles. The strucutre as the space-defining elements creates space with strong sense of centrality, isolation and calm.

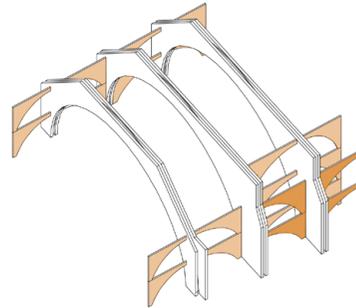


2.2 Base architecture system

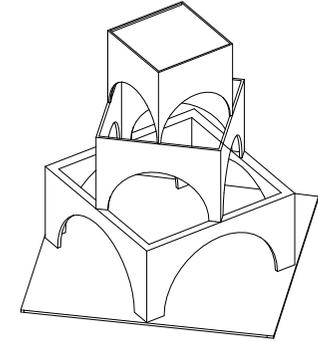
Structurally



Double arch is reinforced and joint in the middle

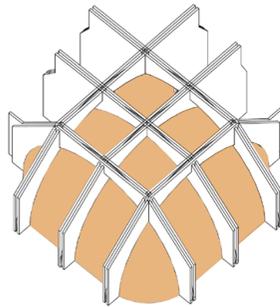


Multiple half arches support the main structure

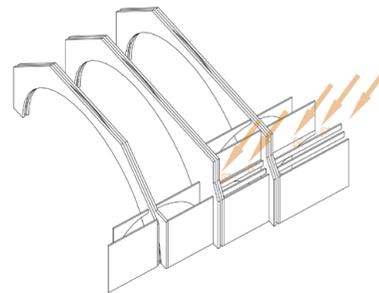


The overlaid semi-circle arches form the light well

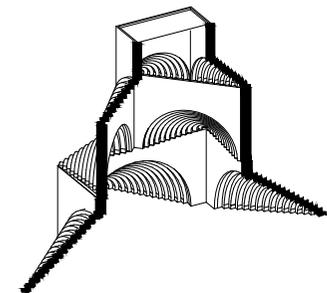
Spatially



Crossed double arches define the interior space

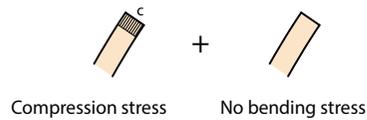
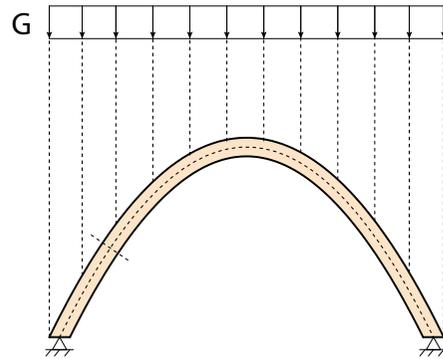


Multiple half arches work as curtains and diffuse the daylight



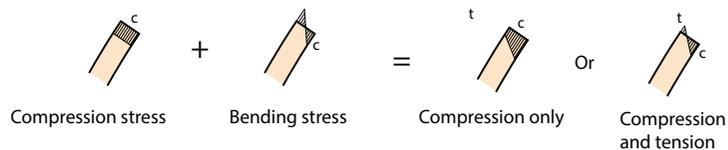
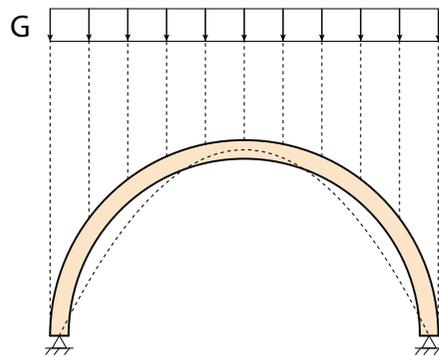
The spayed vaults offer a solution to balance different geometries and provide direct sunlight for inner space

3.1 The mechanical property comparison between parabolic arch and semi-circle arch



Parabolic Arch

The force in the parabolic arch is uniformly distributed along the section of arch. There is only compression stress in the arch, thus the parabolic arch is the ideal figure for tradition materials such as stones and bricks to take fully advantage of their capacity.

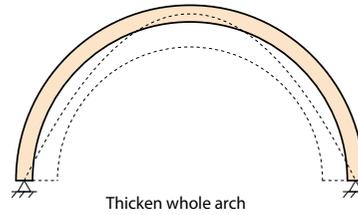


Semi-circle Arch

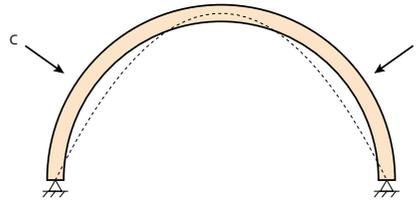
The semi-circle arch is mainly adopted by Romans. Different from parabolic arch, the force condition in semi-circle arch is much more complicated. Where the arch tends to bulge outside, bending stress appears. The tension stress will develop on the outside of arch and compression on the inside with a linear variation of magnitudes from one to the other across the arch thickness.

3.2 Optimizing mechanical property

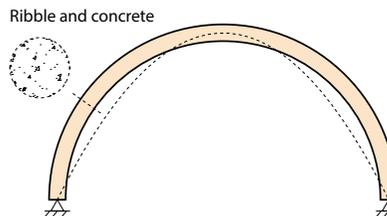
Solution 1
Built the arch with sufficient thickness



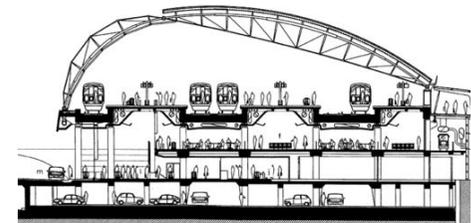
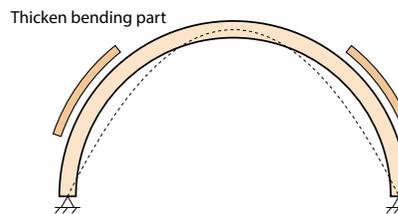
Solution 2
Compression interference from outside



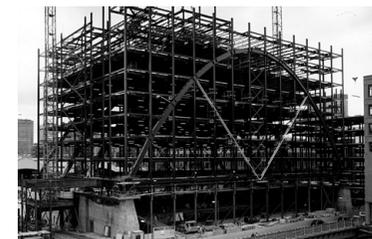
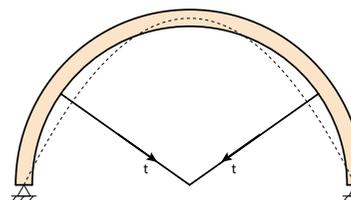
Solution 3
Concrete and rubble changing the loading pattern



Solution 4
Thicken the bending parts

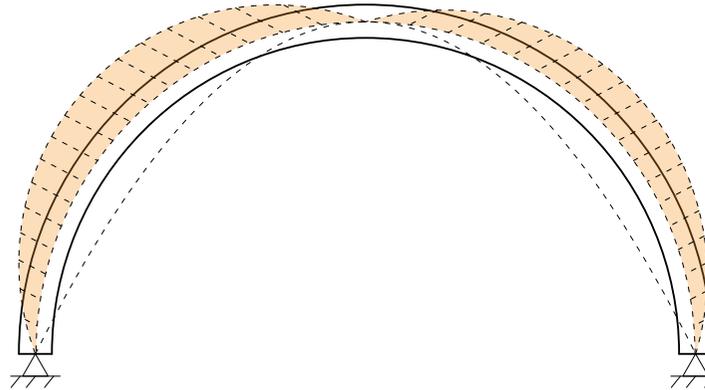


Solution 5
Tension interference from outside



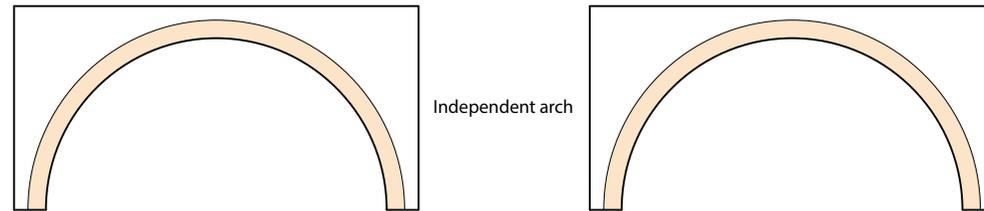
3.3 Horizontal thrust balance the bending forces and compression in semi-circle arch

The magnitude of bending forces is related to the displacement of semi-circle arch to funicular polygon. The largest bending force appear at the most bulging part, which means at that part it needs the largest horizontal thrust to balance the bending forces.

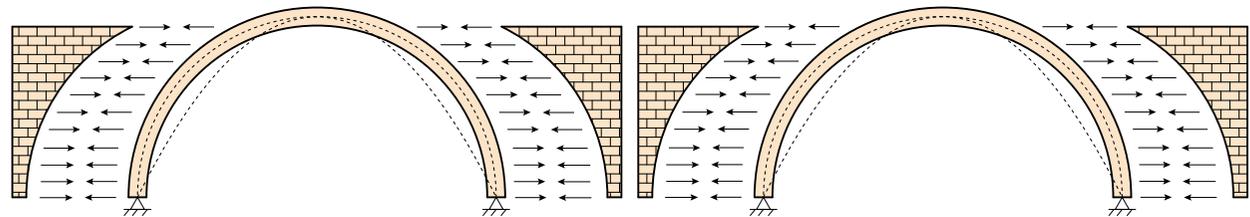


The reinforcement masonry and the semi-circle arches in Colosse, Roma, Italy

The reinforcement masonry produces a horizontal thrust that creates a balance between the bending forces and compression, and modifies the funicular polygon of the loads and brings the line of action of the internal forces back inside the section of the arch.



The reinforcement masonry plays a fundamental structural roles in semi-circle arch, and its removal can cause the arch to collapse.



4.1 Isolated criteria

Element:

Structure system
- arches

Parameter:

Organisation of arches
- Angles
- independent or intersecting

Agent:

People

Outcome:

Orientation
Centrality
Movement
Types of spaces

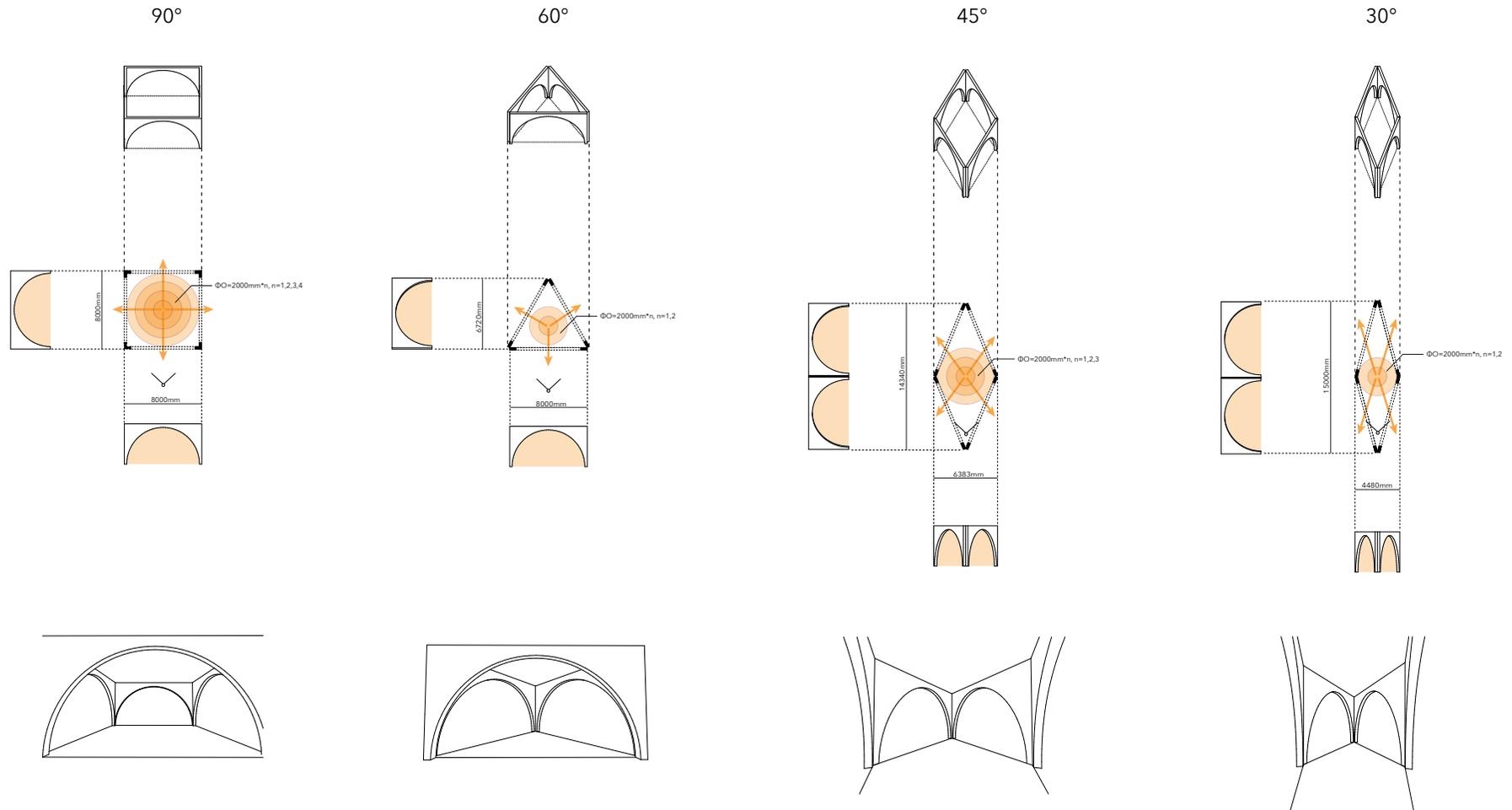
Summary:

Organisation (P) of arches (E) influence peoples' (A) feelings of orientation and movement (O).

	90°	60°	45°	30°
Independent Arches				
Intersecting Arches				
Multi-Intersecting Arches				
Intersecting Arches				
Multi-Intersecting Arches				

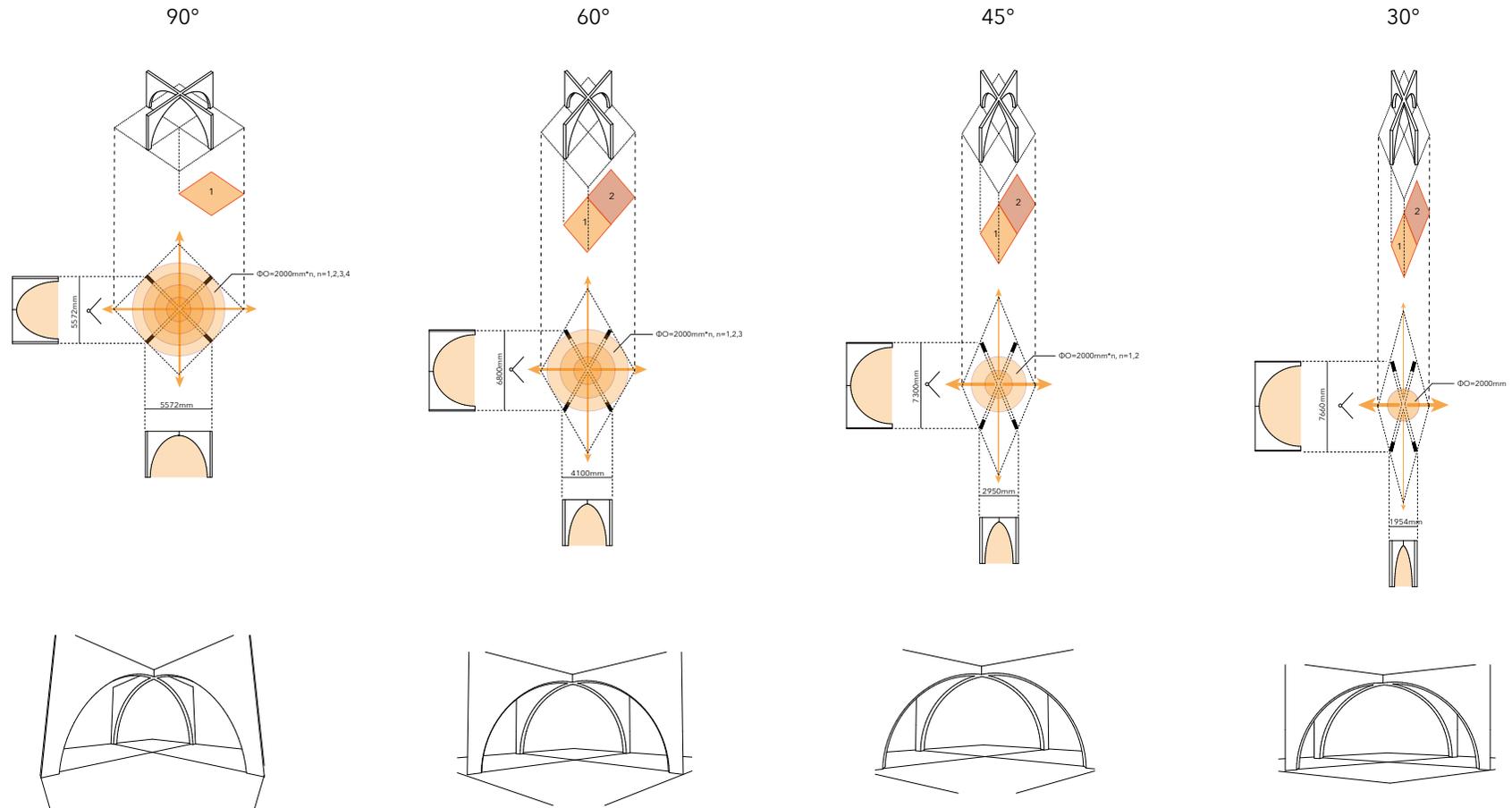
4.2 Organisation of arches and the perception of centrality and orientation

Independent Arches



4.2 Organisation of arches and perception of centrality and orientation

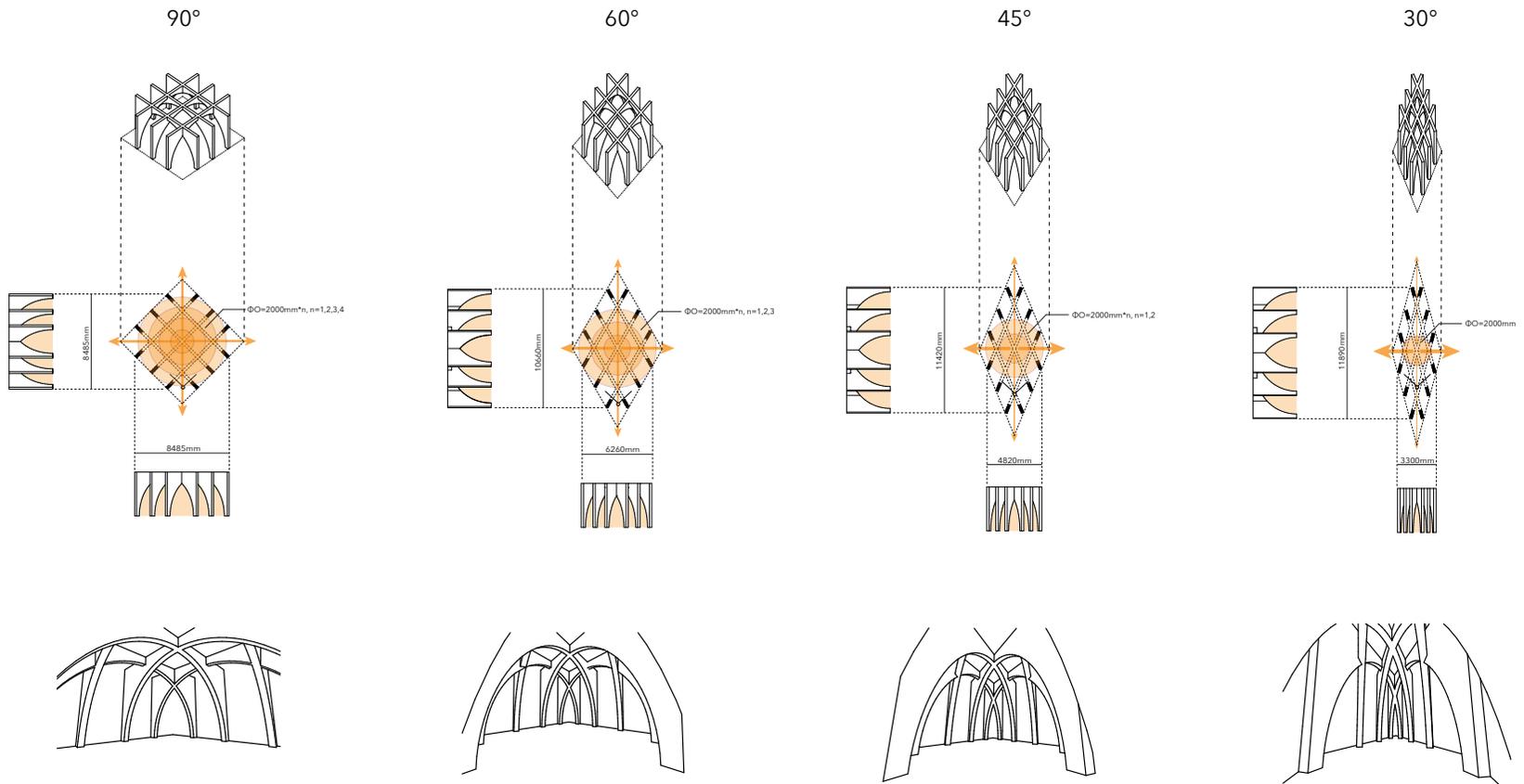
Intersecting Arches



-  = Sense of orientation
-  = Types of space
-  = Intensity of centrality

4.2 Organisation of arches and perception of centrality and orientation

Multi-Intersecting Arches

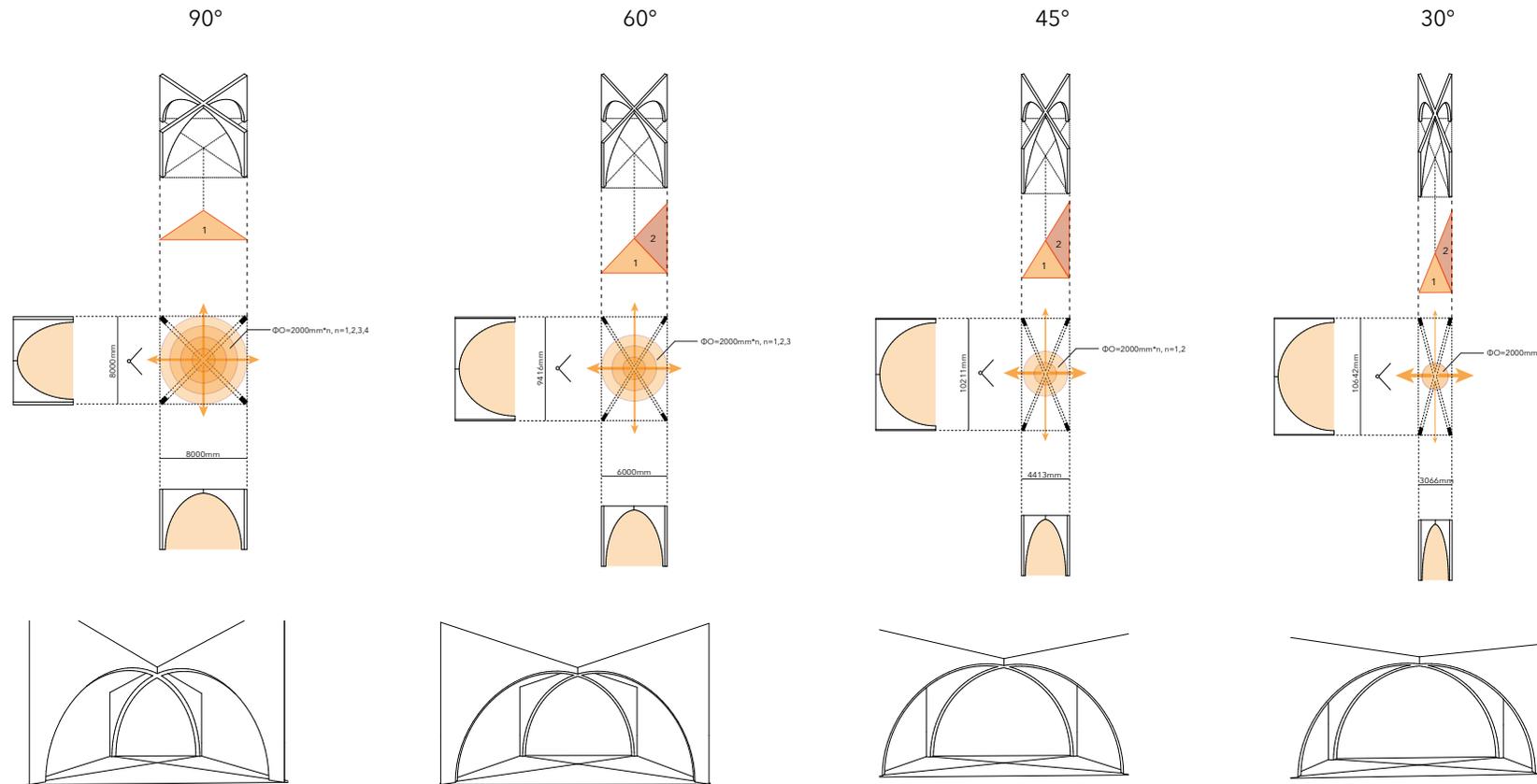


→ = Sense of orientation

⊙ = Intensity of centrality

4.2 Organisation of arches and perception of centrality and orientation

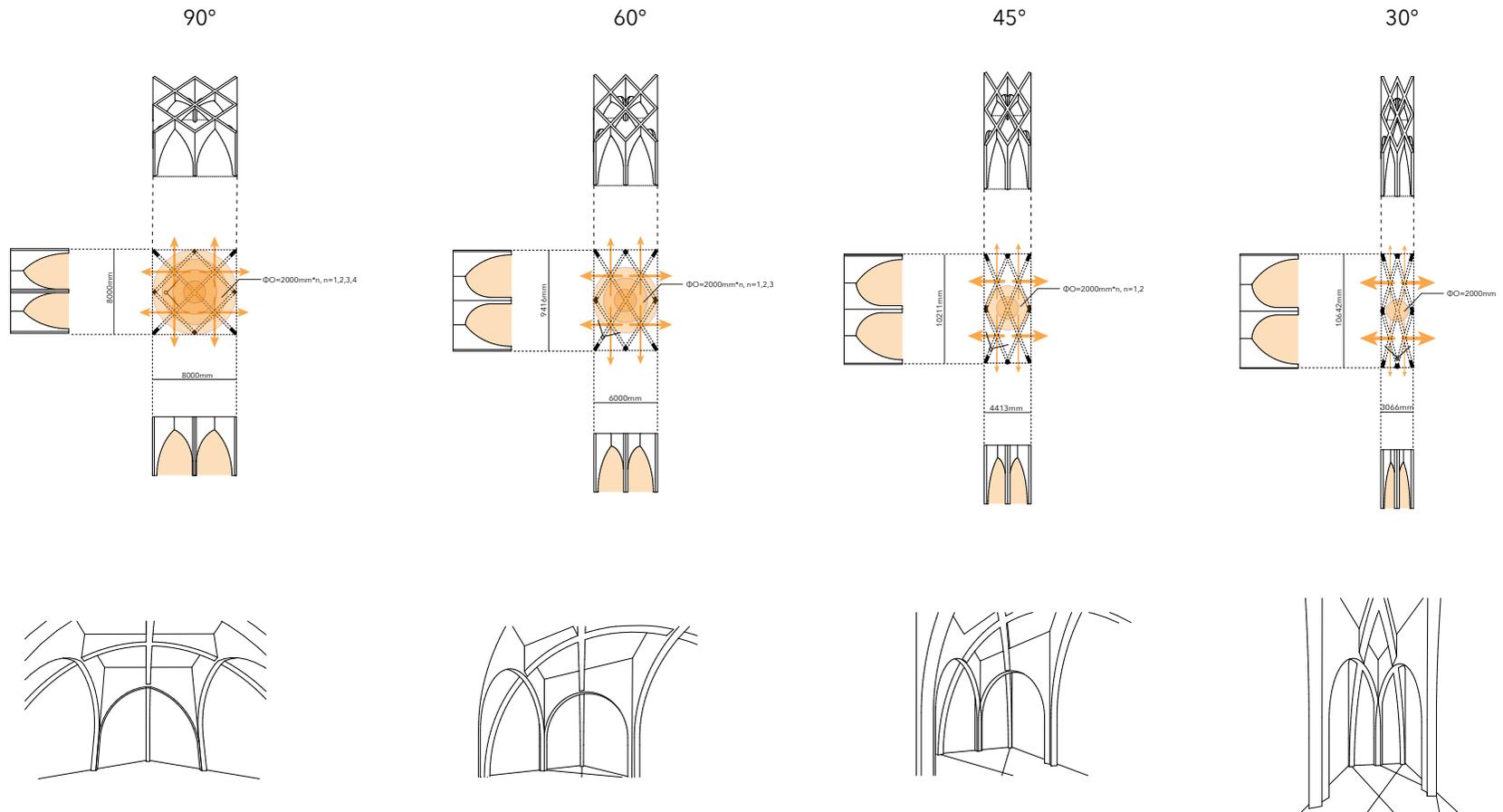
Intersecting Arches



-  = Sense of orientation
-  = Types of space
-  = Intensity of centrality

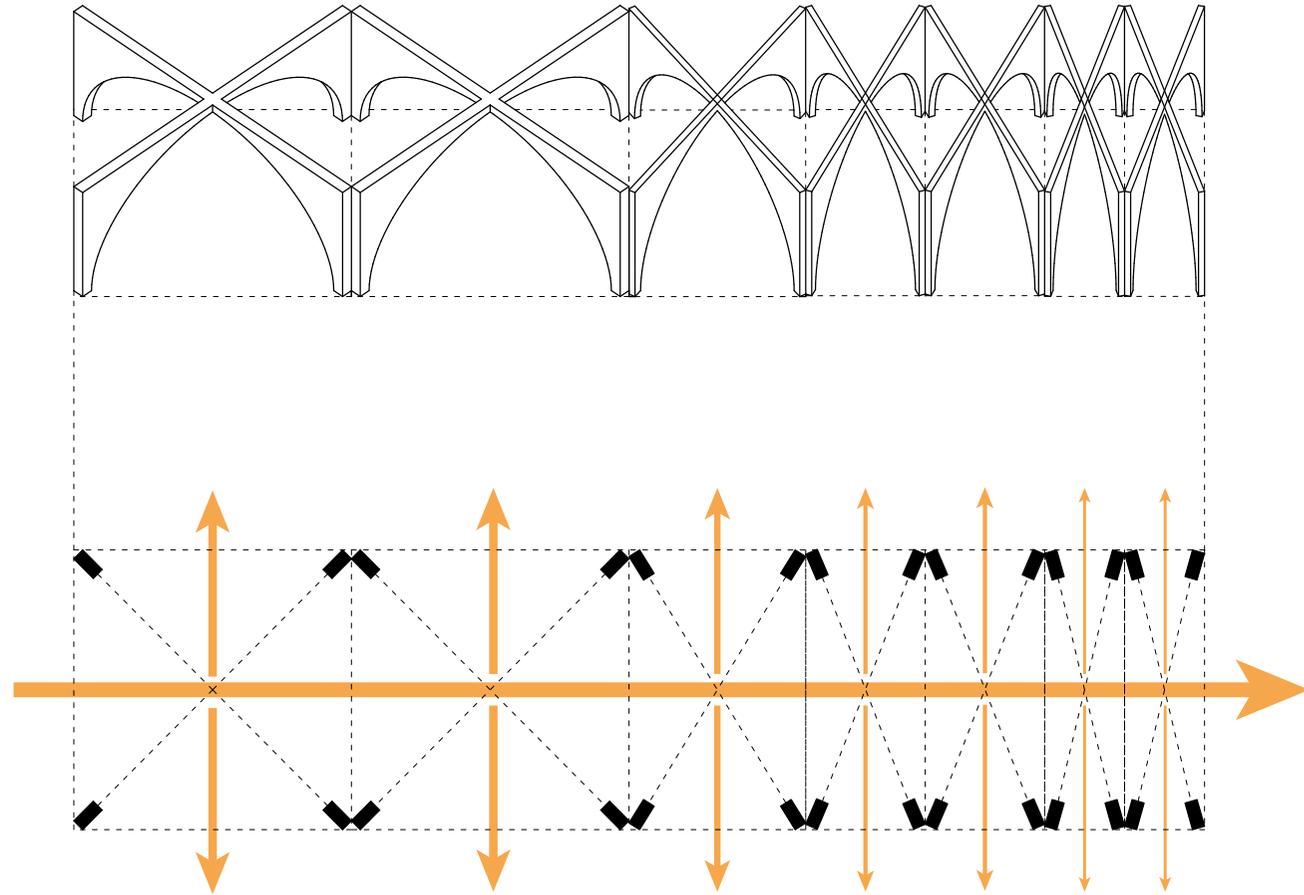
4.2 Organisation of arches and perception of centrality and orientation

Multi-Intersecting Arches



4.2 Consequence of orientation and movement under new system

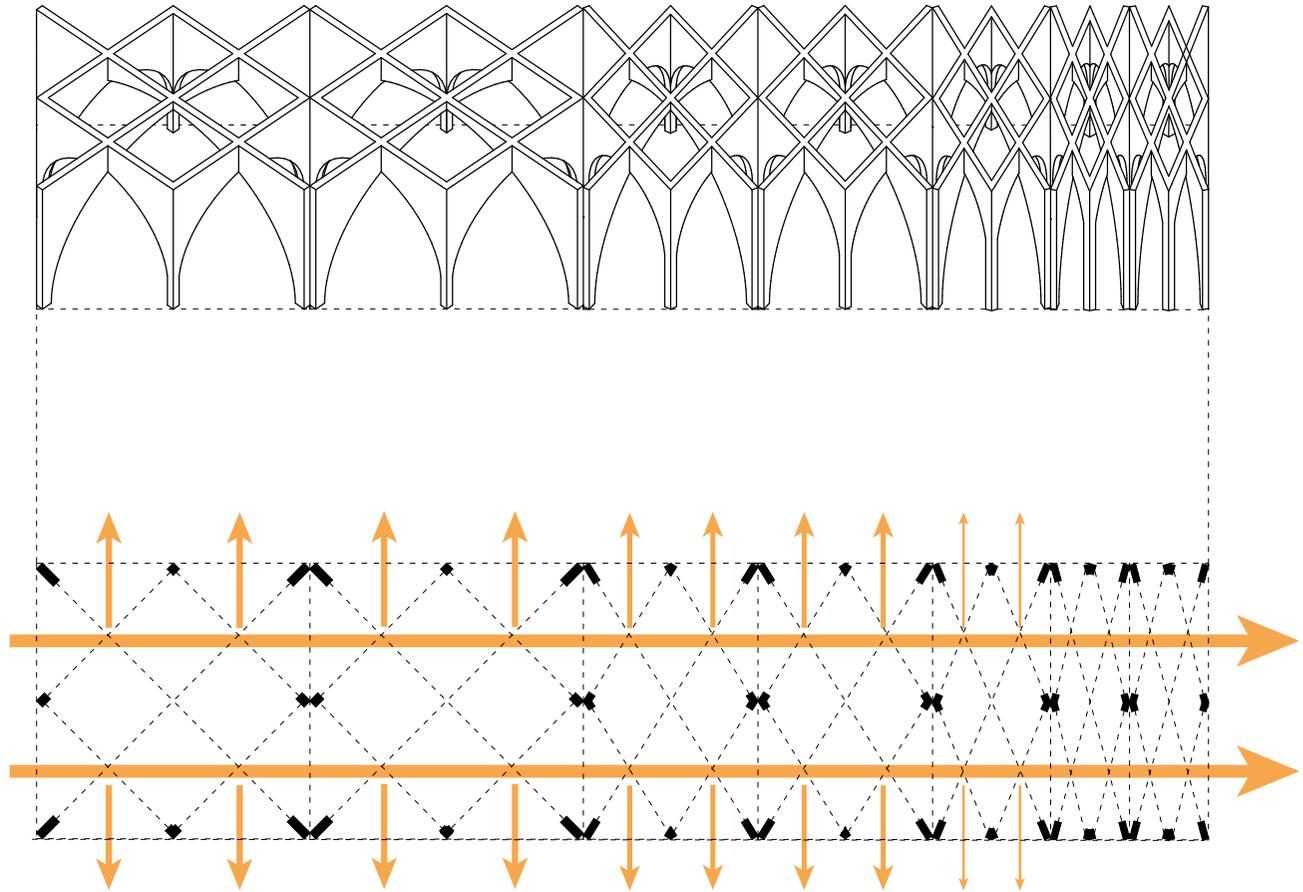
Senario 1: Connecting intersecting arches from big angles to small angles



→ = Sense of orientation

4.2 Organisation of arches and perception of centrality and orientation

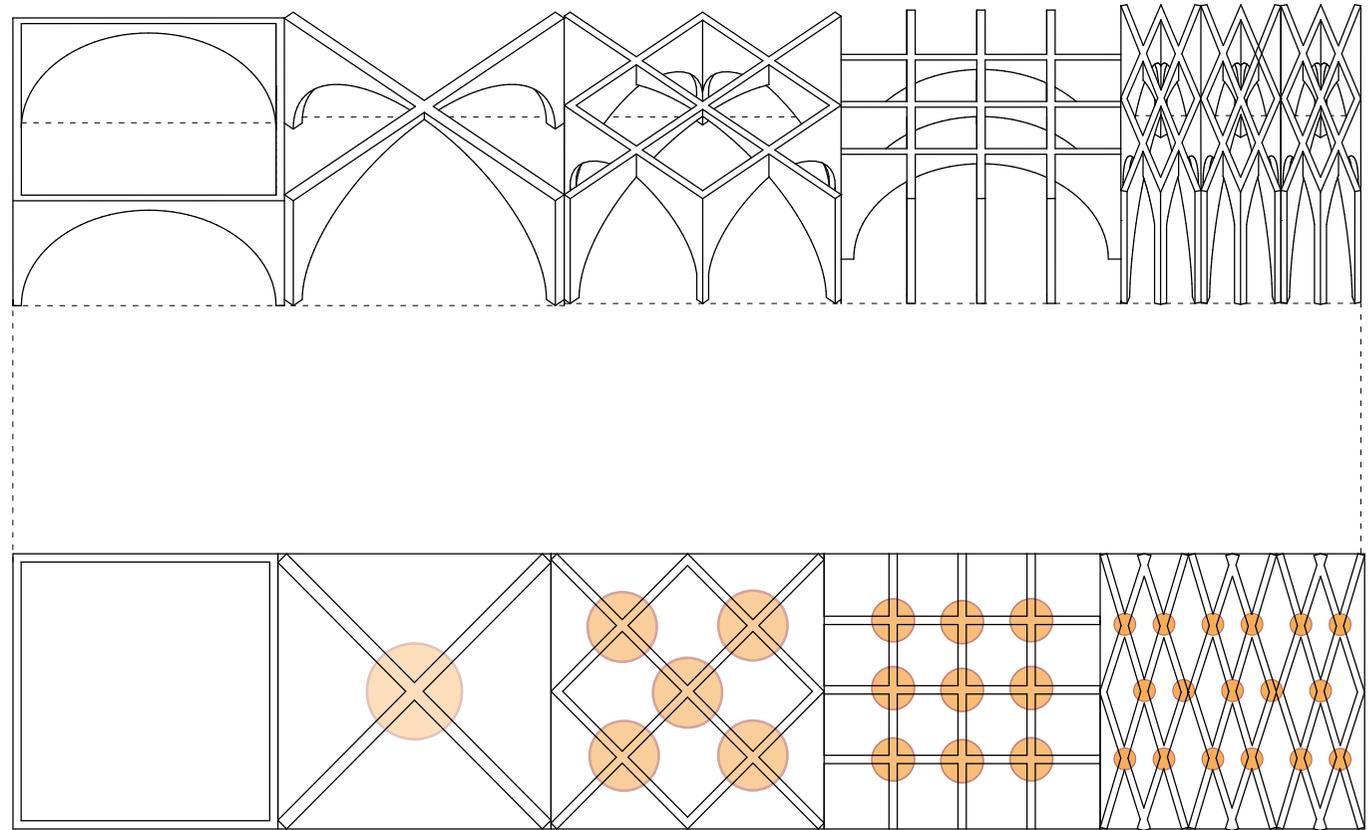
Senario 2: Connecting multi-intersecting arches from big angles to small angles



→ = Sense of orientation

4.2 Consequence of orientation and movement under new system

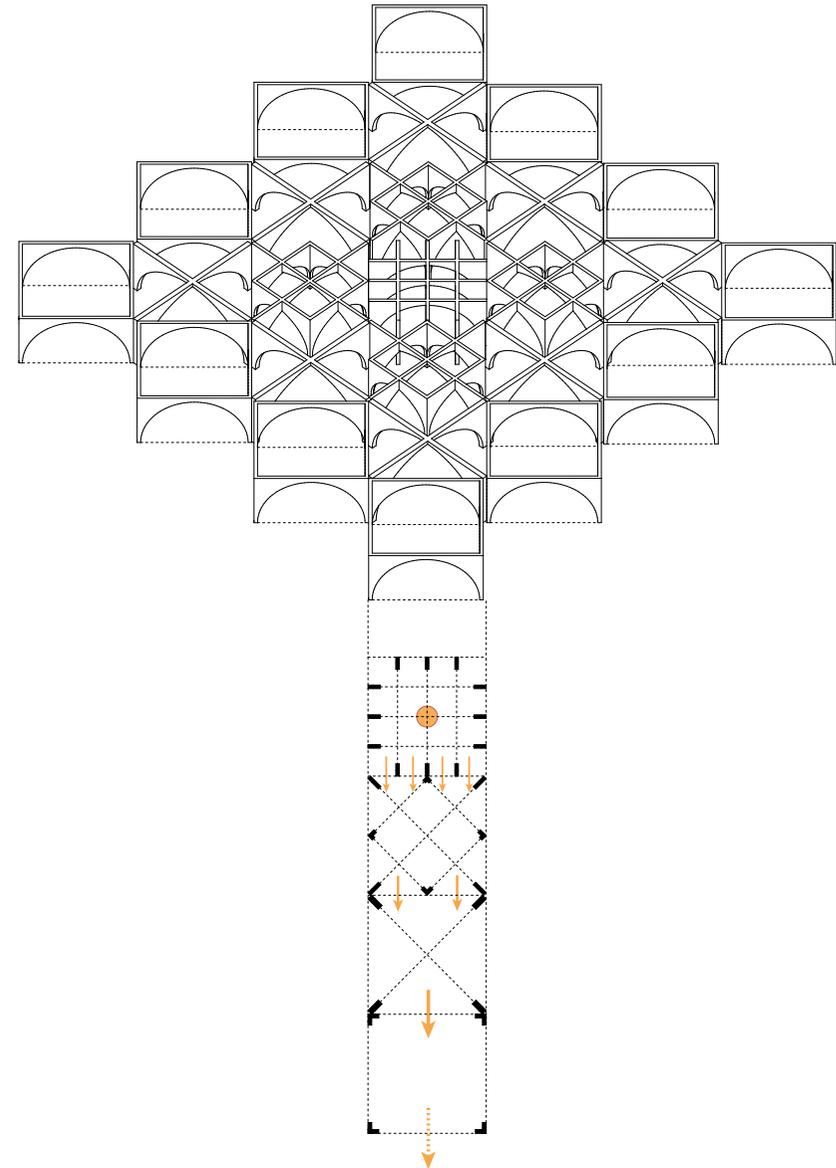
Senario 3: Connecting arches from independent to multi-intersecting



 = Intensity of centrality

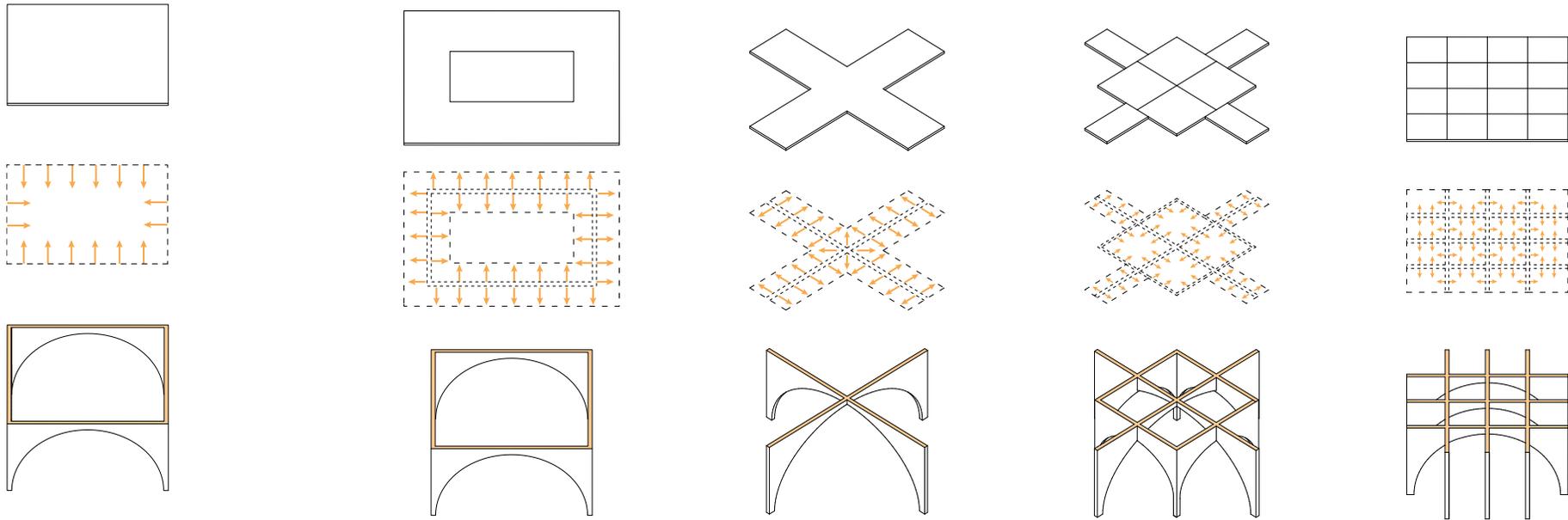
4.2 Organisation of arches and perception of centrality and orientation

Senario 4: Connecting arches from independent to multi-intersecting and also follow the sequence of movement



→ = Sense of orientation

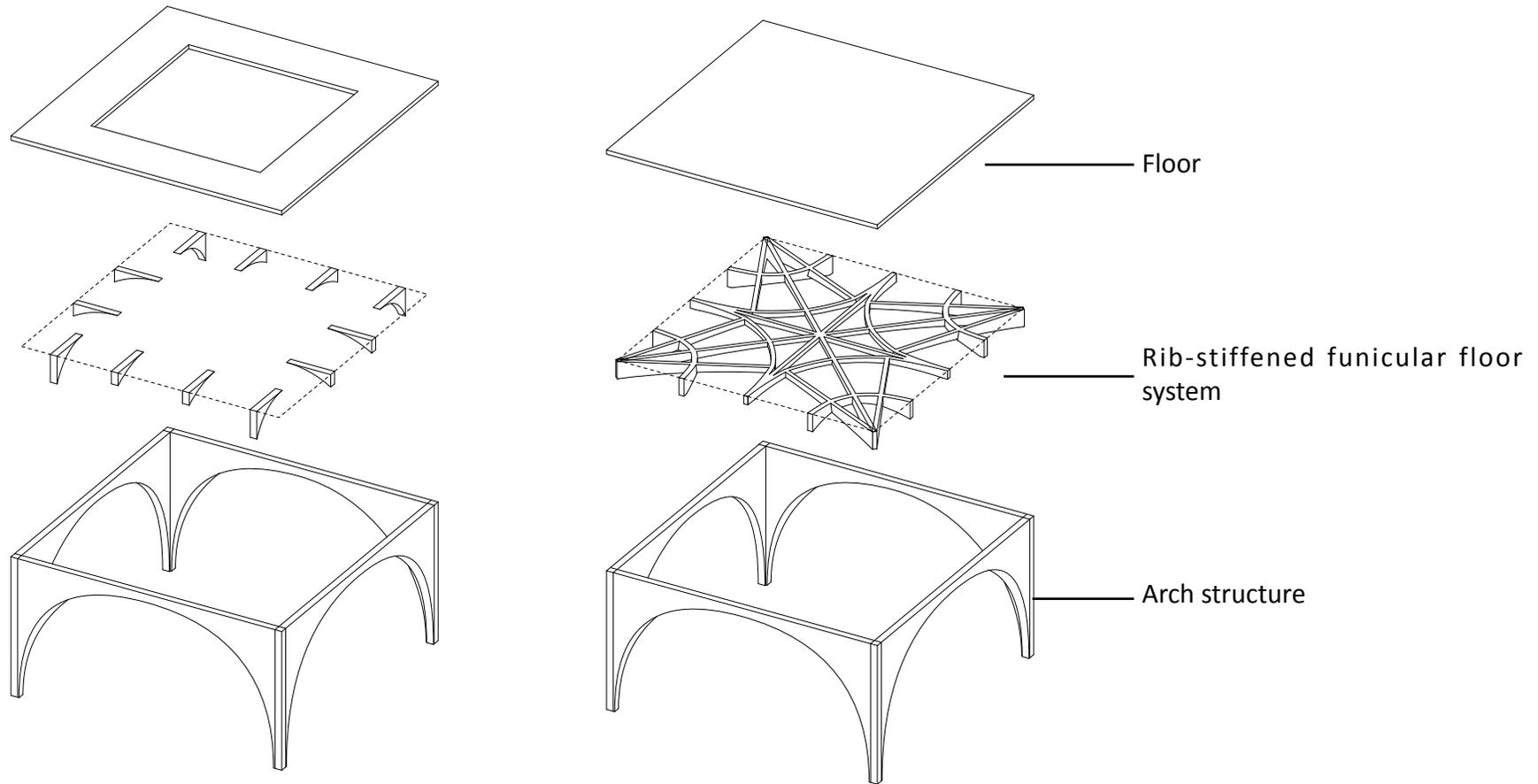
4.3 Floor system based on the arch performance



Independent arch can not give enough support force to the center of floor slab, which means the slab have to bear the load itself

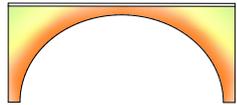
The size and position of floor slab is dominated by the performance of arch, and the arches will always be the primary bearing system. Therefore the performance of arch is not only influence people's perception in the space, but also influence people's movement on the upper level

4.5 The arch system between floor and arch wall

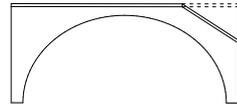


Developed from the floor system, a new system is introduced between floor and arch. These tiny arches dispense and transmit the strength. This system shows the ability of arch on different scale.

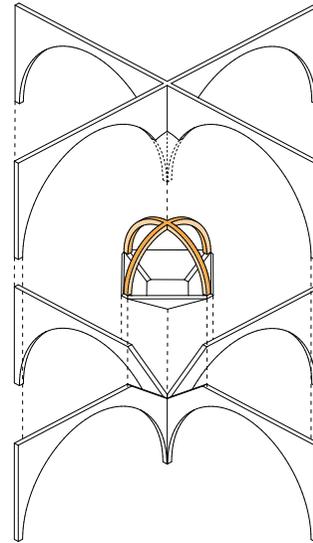
4.4 Refining arches based on the mechanical property and introduce the one third level



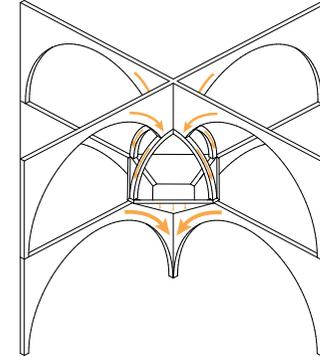
The mechanical stress inside of the single arches



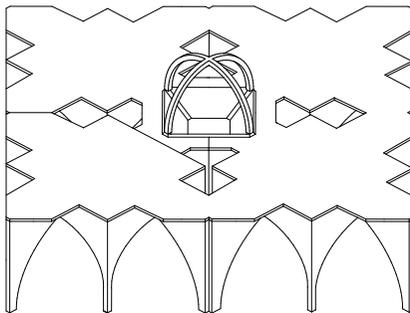
Reduce the unnecessary part in arches



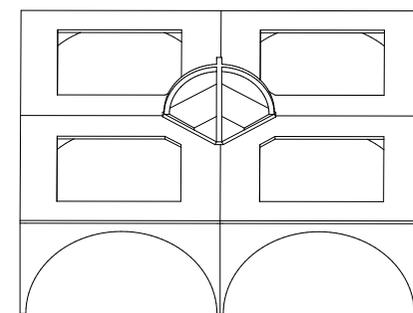
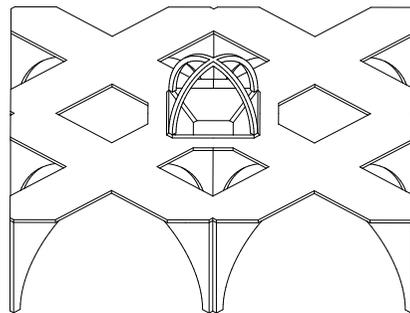
Introduce the small arches in order to make use of one third level



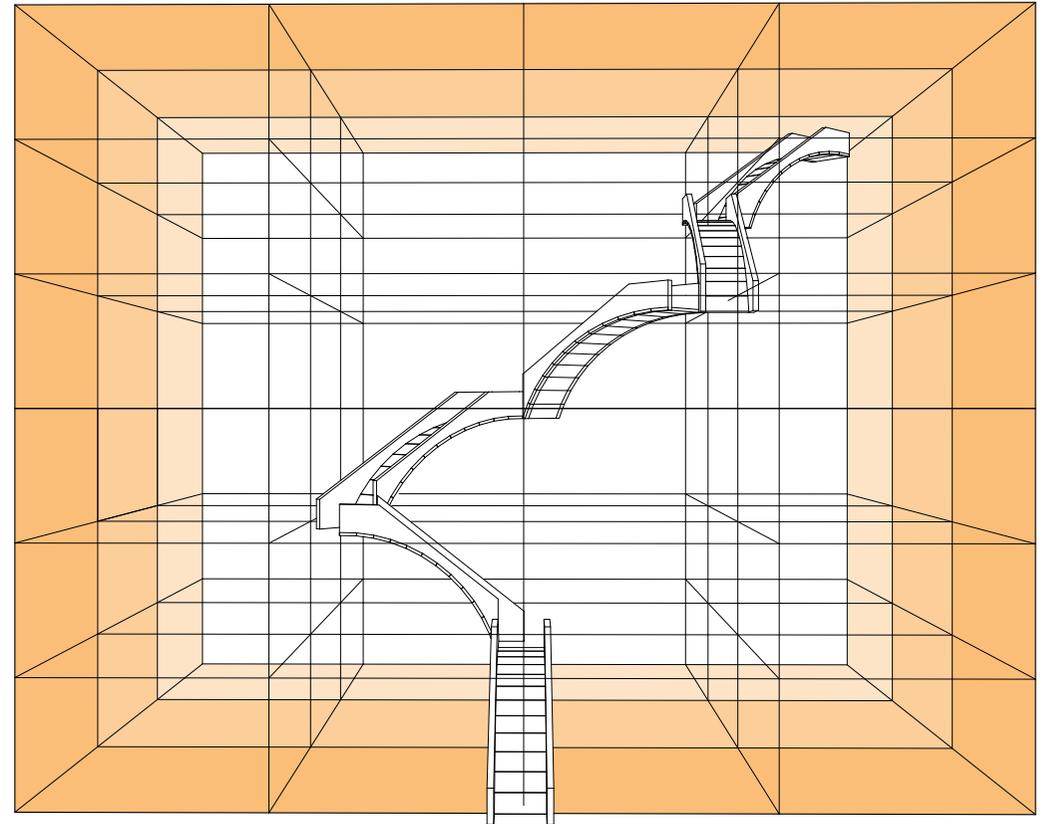
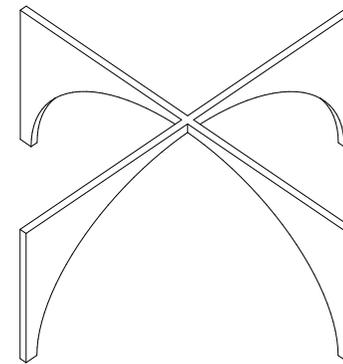
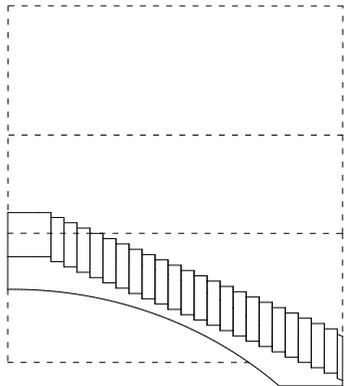
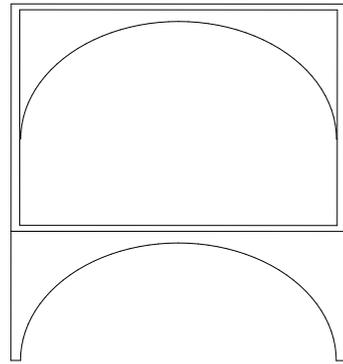
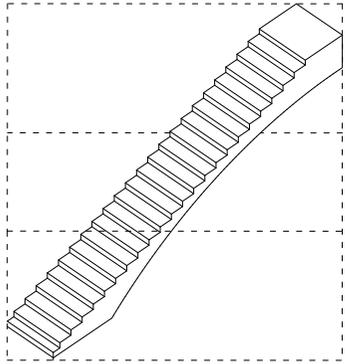
Machanical performance diagram



One third level applys in different combination of arches



4.6 Vertical circulation generation

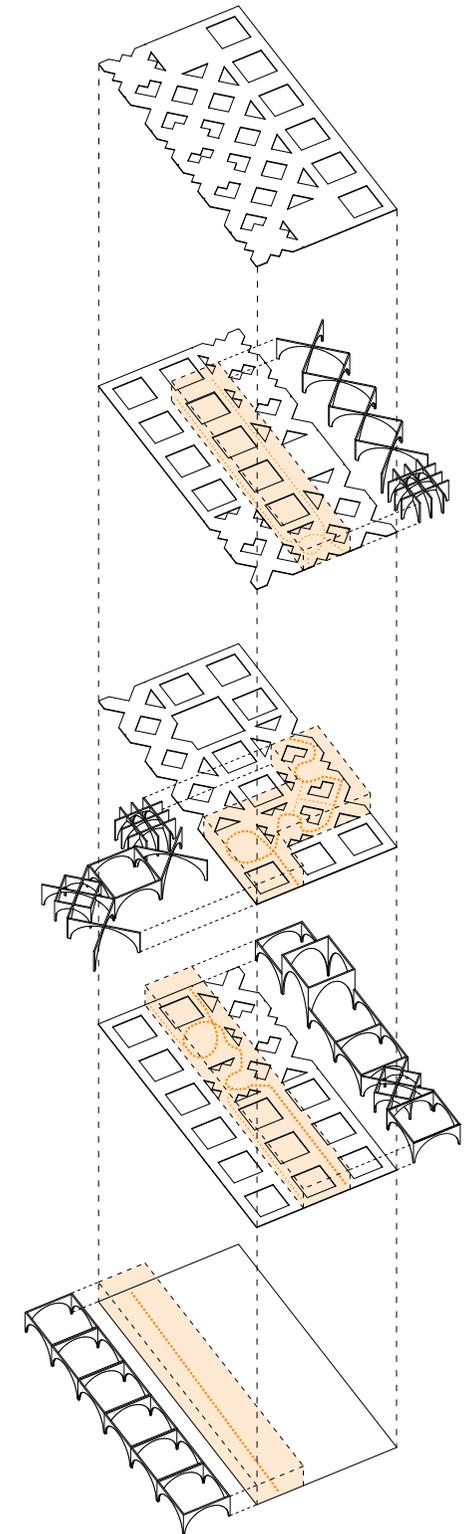


The arches work as the bearing system in the project and half arches work as stairs that connect the normal levels and one third levels. And the position of stairs is dominated by the performance of arches.

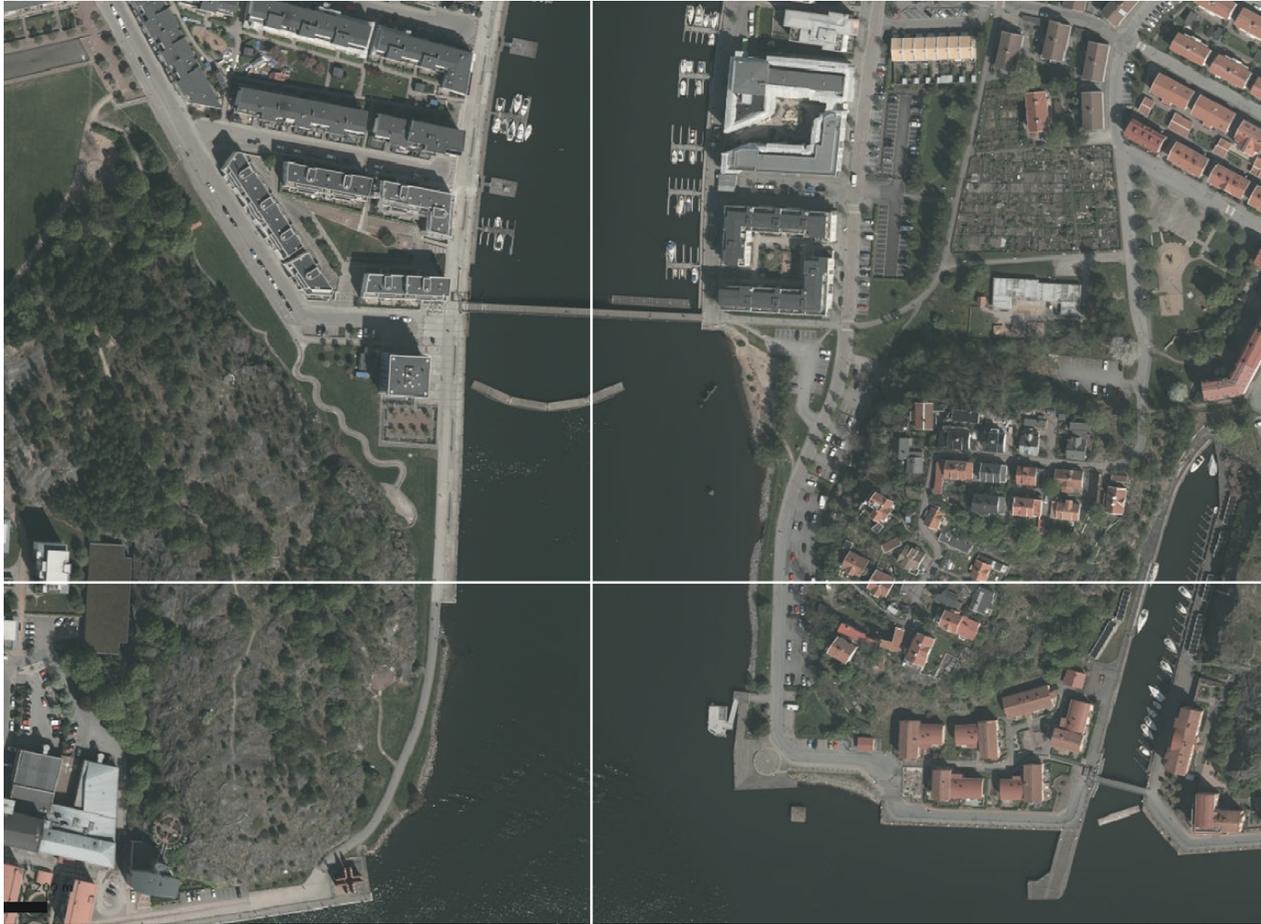
The diagram shows that stairs can develop in different directions between arches and also form the vertical circulation

4.6 Final prototype

People's sense of centrality and orientation is influenced by the performance of arches and their movement is also various depending on the arch performance based floor system



5.1 The site - Slottsberget



The site in this project is at Slottsberget. In history, this place is a important port. And now, it is a wonderful leisure area. The diverse surrounding elements causes dynamick circulation in this area which gives the oppertunity to utilize and integrate it in the project.



Residential buildings



Slottsberget stop



View from the park



Urban farm land



Walking path



Kindergarten



5.2 History of Slottsberget



During 1700s, Gothenburg grew into a huge city. The port's importance grew and thanks to the Swedish East India Company, as well as exports of iron and wood, Gothenburg became a major trading and shipping town.

In 1800s, both industries and the trading houses expanded in Gothenburg. The city has been praised for having succeeded in developing the area where the ship building industries were located.

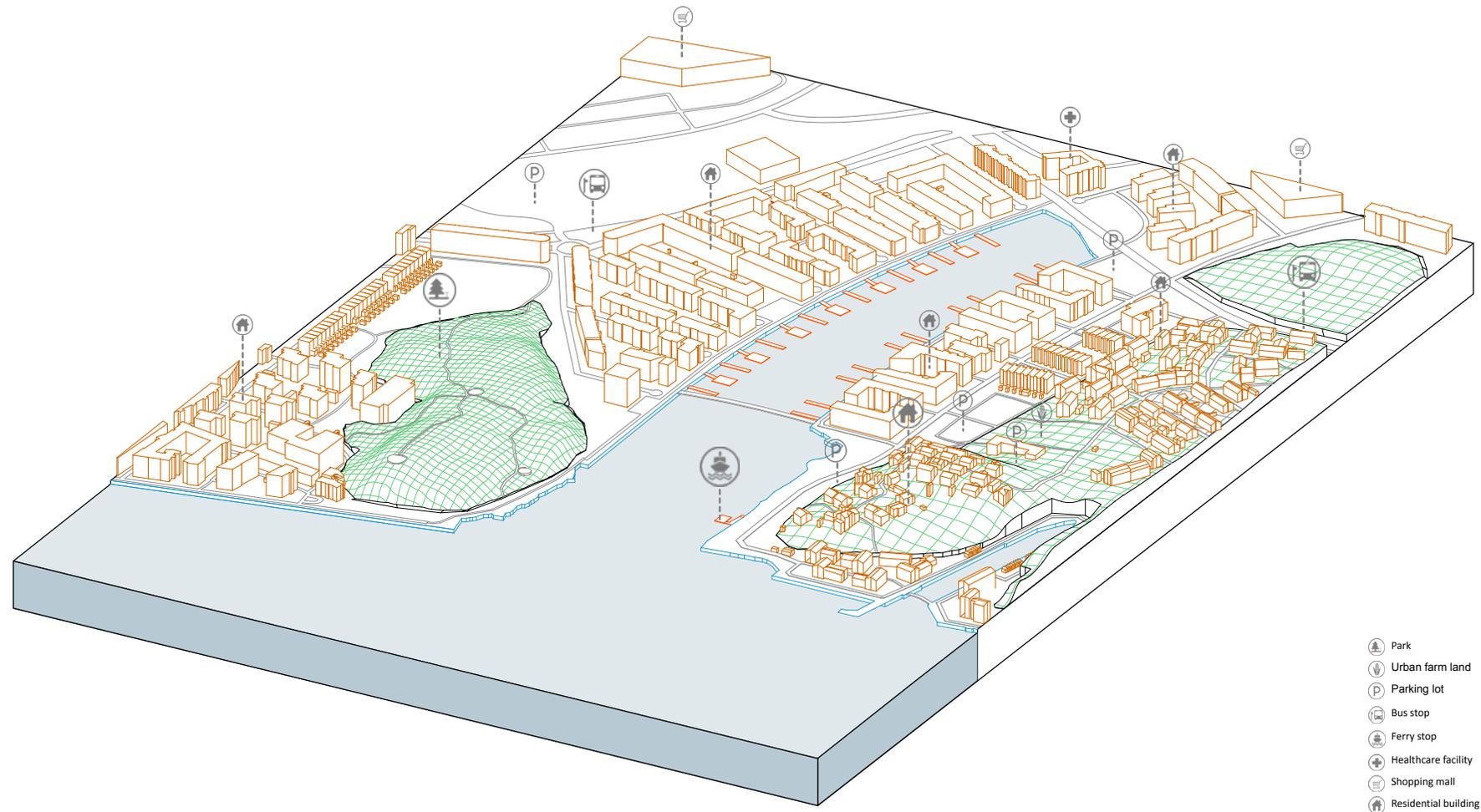


In the 20th century, the port needed to grow and this means expanding across the Göta River. The construction of Sannegårdshamnen began in 1908 and it was completed in 1914. Meanwhile, the engineering company Eriksbergs Mekaniska Verkstads AB was founded. During 1950 and 1960s, Eriksberg was the most profitable shipyard in the country.

In Slottsberget, there are many old houses with historical values which were built by shipyard workers from Lindholmen and Eriksbergs. And for many years it was the central harbour for the import of coal and coke.

However, with the shipyard crisis happened in 1970s, the industrial sections had faced a recession. And now this area is transformed into a popular residential area.

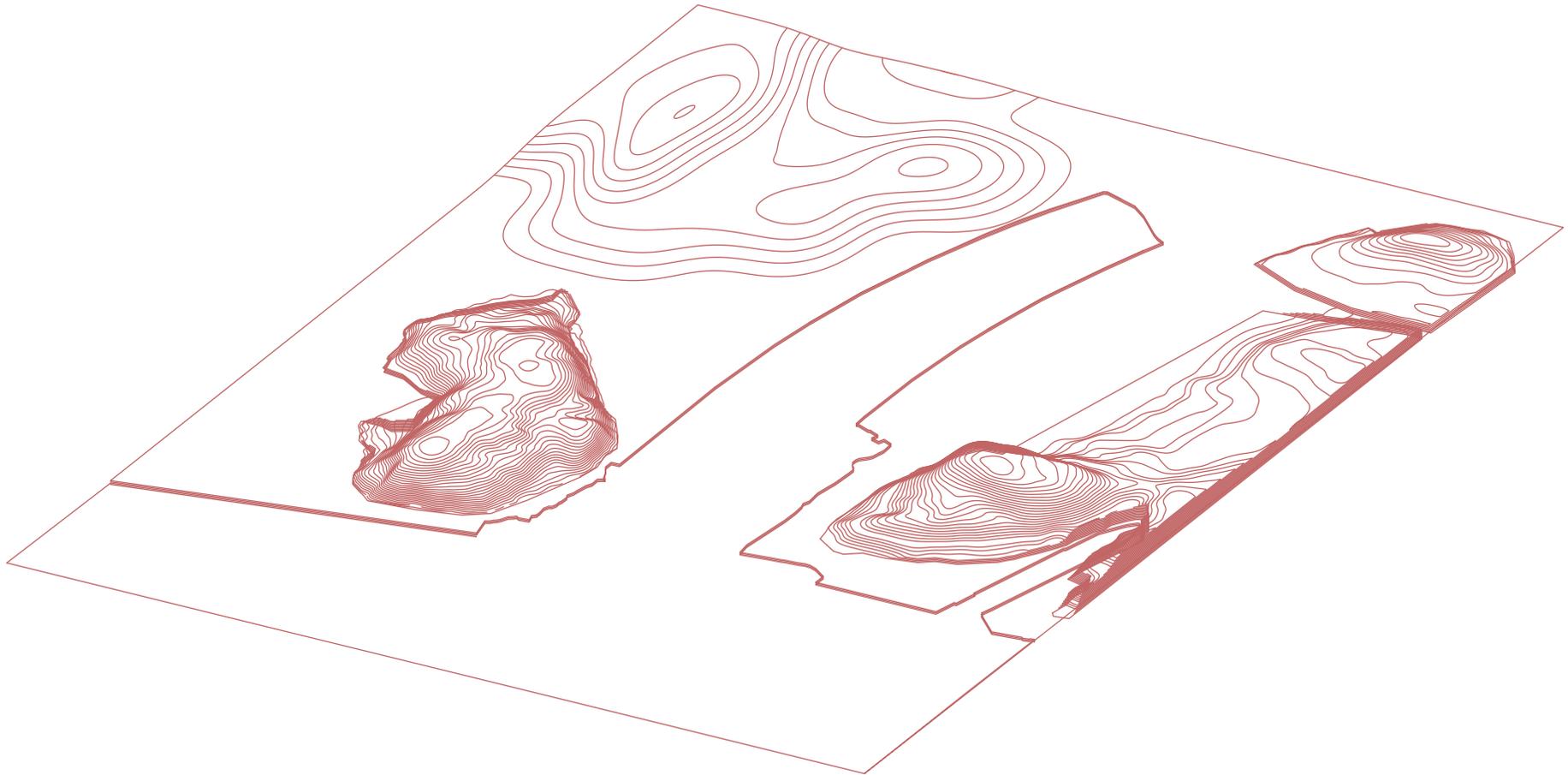
5.4 The overall conditions of Slottsberget



Overall Conditions

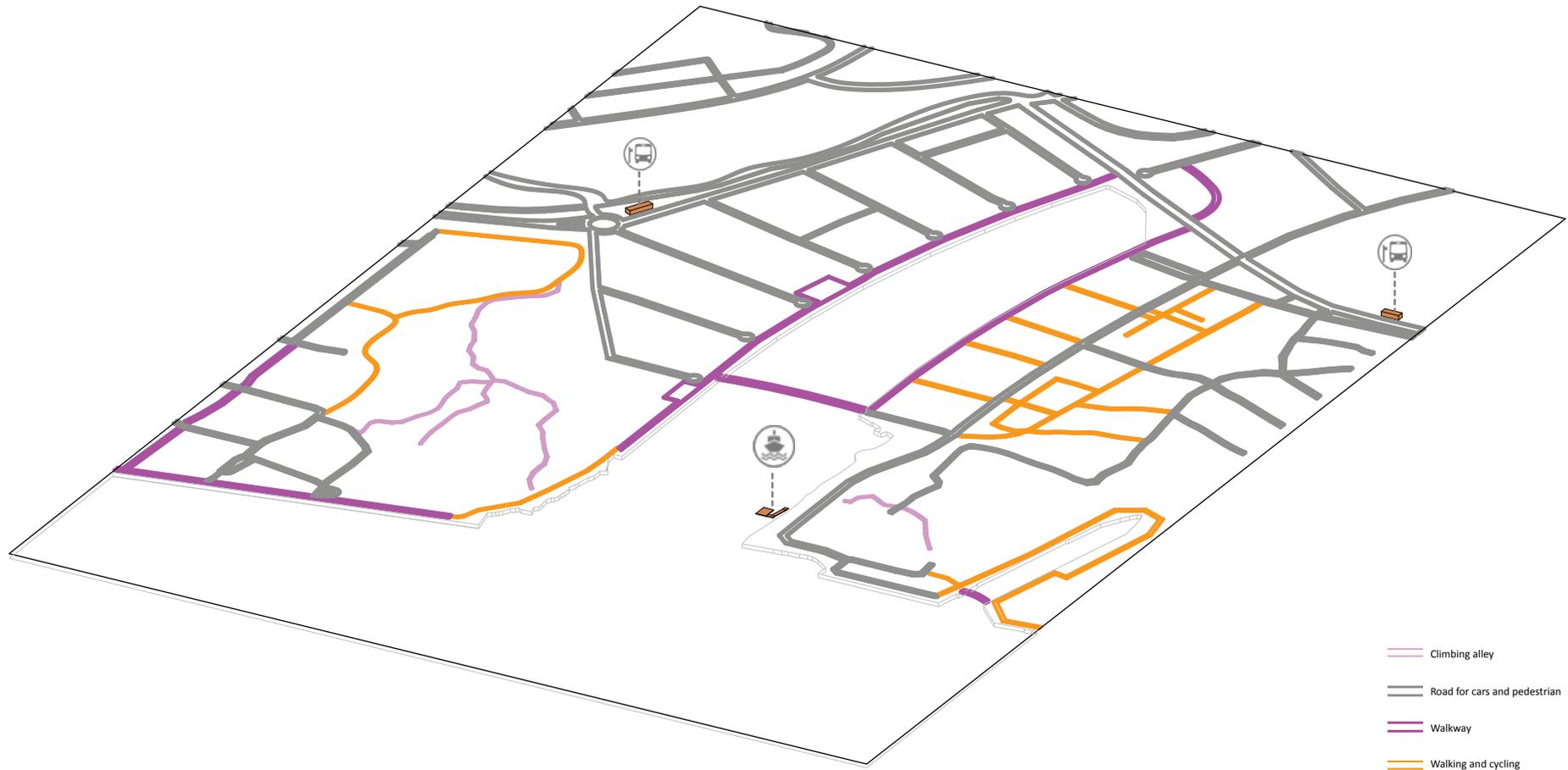
This diagram shows the general conditions of Slottsberget. It is not only a residential area but also a good place for people to spend the leisure time. People have the convenient access to this area by public transport. In this place, you can not only enjoy the view of port, Göta River, but also can get close to nature.

5.5 The topography



Topography

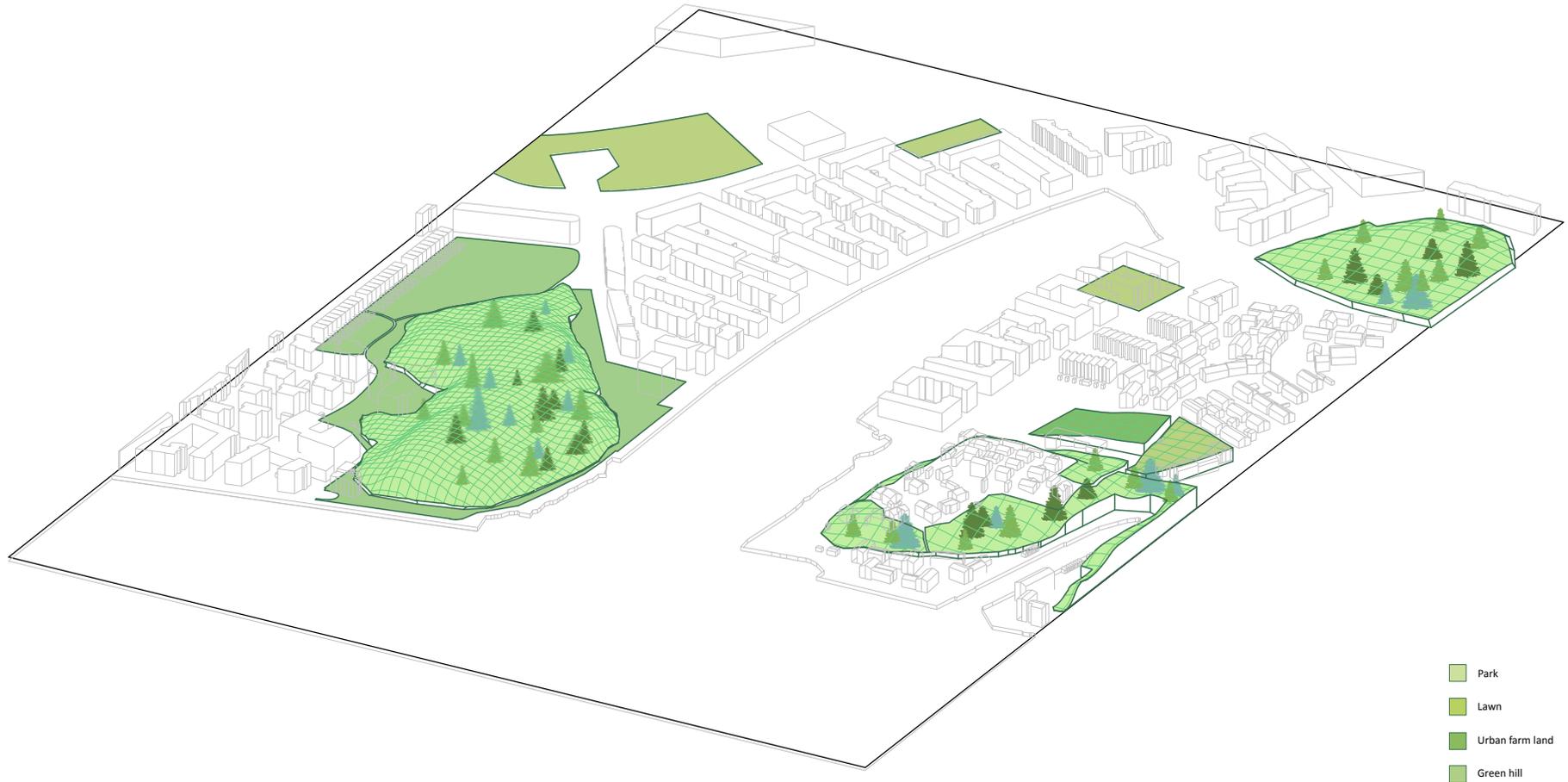
This diagram shows that the most area is quiet flat. The harbour is the lowest point in this area and on both sides of the harbour are small hills, and this causes a valley-like terrain.



Road System

In this area, the road system shows high diversity. It not only includes asphalt road for cars but also dirt road, bridge and wood walkway that only can be used by citizens and leisure people.

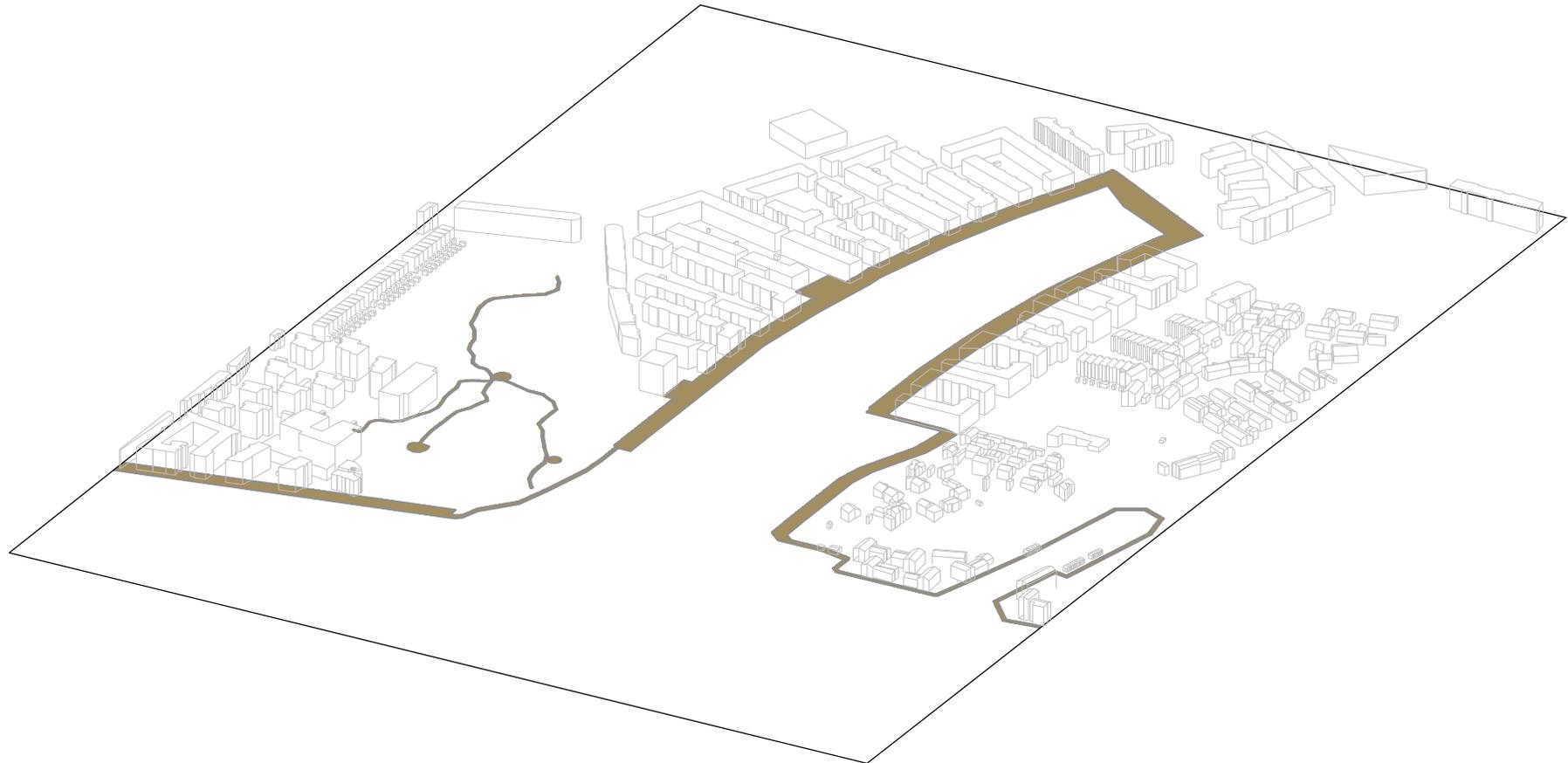
5.7 The green space



Green Space

This diagram shows the green space in this area. The biggest one in this area is Sörhallsberget which is a developed green hill. On top of Sörhallsberget, people is not only can enjoy the nature but also have the best view of the port, Göta River and city center.

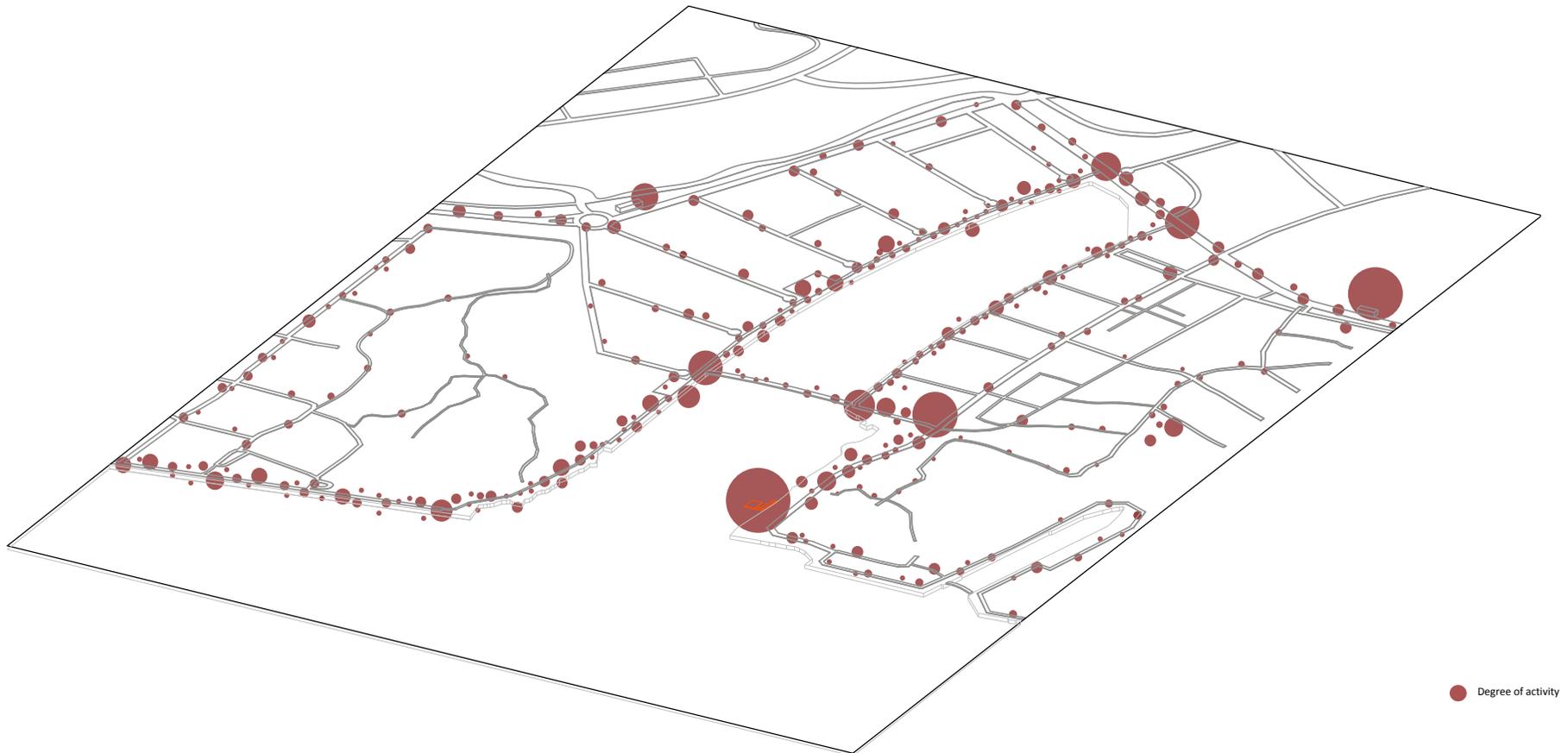
5.8 The leisure space



Leisure Space

This diagram shows that city managers use the space along the coast line and Sörhallsberget as leisure space. It allows people to enjoy the view and green nature in this area.

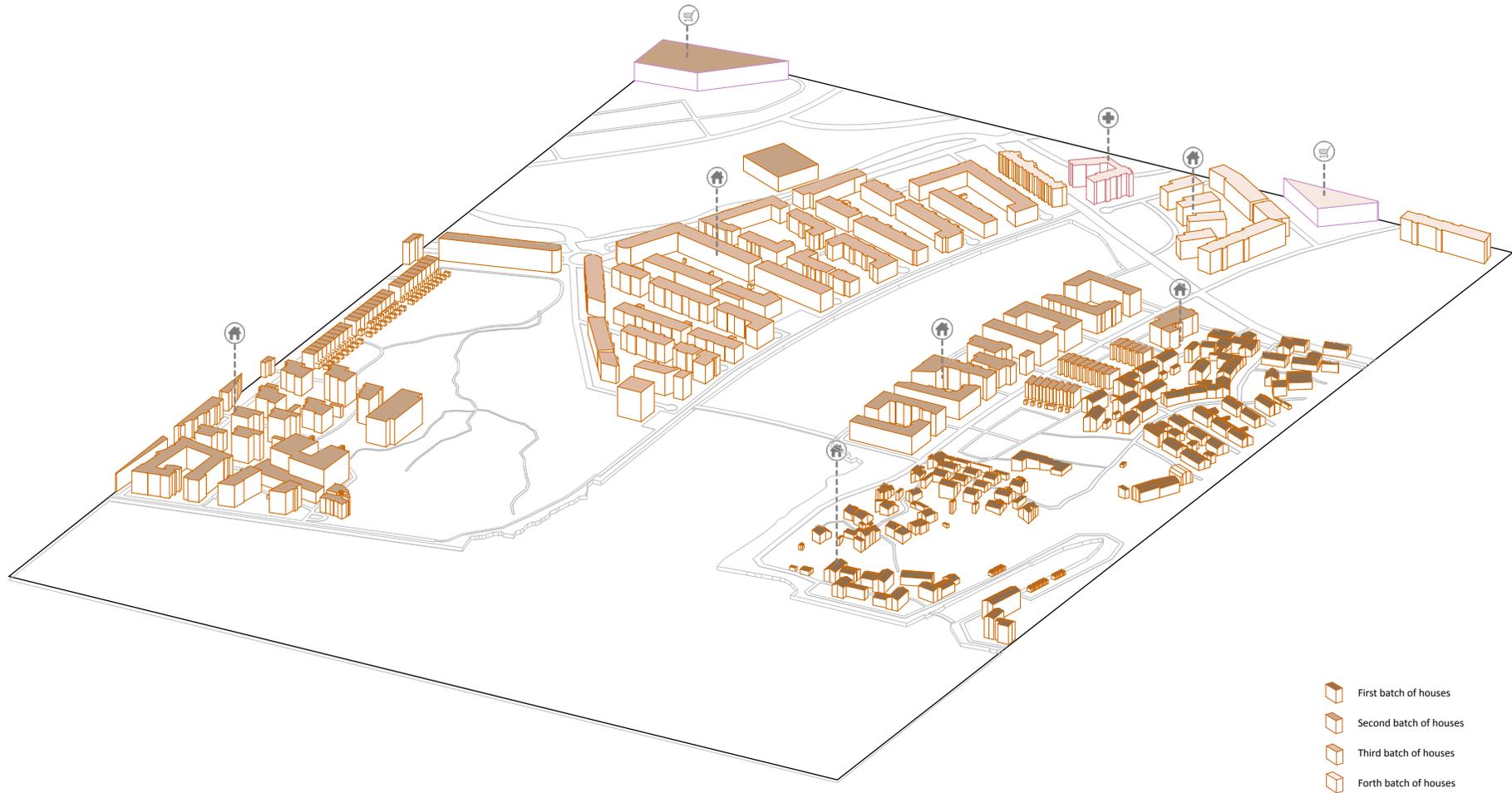
5.9 The degree of people's aggregation



Activity Degree

This diagram shows that people mainly gathering along the coast line and at the public transport stops. However, although Sörhallsberget is located at the center of this activity area, it doesn't attract people attention to make use of this developed green hill.

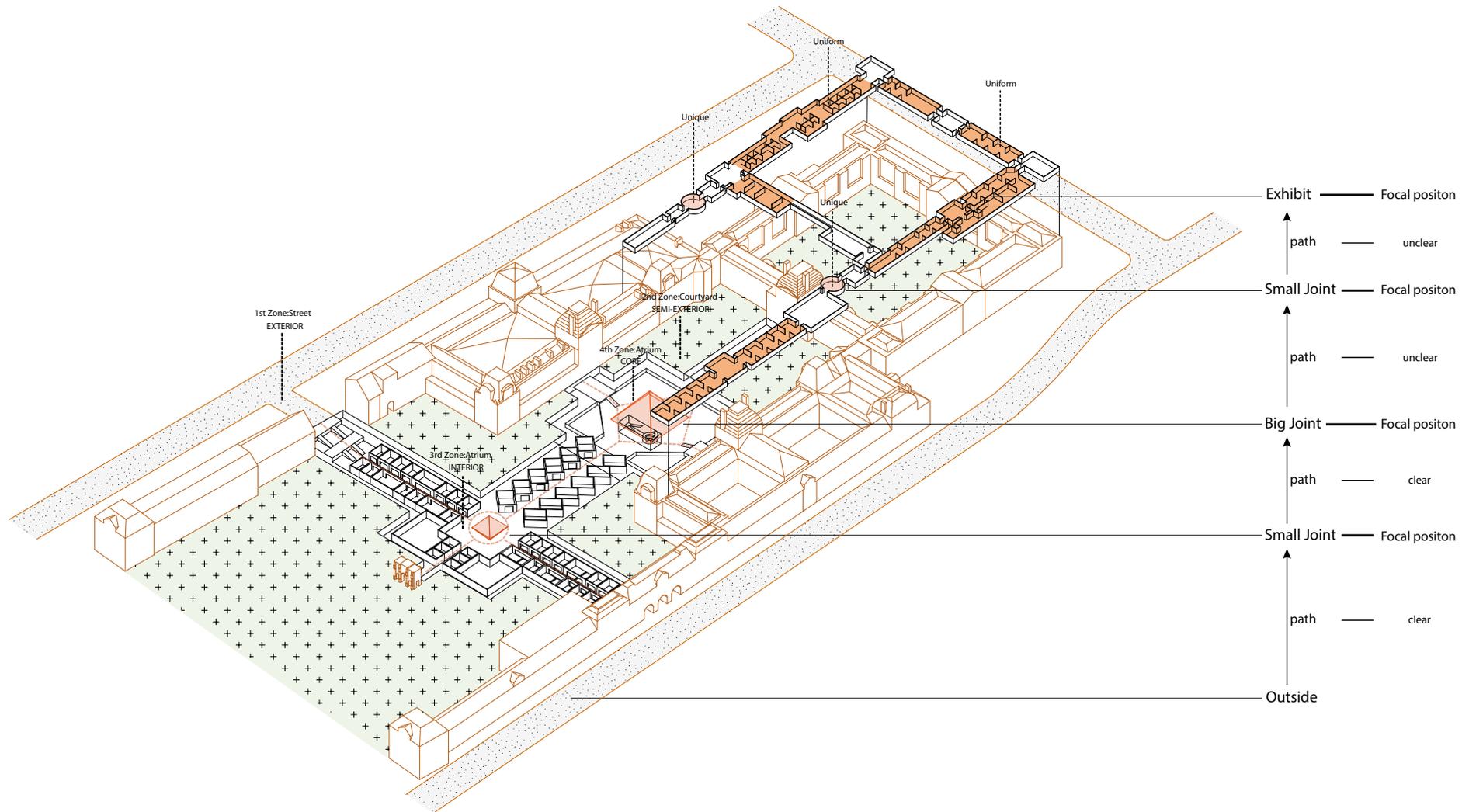
5.10 The housing conditions



Housing Status

The building that existed in this area mainly were built in four stages. The old houses that have historical values were built by the shipyard workers in early 1900s. Then in 1960s, modern residential buildings began to be built. And in 2004 more residential buildings were built along the harbour. In the following years, healthcare and commercial buildings appear in the outskirts of this area.

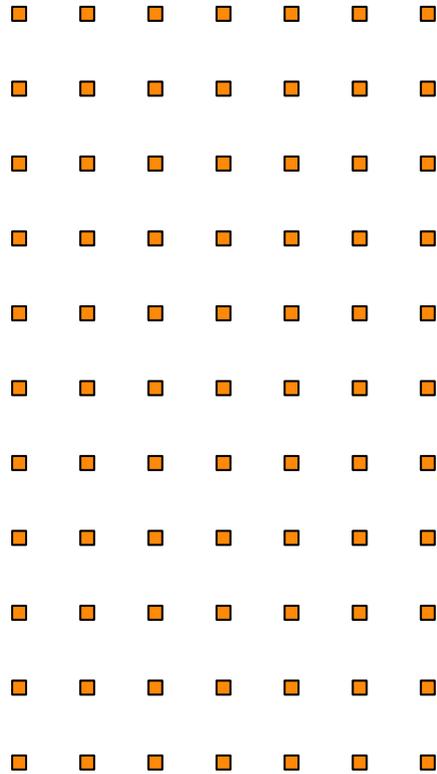
6.1 Joints and pathes, clear and unclear - Musee Du Louvre



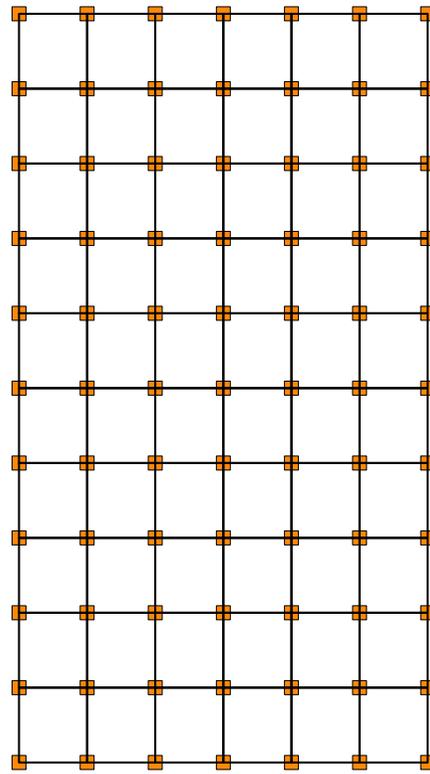
Musee Du Louvre

The project that is chosen as base organisation system is Musee Du Louvre. The diagram shows that the museum can be divided into four different zones - exterior, semi-exterior, interior and core. When people visit the museum, certain sequence happens. In each zone, there are joints that play important role in helping people finding their ways, and different types of paths are added to connect these zones. Some paths show the clear destination and direction, while others are quite confusing and people are easy to lost their way.

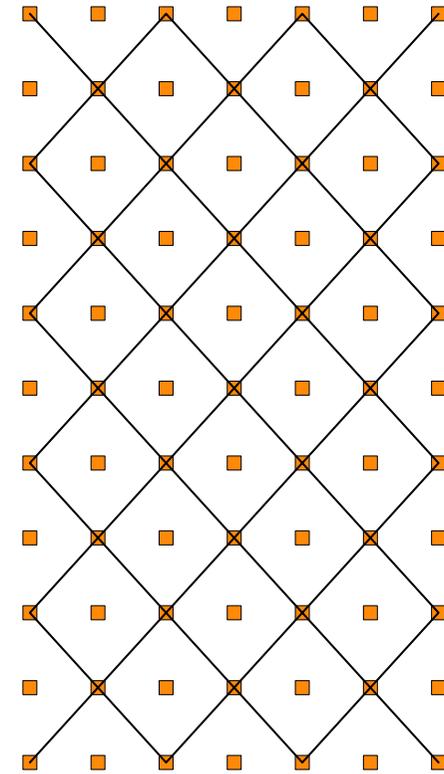
6.1 Cells, paths and joints



Point grid based on the site

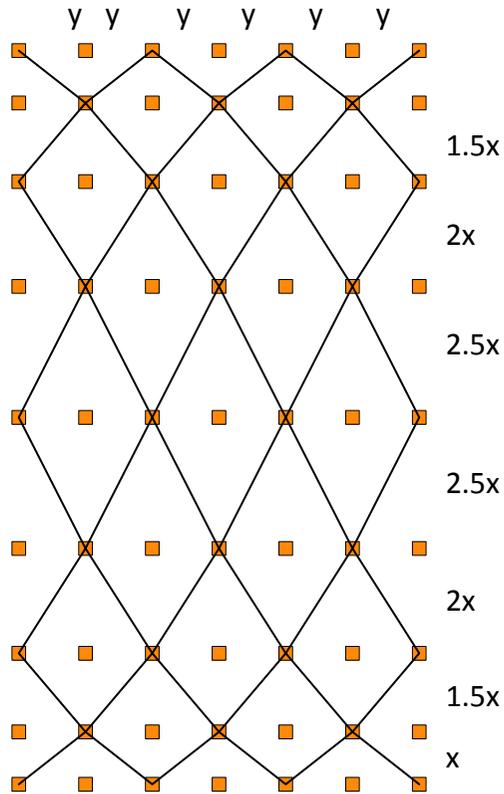


Generate grid

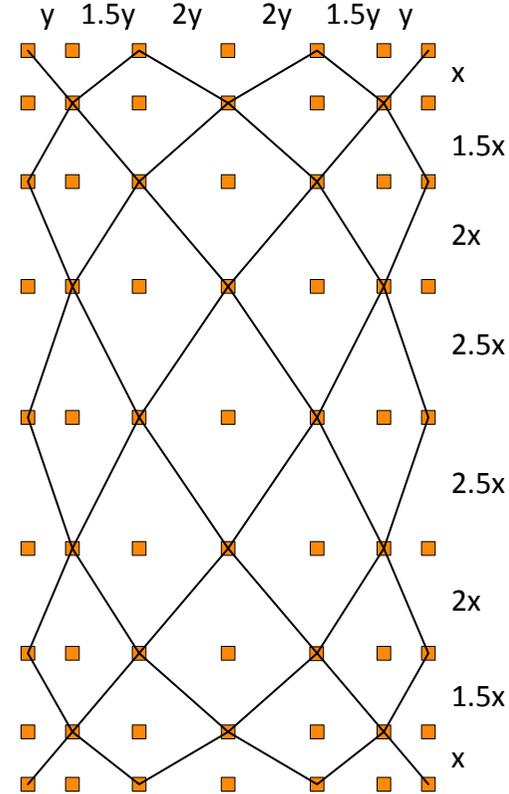


Change grid direction

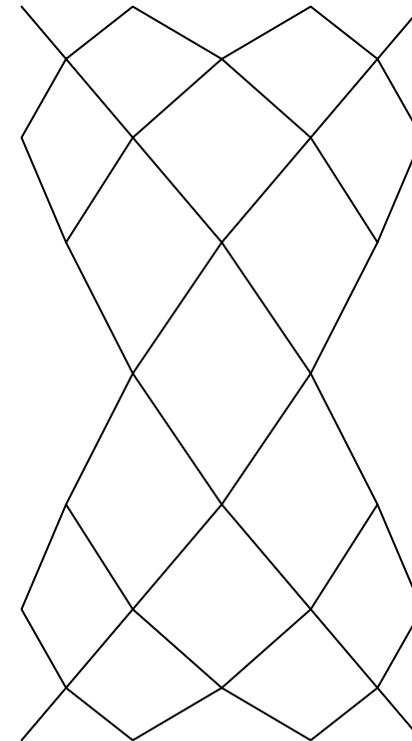
6.1 Cells, paths and joints



Change the grid on x direction

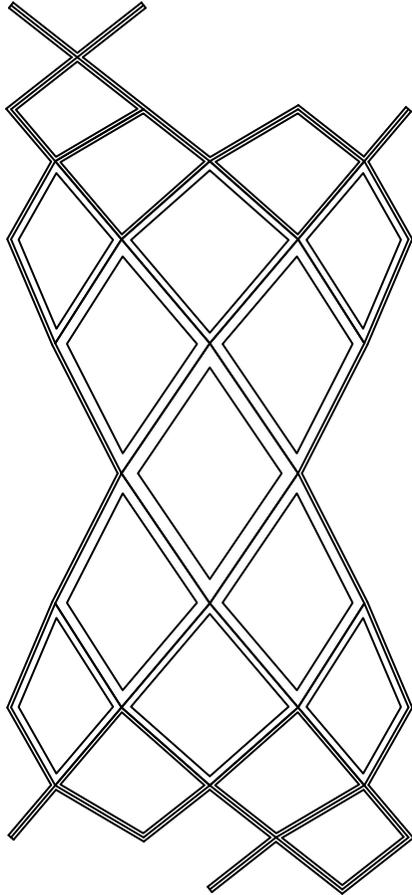


Change the grid on y direction

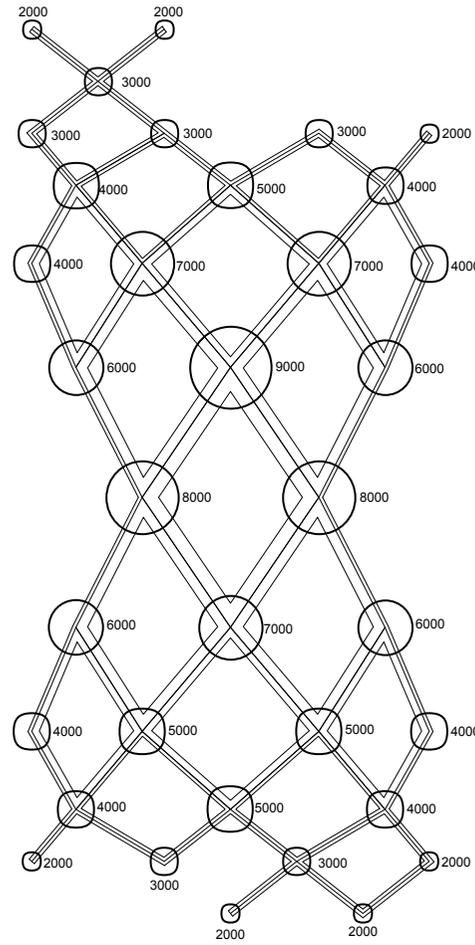


Generate the non-uniform cells

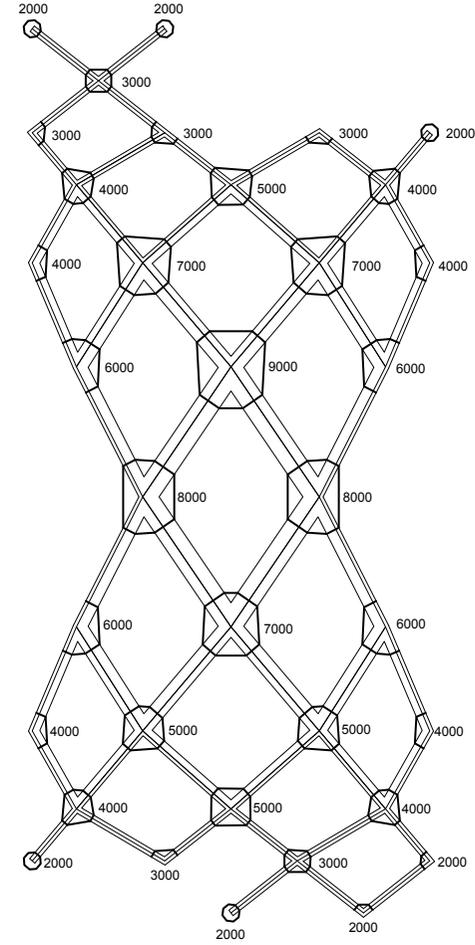
6.1 Cells, paths and joints



Based on the size of cells to generate paths

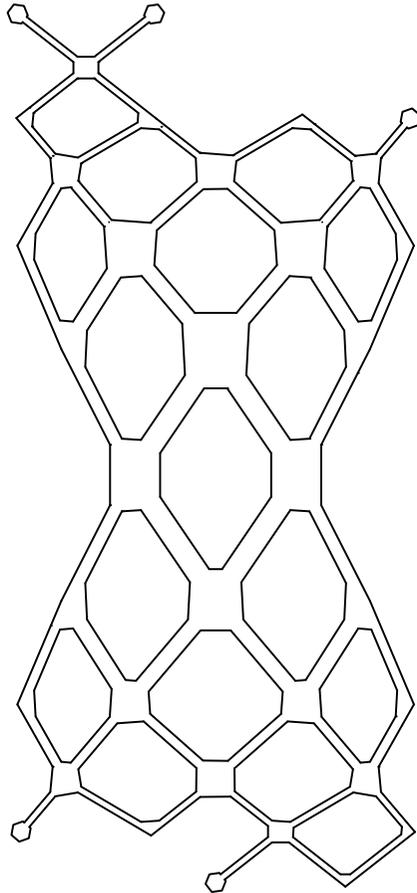


Circles radius shows the size of joints

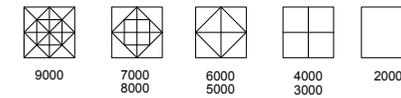
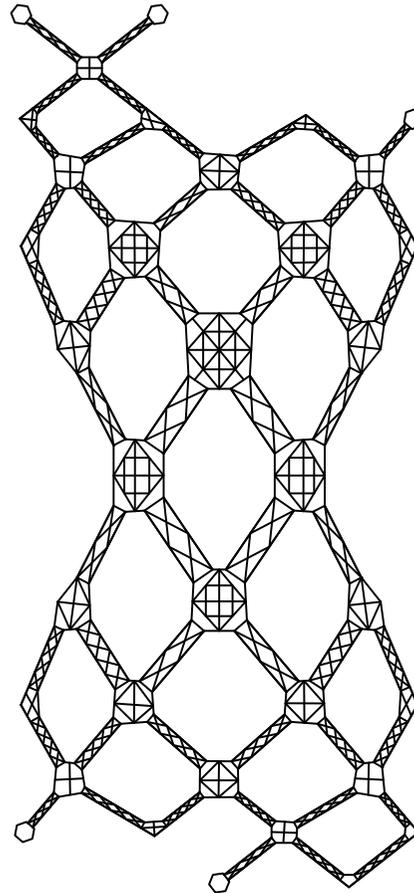


Polygon shaped joints insure the same distance from each paths to the center, and the joints are perpendicular with paths

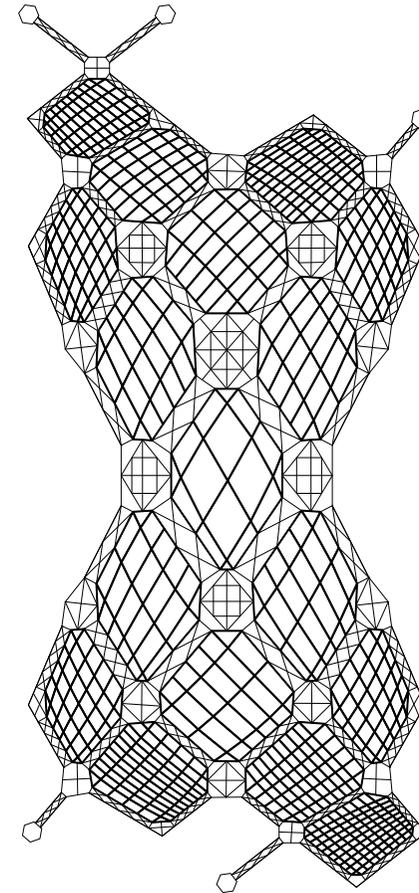
6.1 Cells, paths and joints



Generate the paths and edge line of joints

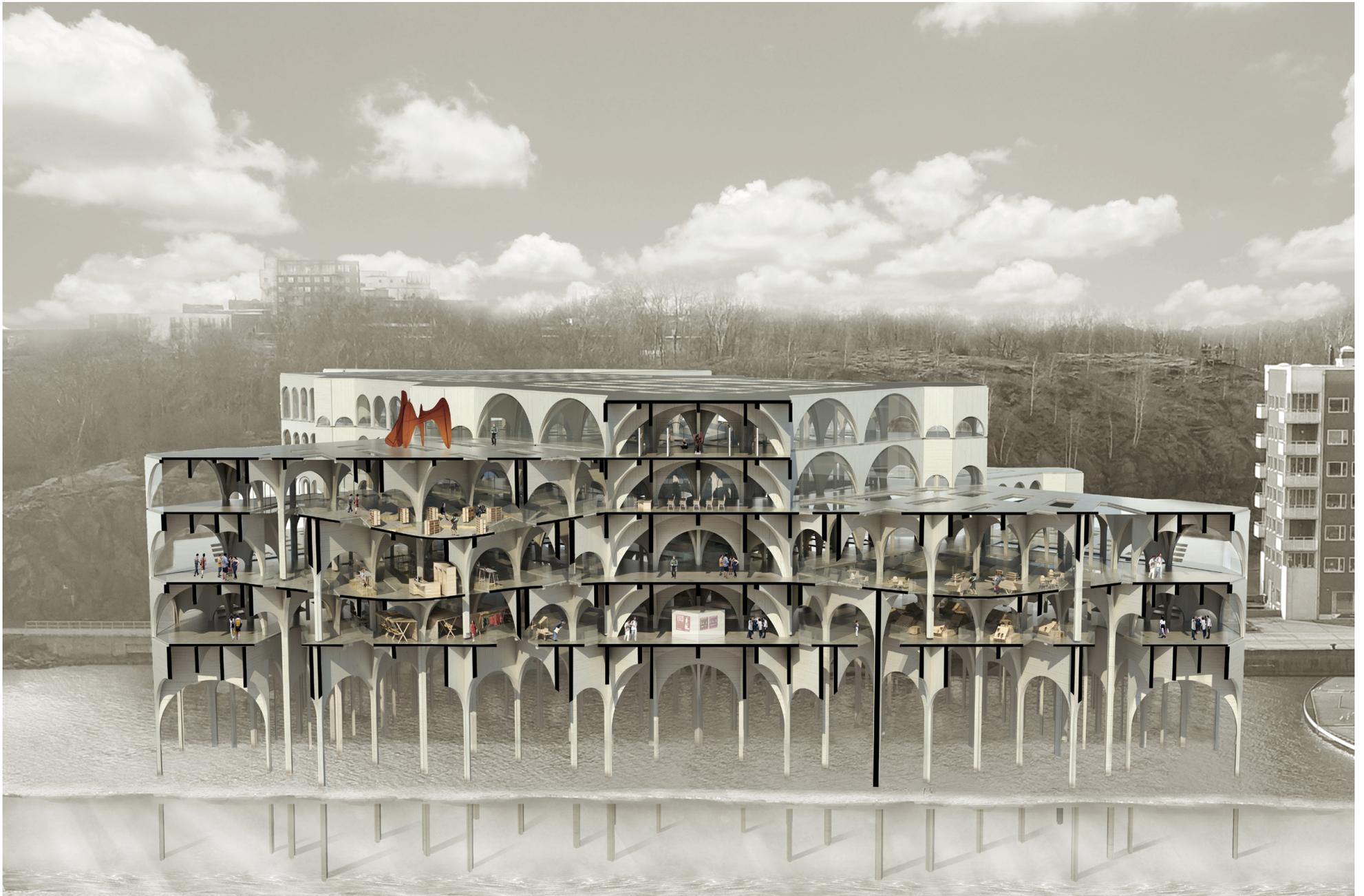


Arches' intersecting level is based on the size of joints



Space in each cell is divided based on the size of cell

7.1 Section perspective



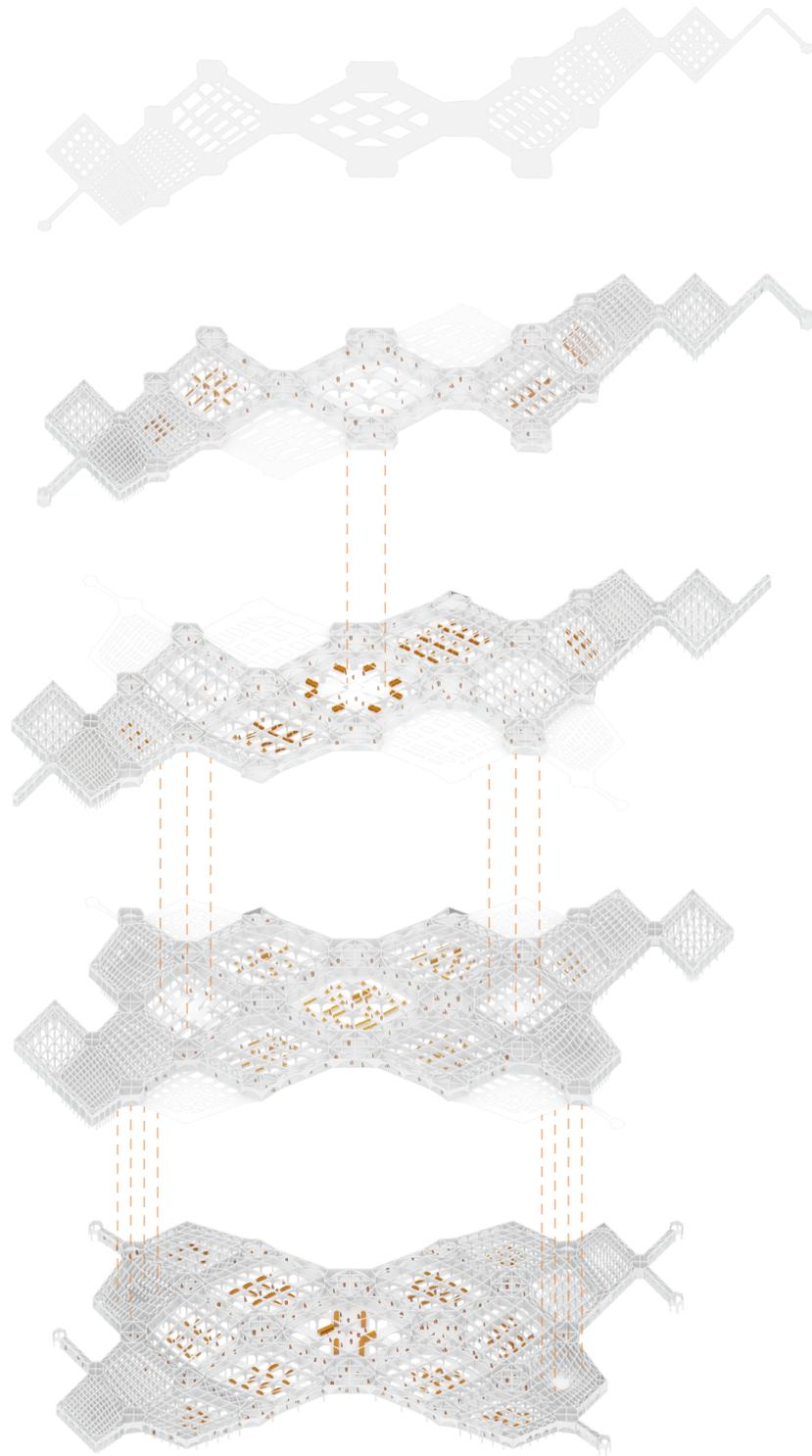
7.2 Boat view perspective



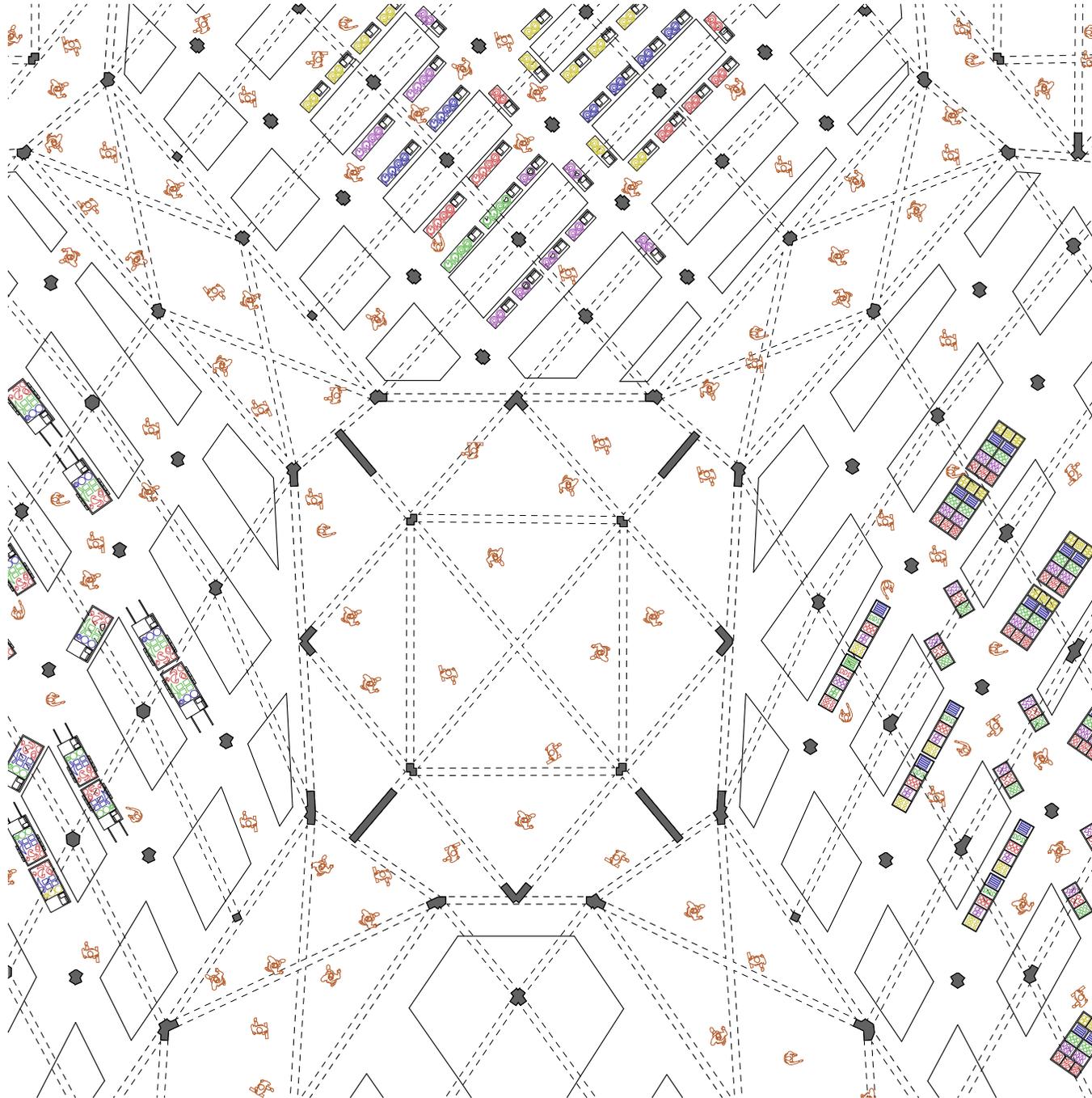
7.3 Interior rendering



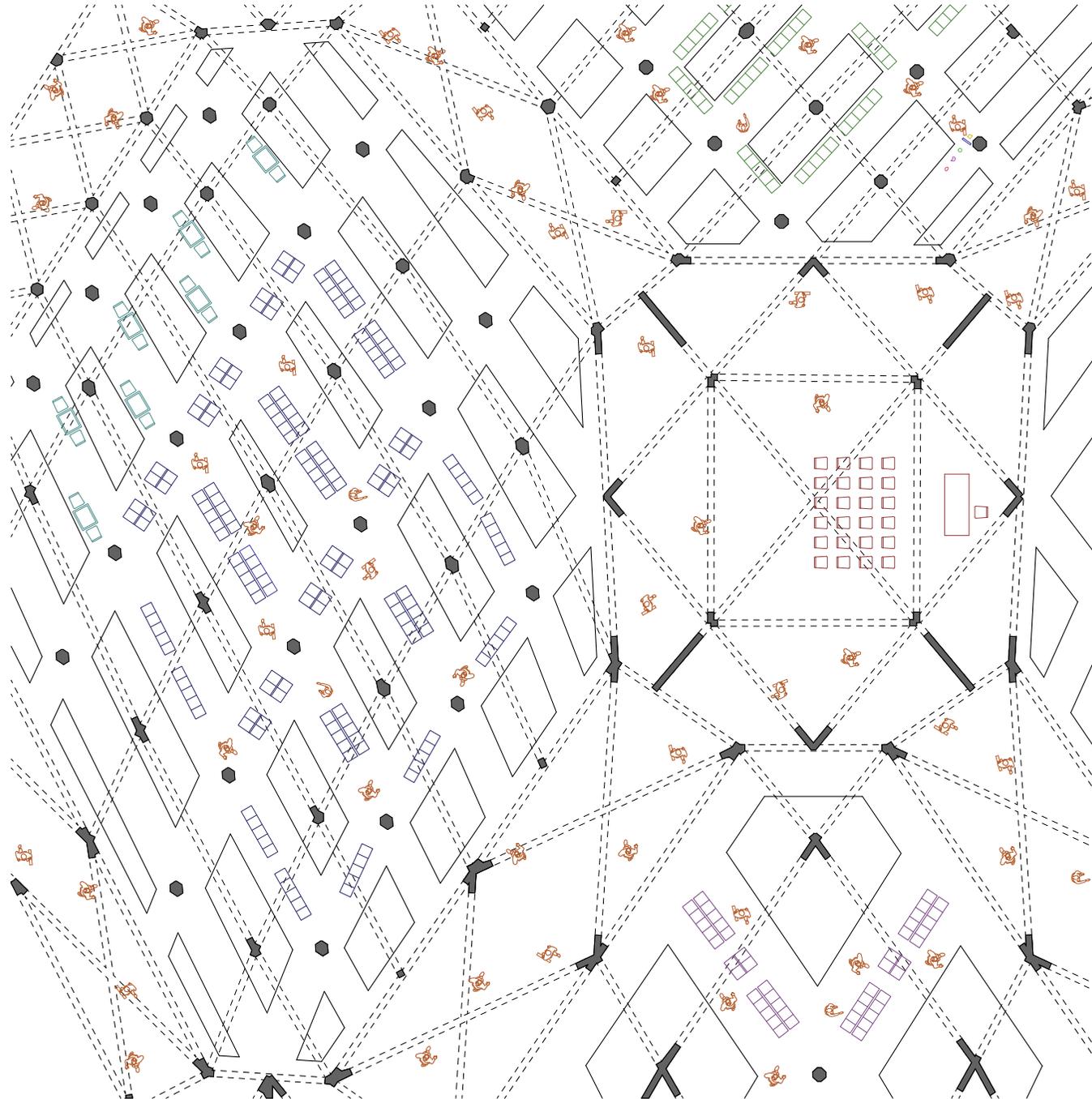
7.4 Boat view perspective



7.5 Daily market floor plan



7.6 Book market floor plan



8.1 Reference list

- 1) Moussavi, Farshid. (2009). The Function of Form
- 2) Mark, Robert. (1982). Experiments in Gothic structure
- 3) Scully, Vincent. (1962). Louis I. Kahn
- 4) Brownlee, David Bruce; De Long, David Gilson. (1991). Louis I. Kahn: in the realm of architecture
- 5) Sandaker, Bjørn Normann. (2008). On span and space: exploring structures in architecture
- 6) Sandaker, Bjørn Normann; Eggen, Arne Petter; Cruvellier, Mark R. (2011, 2nd ed.) The structural basis of architecture
- 7) Nilsson, Karl Robin. (2014). Getting the arch back into architecture
- 8) Santa María, Rodolfo; Palleroni, Sergio; Mijares, Carlos. (1989). Carlos Mijares : tiempo y otras construcciones
- 9) Block Research Group. <http://www.block.arch.ethz.ch/>

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