

CREATING THE SENSE OF NATURAL EXPERIENCE BY STRUCTURAL DESIGN

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ABSTRACT

Human beings are eager to living with nature. A series of researches indicate that natural experience can enhance the quality of living, working and healing. Nowadays the human need for nature and natural life is often not meet. Therefore, there is a wave of exploring how to integrate “natural elements” with built environment. It can be found in a large number of existing buildings that many architects have already implemented various methods to imitate the natural experience. Structure, as one type of architecture language, has great potential to create natural atmosphere due to its flexibility in form, material, scale. Hence, structural design is mainly discussed in the research. The aim of this research is to collect and analyze the ways to create the sense of natural experience by different structure selection. In addition, there is a need for a theoretical and systematic framework in obtaining guidelines and general principles for creating natural atmosphere through structure design.

KEYWORDS: natural experience, structural design, form, materials, atmosphere, principles, AMC

I. INTRODUCTION

1.1. Background: Healing with “natural experience”

In present environment, which is predominantly urban and thus distant from nature, the human need for nature and natural life is often not met. Having some natural atmosphere in building where human beings spend most of time nowadays, improves people’s experience of the space and creates a feeling of familiarity and comfort. According to evidence-based design (Roger. S, 2002), in healing environment, the presence of nature can have a positive effect on the healing process that promote physical and mental well-being. Healing with nature has been a long time since the first time ‘hospital’ appeared (see Fig. 1). The complete timeline shows in appendix I. In an American study, the length of stay after surgery was reduced with almost 10% when the patient had a view on trees. Compared to a view of a brick wall. And patients who had a view on trees used up to 30% less heavy painkillers (Roger. S, 1984, pp.420-421). However, many disadvantages like risk of infection and allergy limit the use of real nature elements. It was shown that the visual impact alone- just looking at the plants- speeds up convalescence for patients (Roger. S, 2002). Therefore, many hospitals and clinics started to use ‘nature surrogate’ instead of planting real trees indoors. The purpose of the research is not to set a real garden in building, but to create a space arousing people’s perception of natural experience.



Figure 1. History of healing with nature (Stephen, V. 2010, p.102)

1.2. Current state of natural architecture

Architects often look to nature for inspiration. Many of them are focus on the analogies between nature and architectural structure. They generally get these ideas from form, function, structure, material or spatial experience. This part mainly discusses their main achievements in structural design (see Fig. 2).

The initiate of natural analogies can be attributed to Frank Lloyd Wright. He discovers the principles of order and unity in nature (N. Ayiran, 2012). These principles include unity of form and function, natural materials and color in structural design.

Antoni Gaudi represents the culmination of inspiring from nature. He expresses his passion to nature in his architecture. He is interested in structures inspired by nature. In his masterpiece Sagrada Familia, columns mirroring trees, roof structures mirroring leaves, all these structural elements allow him to create a natural atmosphere. The structural forms imitated those found in nature provide him with both aesthetic and functional benefits.

Following Gaudi's ideas about nature, Santiago Calatrava studies the natural principles, and transforms images from nature- trees, animals, the human body, for example- into structures. The landscaped structures that he creates evoke people's empathic response to nature (McQuaid. M, 1993, P9). His fascination with nature is integrated into his built projects which will be expatiated in chapter 3.

Learning from an abstract way, Toyo Ito generates the organic aspects of his work which perceived as harmonious with nature and people. "Human beings become free when they are in nature, so what I had in mind was to create an architecture that resembles nature," said Ito. He creates open space with fewer walls, where only vertical tubes that serve as columns hold up the building like tree trunks, which makes the experience in structure more nature (Woo-young. L, 2013).

Junya Ishigami(石上純也), as one of the most experimental of Japan's younger generation of architects, has been exploring a more abstract way to reinterpret the natural phenomena in architecture. He is dreaming of structures that are as light as a cloud, as vast as the sky, as random as the trees in a forest or the stars in the sky (Oliver. W, 2018). Rather than using nature metaphors, he devoted to stimulate people's imagination of nature by extreme structure.

In conclusion, nature as structural, functional, spiritual and decorative inspiration for architecture, often goes deeper than imitating just the surface features of nature. In other words, this research is not going through imitation of nature, and it focusing on the people's sensory perception of natural experience. The role of nature in architecture is evocation rather than imitation.



Figure 2. Structure inspired by nature elements

1.3. Research question

As architects, creating the sense of nature experience by architectural language is an innovation. Structure, as one type of architectural language, is capable of expressing the atmosphere that pervades a space. It has great potential to create natural experience which has been illustrated in the previous part. Consequently, structural design will be mainly discussed in this research. This leads to the main research question:

"How to transform the sense of nature experience into architectural space by structural design?"

In order to respond to the main question, the following sub-questions will be explored as well:

- What are the categories of architectural structure creating the sense of natural experience?
- What are the principles of transformation from natural experience into architectural languages?
- What is the boundary between artificial nature (by structural design) and real nature?

The answers to these questions intend to draw a framework in obtaining guidelines and general principles for creating the sense of natural experience in healing environment by structural design.

II. METHODOLOGY

To give an answer to the research question, the following three parts have been employed in the research. Each step will be elaborated in Results Chapter. First part is doing literature reading and case study. This part requires collecting relevant data from precedent theories and projects in order to arrive at a comprehensive understanding of the characteristics that people perceive and concise in natural experience. Second, the research will analyze, select and classify this precedents including completed projects, exhibition devices, giant structures, and architectural facilities, which utilize different structure selection to create natural experience. The accomplished projects database helps to develop the general guidelines or principles for building natural experience. Third part is to verify the previous guidelines or principles in specific context (AMC- Academic Medical Center in the research). The sense of natural experience, simulated by physical model (a full-scale, real-life mock-up), can be effectively investigated. The design strategies concluded in last step will conduct the next design process.

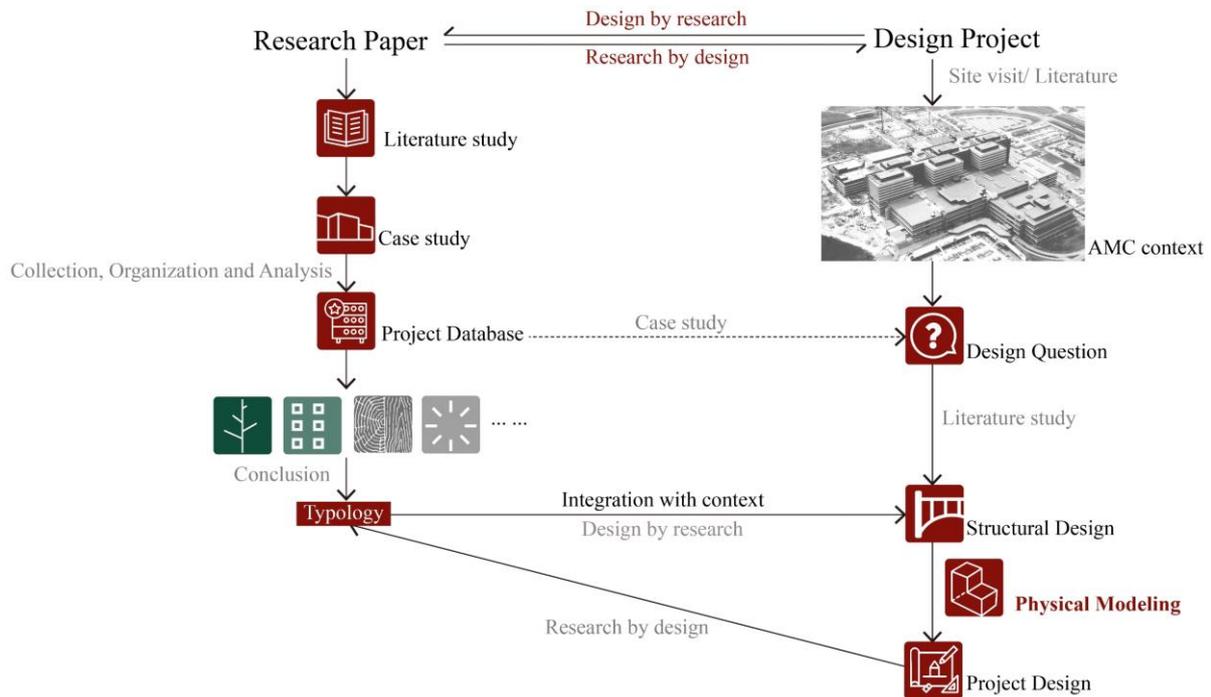


Figure 3. Diagram of research and design process (own image, 2018)

In conclusion, series of methods are involved in the research, such as literature study, case study, category and simulation. During the design process, far from being a stereotype, it is typically demanded to revise the research continually as the design project develops. Research and design are complementary processes.

III. RESULTS

Nowadays there is a wave of exploring how to integrate nature with built environment. It can be found in considerable existing structures that many architects and structure engineers intend to create natural experience by structural design. In this chapter, various projects will be studied, analyzed and categorized. The projects database will assist the structure selection at the preliminary design stage. In final part, three different structure selections will be tested in three-dimension model under the context of AMC buildings. The result can form a critical tool and conduct further design for AMC renovation.

3.1. Projects Database

The collection of projects in the database should be considered on two levels: as a design possibility to explore how far can structure perform when it transforms natural experience, from the visual sense to

sensory perception; and then as design typologies of creating natural experience, from literal approaches like similar forms and materials to abstract aspects like feeling, hierarchy and atmosphere. (*Appendix II*)

3.1.1 Category from literal aspect to abstract aspect

Natural expression of structure encompass different degree of explicitness. Creating sense of natural experience has five main categories from literal to abstract which are: total mimicry, partial mimicry, non-biological analogy, abstraction, inspiration. Therefore, some examples of natural experience are universally recognized, some less unambiguous are not. The purpose of this category is to explore how abstract the structure can be when creating the sense of natural experience. In order to, There are three aspects can be renowned in architectural structure, named as visual, haptic and sensory. Visual and haptic aspects can be interpreted as structural representation, and sensory aspect as symbolic structure (*see Fig. 24*).

-Visual aspect of structure indicates its form, appearance and scale. This structural representation is understood as structure typifying a physical object, like a tree. Plant forms that recall the shape of well-developed trees are most common “natural construction”(Irene. M & Eberhard. M, 2015). Of all natural construction, tree-like form and forests are by far the most likely to be represented structurally, and their popularity among architects is reflected in the projects database. In a literal instance of representation, “tree” become the primary elements of the orient station(*see Fig. 4*). The use of the arched ribbing and thin sections recall similar properties of palm tree and the strengthen the botanical analogy. In addition, a forest, rather than a tree, is depicted in the Kanagawa Institute of Technology KAIT Workshop, Japan (*see Fig.31*). Its slim rectangular columns are devoid of branches. Although such regular columns on their own could hardly be considered to represent trees, their sheer numbers and their collective ‘random’ placement evokes a forest (*see Fig. 5*).

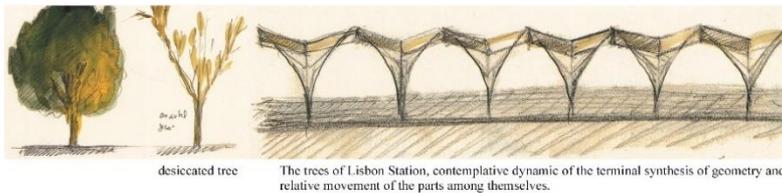


Figure 4. Concept of orient station (drawn by Santiago Calatrava, p.275)



Figure 5. KAIT vs. Forest

- Haptic aspect of structure is focus on the multi-sensory perception, acoustic, haptic, tactile and olfactory senses. This multi-sensory design means that architects should consider all the sense and how they can be influenced, and not just the visual appearance (Jurg. C, 2006). For structural design, the different color, texture of materials will trigger subtle experiences. For example, Japanese architect team O+H, sets a “nature” structure in the art gallery(*see Fig. 6*). They use the solid and rough stone to imitate the ground, and the light and smooth plastic to imitate sky. Without any literal shape, the texture of material gives the specific perception. Similarly, Peter Zumthor gives a complete sensory experience in The Therme Vals (*see Fig. 7*). Blocking the view of people, the sound of water and touch of stone evoke the sensations of the real nature.



Figure 6. Dream of cave by O+H



Figure 7. The Therme Vals by Peter Zumthor

- Sensory aspect of structure refers to people’s sensory perception of the space created by the structure, or, atmosphere caused by structure. It recalls an idea, a quality or a condition. Sensory aspect is less explicit than the former two. To specify this statement, the research primarily discusses about **light**

and shadow. Many architects use light to affect people's perception of a space. For instance, light gives sacred phenomenon in church. Similarly, light can create the sense of nature as well. Louis Kahn's aphorism 'Structure is the giver of light' (Louis. K, 1975) defines that structure source and modifier of light in a space. For instance, the ribbed structures in BCE gallery (see Fig. 29) functions as a tree-lined garden. Depending on intensity, light creates strong gradations of light and dark. Experiencing the rhythm of light, no light, one strongly feels like under the shade of grove (see Fig. 8).



Figure 8. Shadow of ribbed structure vs. Shade of grove

3.1.2 Category by nature characteristics

It is necessary to compare the structural nature with the real nature. Acknowledge of the perception of real nature conduces to the know the characteristics that people perceive and concise in natural experience. Therefore, this category, as a data base, forms a general criterion that can evaluate whether the structure and the space delineates the sense of natural experience. Perception of nature is classified into four parameters corresponding to four factors of structure selection (see Fig. 25).

- Form, structure, habit (structural form): Plants are perceived according to their form, structure, and habit; and the structure leaves first impression by its form as well. Classification in form and habit type, makes plant easier to compare different species and to decided which is best suited to which spatial situation. Similarly, structural form should be sorted, which is convenient for structure selection of various building types (see Fig. 9).



Figure 9. Form, Above: Form, structure, habit of nature, Below: structural form

- Growth height and the horizontal plane (structural member and array): Thinking in terms of vertical plane, it is possible to divide plant into foliage, trunk, and root, which analogy for structural member in architectural realm. For instance, an interpretation of the tripartite section as foliage (roof), trunk (column), and roots (base) is reflected in one of Calatrava's first sketches for the Saint John the Divine cathedral. The different horizontal array of plants dominates, and makes a powerful contribution to shaping the space. The arrangement and density of structure also decide the boundary of a space (see Fig. 10).

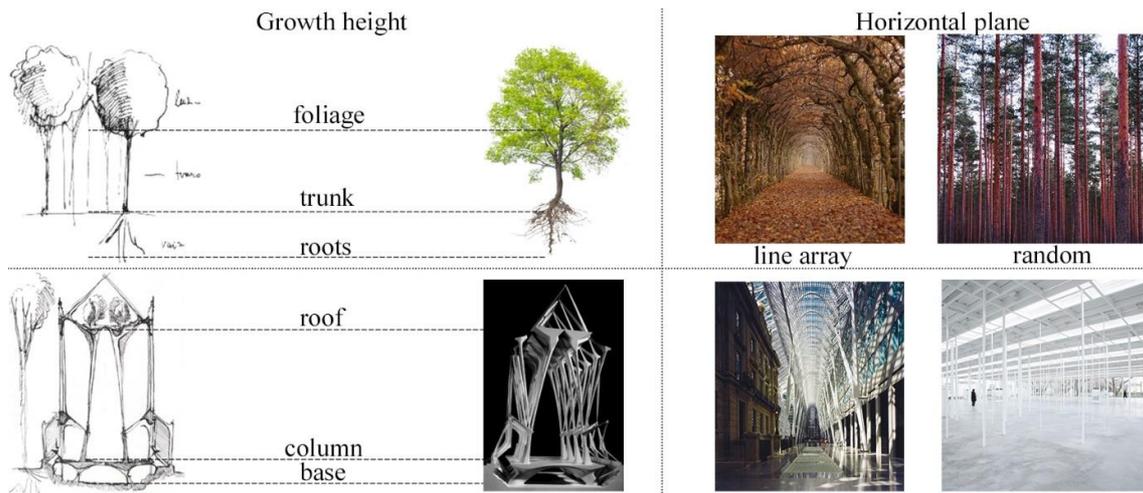


Figure 10. Individua and group, Above: Growth height and the horizontal plane, Below: structural member and array

- **Texture (structural material):** The selection of plant textures can relate to the texture of the building materials in order to develop certain harmonies or contrasts. Fine-textural materials like steel or plastic are more like the smooth branches, whereas the coarse-texture materials will tend to convey an impression of rough ground or trunk (see Fig. 11).



Figure 11. Materials, Above: texture, Below: structural material

- **Atmosphere (structure and light):** Individual aspects and combinations of the aforementioned effects can be used to express many different qualities for the atmospheric impact of planting. It is equal to structural design that form, detailing, and material can work together to enhance the experience and sense of nature offered by the structure. Specifically, the play of light and shadows on trees, structure as well, and the play of shadows on the ground can be very attractive (see Fig. 12).



Figure 12. Atmosphere, Above: light and shade, Below: structure and light

3.1.3 Principles of design natural experience

After collecting, classifying and analyzing the cases, following seven criteria have been concluded to conduct the design. Knowledge of generally applicable principles of design gives architects the tools to make the idea- creating the sense of natural experience by structural design- clear and recognizable, different from the traditional natural architecture which is confirmed to introducing real plants or imitating the form of nature.

- **Form:** Dendriform structure is the most instinct and common way to associate with tree and nature.
- **Material:** Selection of material in different circumstance considers in terms of color and texture. For example, wood color material is similar with the real trees, coarse-textural material cause imagination of earth or trunk and so on.
- **Light and shadow:** The play of light and shadow strengthens the natural phenomenon. Depending on the color tones of leaves, bark, soil, and the nature of the foliage and branch structure, a unique pattern of shade is created: short-though-with-light, light, dark, heavy, sharp, soft, colorful, full of contrasts, diffuse (Haike, F, 2011). Combination of various materials and this kind of light and shadow can give impression of nature.
- **Rhythm:** It is necessary to include the same and similar motif -structure selection repeatedly in order to give coherence and harmonious to a space like planting in garden or park. Too many elements will disturb the visual stability. This explains particularly clearly in the thematically differently designs of the public space in AMC.
- **Repetition:** Structural arrangement of creates a less explicit sense of nature. There are two main ways: one is orderly repetition; the other is random placement. The former one recalls of well-arranged tree-lined street, the latter one evokes a forest.
- **Array:** The intervals between the structural unit, and the number of units, should be varied, depending on the type and scale of the space.
- **Equilibrium:** Equilibrium is a common aim of design. It describes a state of balance and harmony between various design components (Haike, F, 2011). The form, material, color, scale of the structure should harmonize with the architecture or the available space.

3.2. Context- AMC building analysis

Each design emerges in its own specific context. Towards the graduation project, the main renovation part is the in-between space of AMC building. The original metal truss and plastic shelter will be replaced by the new structure. The purpose of design is to transform the industrial atmosphere into natural experience in public space. **Once inside, people should feel like promenading along a tree-lined avenue.**

- **Identity:** The concrete building blocks of columns, beams, plates and cans, together with the presence of technology, tubes and color, make AMC architectural manifest industrial (*see Fig. 13*).



Figure 13. Views of AMC buildings, Left: aerial view of AMC in 2010, Middle: entrance, Right: interior

- **Façade:** The strongly horizontal facade make AMC unique in that era. In the low-rise buildings, continuous concrete balconies occur on user layers, whereas concrete bands characterize the technical layers. The high-rise building consists of a concrete façade cladding that alternates with strips of glass. In the interior façade, both low-rise and high-rise buildings have a horizontal articulation in the façade, which can mainly be read from the concrete elements (*see Fig. 14*).



Figure 14. Facades, Left: high-rise exterior facade, Middle: low-rise exterior facade, Right: interior facade

- Spatial characteristics: The atrium is clamped in two interior facades, one 4-storey low-rise building (18 meters) and one 9-storey high-rise building (40.3 meters). The scale of atrium part is 190-meter long, 6.5-meter wide and 18-meter high. The atrium is conceived as a single sequence. The liner street combined with horizontal concrete crossbeam gives a strong directionality (see Fig. 15).

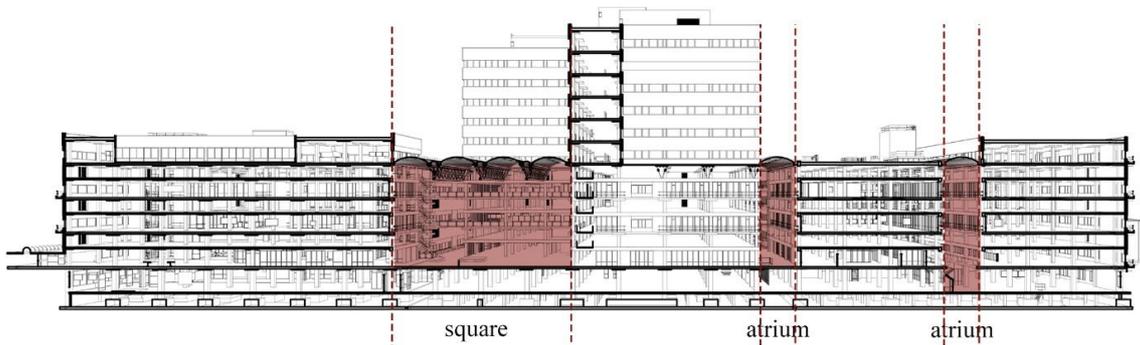


Figure 15. Spatial characteristics of renovated parts

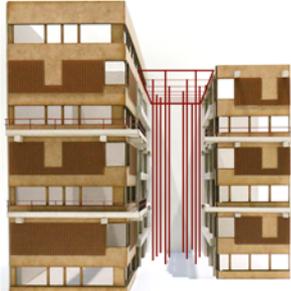
3.3. Application of cases in physical model (1:50)

This part is going to simulate realistic scene of atrium part in AMC building by making 1-50 physical model (see Fig. 16). The purpose of the physical model is to recreate the actual spaces in three-dimensional way, which can stimulate observers' sensory reaction to specific phenomena. In this research, the test process involves the selection of structural types, materials, and control of light environment. First, structures that are applicable to atrium of AMC will be redesigned, then applied in the fragment model of AMC. Second, for the same structure, various material will be tested. In addition, the model will be oriented to the artificial light which imitates sunlight to observe how the actual space might look under the real situation. The process is able to investigate under research conditions what, on subjective grounds, characteristics can evoke the sense of natural experience.



Figure 16. Fragment model of AMC atrium (1-50)

A similar investigation of alternative structural selection and their influence upon interior space can be, and should be tested on AMC building at the preliminary design stage. According to the previous analysis of AMC building, the evaluation form of six cases lists in table 1. The three proposed options of structure will be tested in the following part. (Appendix III)

CASE	APPLY IN AMC	ELEMENT	EVALUATION	SCORE
 <p>Tree-like Support Structure</p>		<input checked="" type="checkbox"/> Form <input checked="" type="checkbox"/> Material <input type="checkbox"/> Light and shadow <input checked="" type="checkbox"/> Rhythm <input type="checkbox"/> Repetition <input type="checkbox"/> Array <input type="checkbox"/> Harmony with AMC	<p>ADVANTAGES: This structure is most like the real tree.</p> <p>DISADVANTAGES: This structure is used for long-span space, it is not efficient for atrium. It is not harmony with the original AMC building.</p>	<p>5/10</p>
 <p>Dendritic structure OPTION 1</p>		<input checked="" type="checkbox"/> Form <input type="checkbox"/> Material <input checked="" type="checkbox"/> Light and shadow <input checked="" type="checkbox"/> Rhythm <input checked="" type="checkbox"/> Repetition <input checked="" type="checkbox"/> Array <input type="checkbox"/> Harmony with AMC	<p>ADVANTAGES: The form of the structure is between real tree and structure. The roof and columns work as a whole. It is good for natural lighting. The light material is harmony with the heavy concrete panels.</p> <p>DISADVANTAGES: The scale of the structure is unreasonable. The scale of atrium is extremely narrow, the partitions which separated by columns is not good for use.</p>	<p>7.5/10</p>
 <p>Tree-like structure</p>		<input checked="" type="checkbox"/> Form <input type="checkbox"/> Material <input checked="" type="checkbox"/> Light and shadow <input checked="" type="checkbox"/> Rhythm <input checked="" type="checkbox"/> Repetition <input checked="" type="checkbox"/> Array <input type="checkbox"/> Harmony with AMC	<p>ADVANTAGES: The form of the structure is inspired by tree structure. The roof and columns work as a whole, and offer an extra space on the roof. It is good for natural lighting. The structure system is fit for linear space.</p> <p>DISADVANTAGES: The stone material is not harmony with the heavy concrete panels. It is more efficient for long-span space.</p>	<p>7/10</p>
 <p>Random columns OPTION 3</p>		<input type="checkbox"/> Form <input type="checkbox"/> Material <input checked="" type="checkbox"/> Light and shadow <input checked="" type="checkbox"/> Rhythm <input type="checkbox"/> Repetition <input checked="" type="checkbox"/> Array <input type="checkbox"/> Harmony with AMC	<p>ADVANTAGES: The pillars with different shapes and size is more like trees in a real forest, and give enjoyment in the space. The columns create various spatial experience. The light material is harmony with the heavy concrete panels.</p> <p>DISADVANTAGES: The scale of the structure is unreasonable. It works more obvious for open space rather than linear space. These spaces separated by columns are too narrow to use.</p>	<p>7.5/10</p>
 <p>Arcade + tree-liked support OPTION 2</p>		<input type="checkbox"/> Form <input type="checkbox"/> Material <input checked="" type="checkbox"/> Light and shadow <input checked="" type="checkbox"/> Rhythm <input checked="" type="checkbox"/> Repetition <input checked="" type="checkbox"/> Array <input checked="" type="checkbox"/> Harmony with AMC	<p>ADVANTAGES: The condition of BCE is most similar to AMC. The new structure is a free-standing element between existing buildings, while reserve the original interior facade of AMC. The colonnade and sequent arcades emphasis the directionality and express classical aesthetics. It is good for natural lighting.</p> <p>DISADVANTAGES: The hierarchy of two space is not obvious due the narrow atrium.</p>	<p>9/10</p>
 <p>Double-twisted columns</p>		<input checked="" type="checkbox"/> Form <input checked="" type="checkbox"/> Material <input checked="" type="checkbox"/> Light and shadow <input checked="" type="checkbox"/> Rhythm <input checked="" type="checkbox"/> Repetition <input checked="" type="checkbox"/> Array <input type="checkbox"/> Harmony with AMC	<p>ADVANTAGES: Rather than literal imitation, the cathedral recalls natural experience by atmosphere and perception. The colonnade and sequent arcades emphasis the directionality and express classical aesthetics. The lighting inside is best.</p> <p>DISADVANTAGES: It is not harmony with the original AMC building. The system is hard to use in modern architecture.</p>	<p>6/10</p>

Selected
 Deselected

Table 1. Evaluation of six cases

3.3.1



Option 1: Dendritic structure

Case: Oriental station

Spatial characteristic: no column in atrium

- **Form of structure:** The branch structure is inspired by desiccated tree (*see Fig. 4*). The canopy appears light-weight and delicate by comparison to the heavy concrete interior façade of AMC. The steel ribbed canopy bears a strong resemblance to a grove of palm trees- an association reinforced by its detailing. Apart from its square fabricated-steel column-bases, other members of the roof canopy comprise I-sections. The main arch members not only curve, but also taper. The hunched and rounded rib-to-arch connections and the use of sharp-edged and thin sections recall similar properties of palm thongs and arouse the sense of natural experience (*see Fig. 17a*).

- **Material of structure:** The individual structure unit is literal white steel replicas of tree.

- **Atmosphere (light and shadow):** Beneath dendritic structure, the shadows on the ground and wall is similar with mottled shade of tree. The form of the shadow changes continually and tells the time of the day. At midday, sunlight is bright and hard, and shadows are short, while in the late afternoon the light is soft and yellow, and the shadows grow increasingly long, strengthening the impression of three-dimensionality in the atrium (*see Fig. 17b,c*).

- **Evaluation:** This structure is most instinct link to nature because its interpretation and use of the tree form. Due to the shape and arrangement of the structure, the in-between space resembles as a tree-lined street. People go through the passage and underneath tree-like structures that support the transparent canopy above, feeling like the transition from real nature into architectural nature (*see Fig. 40*).

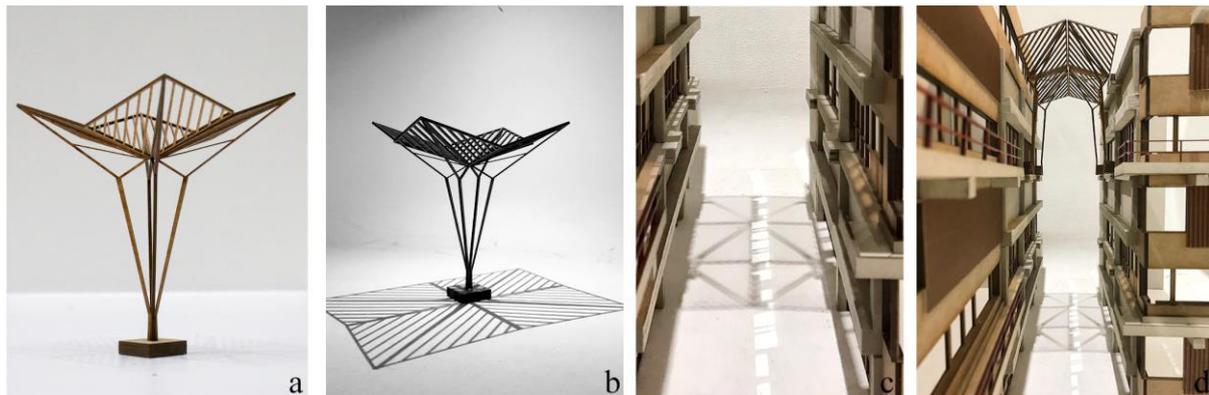


Figure 17. 1:50 model of option 1 (a: form and material, b: structure and light, c: shadow, d: view of atrium)

3.3.2



Option 2: Arcade

Case: BCE Place Gallery

Spatial characteristic: colonnade

- **Form of structure:** The steel pillars, inclined and independent of the lateral facades, branch out from the single level, to meet the arched ribbing above, defining a colonnade of parabolic vaults, a “corridor of light” covered by a band of radial elements connected by transverse beams. The continuous roof structure gives sequential direction to the arcade (*see Fig. 19a*).

- **Material of structure:** The whole structure is made of welded steel, these tight vaults resemble the timber structures that Calatrava had used for the barrel roof of Wohlen High School in Switzerland (1983—1988) (*see Fig. 18*).



Figure 18. Material comparison, Left three: Wohlen High School in Switzerland(wood), Right: BCE Gallery (steel)

- **Atmosphere (light and shadow):** This sequent arches devotes to the elements of light and space. The arched and ribbed shade-structure encloses the whole atrium, and people experience its light-filtering qualities. The striped shadow recalls the scene when light is going through the dense branches and twigs (see Fig. 19b,c).

- **Evaluation:** The intervention covers the in-between space of AMC buildings with a soaring roof and creates a block-long arcade, connecting various buildings and surrounding environment. The new structure has been conceived as a free-standing element between existing buildings, while reserve the original interior façade of AMC (see Fig. 47).

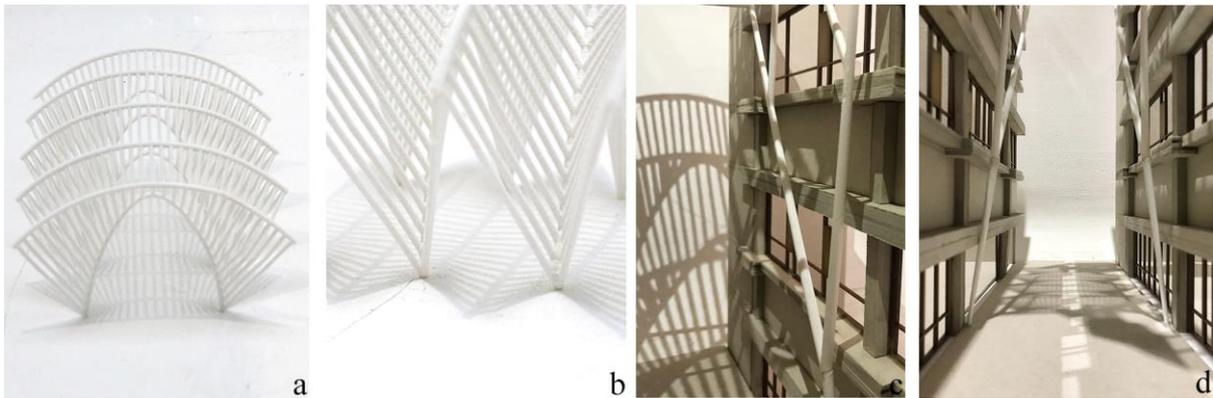


Figure 19. 1:50 model of option 2 (a: form and material, b: structure and light, c: shadow, d: view of atrium)

3.3.3



Option 3: Random columns

Case: KAIT Workshop

Spatial characteristic: free plan

- **Form of structure:** This structural system relies entirely on an ensemble of slight columns of varying proportions. All pillars are dotted throughout, with differences in size and shape they reference the irregular nature of tree trunks, evoking the sense of wandering through an unknown white forest. Subtle differences in the shape of the columns are defined by their structural purpose and the role of the spaces they create (see Fig. 20a).

- **Material of structure:** The individual column is made of white steel in order to achieve the abstraction and dematerialization.

- **Atmosphere (light and shadow):** The light filled interior of the atrium though the flat roof. The shadow of the group of columns changing over time seems as the shadow of tree trunks. The movement of shadow enriches the natural vitality in atrium (see Fig. 20b,c).

- **Evaluation:** Such regular column on its own is hard to be recognized as a tree, it is the random arrangement of numerous columns that recalls of a forest. The columns are arranged within the architecture as trees placed on a landscape. It makes a comfortable space like forest. Simultaneously, the random columns enable maximum flexibility for interior, which offers a range of activities within

the one room. The structure system both blurs the boundary, and links the exterior and interior space of AMC buildings (*see Fig. 54*).

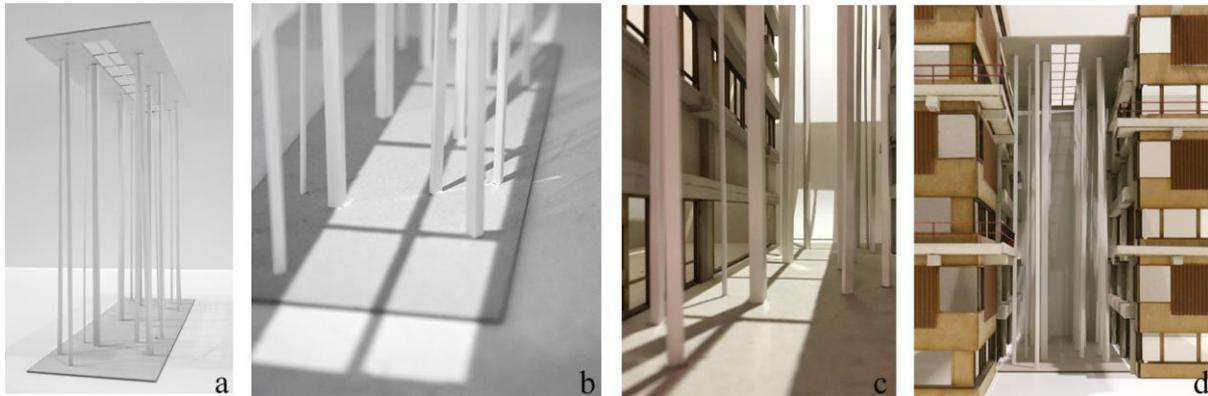


Figure 20. 1:50 model of option 3 (a: form and material, b: structure and light, c: shadow, d: view of atrium)

3.3.4. Comparison of three options

People perceive the natural experience when they read the structure as trees or a forest. The previous three structures create the sense of natural experience through very different aspects. Horizontal comparison can draw a better guideline for renovation of AMC (*see Fig. 55*).

In terms of the structural forms, option 1 is the most explicit interpretation of tree form, while option 2 and 3 prefer a more abstract way to depict the nature. As for the materials, in order to be contrast to the original rough concrete panels, slight materials like wood or white steel are appropriate. In addition, light and shadow play a considerable role in the atrium. Option 1 and 2 give the filter light which emphasis the rhythm of lighting, while option 3 imitates the shade of grove that is not so obvious in liner space. From the perspective of space, the whole internal volume is essentially perceived as one space in option1, 2 provides two separate and differentiated spatial zones, 3 makes a space with very ambiguous borderlines, which has a fluctuation between local spaces and the overall space (*see Fig. 21*).

Form	Material	Light and shadow	Rhythm	Repetition	Array	Equilibrium
Form of structure		Material of structure		Atmosphere (light and shadow)		
> >		= >		= >		

Figure 21. Comparison of three options (own image, 2018)

IV. CONCLUSIONS

To give answers to the main research question “*How to transform the sense of nature experience into architectural space by structural design?*”, a series of design principles have been concluded through the research, which can be used as a toolbox, a critical evaluation or design methodology of architectural structure. Ultimately, the guidelines and principles are specifically used in AMC building to solve the overall design question “*How can we redesign in-between space (atrium/ square) of AMC to create the sense of nature experience?*”. In other words, this research explores how exposed structure creates the sense of natural experience in the atrium of AMC building, by virtue of their forms, materials and other details. The three examples examined in the atrium of AMC by physical modeling can be the inspiration or preliminary design for design phase. Therefore, based on the three-dimensional simulation, the following design principles aimed at AMC are obtained (see Fig. 22):

1. **Column-free structure** is appropriate to the narrow-shape of the atrium.
2. **Slight and light-weight structural members** is analogy of slender branches and twigs.
3. There is no pure straight lines in nature found by Gaudi. Hence, **curved members** recall similar properties in nature.
4. **The continuous and repetitive structure** emphasizes the linear direction of atrium halls, similar to the tree-lined avenue and tree block. Whereas the random columns is more suit for big square space. Rhythmic beauty shows particularly clearly in the designs of the linear space.
5. Compared to the original heavy concrete components, the new material should show strong contacts to existing building like **light-weight materials**. In addition, the atrium in AMC is the source of nature light, thus solid, heavy materials is inappropriate for AMC building.
6. Light and shadow: Numerous **closely spaced and often layered structural members** filter light. Where structural layout and density evoke the trees of a forest, daylighting is experienced as if filtered through a canopy of tree branches.

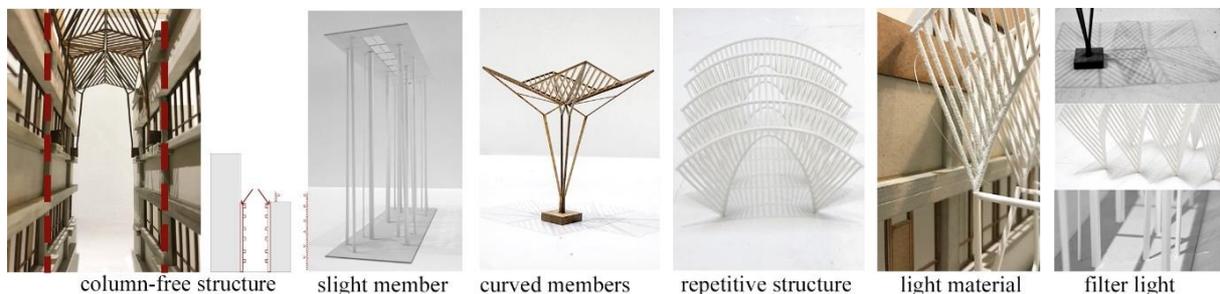


Figure 22. Design principles for AMC (own image, 2018)

In conclusion, nature is a crucial element in healing environment, but imitating or being inspired by natural-looking forms, textures and colors alone is not the essence of natural experience. This research intends to explore the sensory perception of natural experience and draws up a guideline for the design of natural atmosphere in more comprehensive aspects. The shift from industrial identity to naturalistic atmosphere of AMC building can be accomplished by intervention of new structure. Furthermore, this three-dimensional nature surrogate can be universally obtained in healing environment.

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The definition of *Evidence-based design*: In recent years, a large number of studies have shown that aesthetics and the physical surroundings, such as daylight, good acoustics and the presence of nature, can have a significant effect on the healing process. This knowledge helps health sector planners and architects to find answers to practical questions of hospital organization. It is called evidence-based design.

Evidence-based design has been used in the project to create healing environments that promote physical and mental well-being and healing processes, support the participation of relatives, help staff to be more efficient, and reduce stresses and loads. The design decisions have been based on the best available knowledge from research and project evaluations, and have been assessed in relation to the unique conditions of DNU.

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REFERENCES

ILLUSTRATIONS

Figure 1. *History of healing with nature* (Stephen. V, 2010, p.102) (redraw, own image, 2018)

Figure 2. *Structure inspired by nature elements* (Source from left to right as a to e:

a. <https://en.wikipedia.org/wiki/Fallingwater>

b. https://www.allposters.com/-sp/Spain-Barcelona-Sagrada-Familia-Interior-Posters_i9814753_.htm

c. https://commons.wikimedia.org/wiki/File:Dune_SantiagoCalatrava.jpg

d. <https://iwan.com/portfolio/national-taiwan-university-library-taipei-toyo-ito/>

e. <https://www.flickr.com/photos/desingel/8443392101/>)

Figure 3. *Diagram of research and design process* (own image, 2018)

Figure 4. *Concept of orient station* (drawn by Santiago Calatrava, p.275)

Figure 5. *KAIT vs. Forest* (Source from left to right as a to b:

a. <https://www.flickr.com/photos/desingel/8443392101>

b. <https://www.worldwildlife.org/habitats/forest-habitat>)

Figure 6. *Dream of cave by O+H* (Source: <http://www.onishihyakuda.com/cave-in-a-dream/>)

Figure 7. *The Therme Vals by Peter Zumthor* (Source: <https://www.archdaily.com/13358/the-therme-vals>)

Figure 8. *Shadow of ribbed structure vs. Shade of grove* (Source from left to right as a to b:

a. <https://www.archinform.net/projekte/2809.htm>

b. <http://weknowyourdreams.com/grove.html>)

Figure 9. *Form, Above: Form, structure, habit of nature, Below: structural form* (own image, 2018, photos from Internet)

Figure 10. *Individual and group, Above: Growth height and the horizontal plane, Below: structural member and array* (own image, 2018, photos from Internet)

Figure 11. *Materials, Above: texture, Below: structural material* (own image, 2018, photos from Internet)

Figure 12. *Atmosphere, Above: light and shade, Below: structure and light* (own image, 2018, photos from Internet)

Figure 13. *Views of AMC buildings* (Left: Anatomy of the AMC , Middle& Right: own photos)

Figure 14. *Facades* (2016.1065.00R004v002 management rapport Hoogbouw)

Figure 15. *Spatial characteristics of renovated parts* (own image, 2018)

Figure 16. *Fragment model of AMC atrium (1-50)* (own photos)

Figure 17-19. *1:50 model* (own photos, 2018)

Figure 20. *Material comparison* (Source from left to right as a to d:

a b c: <http://www.galinsky.com/buildings/wohlen/index.htm>

d: <https://www.pinterest.com/pin/511721576395660376/?lp=true>)

Figure 21. *Comparison of three options* (own image, 2018)

Figure 22. *Design principles for AMC* (own photos)

Table 1. *Evaluation of six cases* (own image, 2018)

ILLUSTRATIONS (APPENDIX)

Appendix I

Figure 23. *Timeline of healing with nature* (Stephen, V. 2010, p.102) (redraw, own image, 2018)

Appendix II Project Database

Figure 24-27. *Category* (own images, 2018)

Figure 28. *Case study: Stuttgart Airport, Kanagawa, Germany* (Architecture group Gerkan, Mag and Partners, 2011)

Figure 29. *Case visit: Orient Station, Lisbon, Portugal* (Santiago Calatrava, 1993-1998)

Figure 30. *Case study: St. John the Divine, New York, United States* (Santiago Calatrava, 1991)

Figure 31. *Case study: The KAIT Workshop, Tokyo, Japan* (Junya Ishigami and Associates, 2011)

Figure 32. *Case study: BCE Gallery, Toronto, Canada* (Santiago Calatrava, 1987-1992)

Figure 33. *Case visit: Sagrada Familia, Barcelona, Spain* (Antoni Gaudi, 1882-)

Appendix III Simulation- physical model

Figure 34-55. own photos and images, 2018

Appendix

Creating the sense of natural experience by structural design

The aim of this research is to answer the question “How to transform the sense of nature experience into architectural space by structural design?” In addition, there is a need for a theoretical and systematic framework in obtaining guidelines and general principles for creating natural atmosphere through structure design.

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Master of Architecture, Urbanism and Building Sciences:

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Date:

January 4th, 2019

Appendix I

PEAK PERIOD:
BC 1000 - AD 100

ASCLEPIUS
earliest known
formal 'hospital'



healing centers:
courtyards, forests,
temple, stoa

AD 1400

NATURE AS HOSPITAL

Palace Hospitals
Birth of scientific-based
treatment



courtyards

NATURE AS THERAPEUTIC MODALITY

Nature continues to play key role in Far Eastern healthcare environments

AD 1500

1846-1849
Hartford Retreat
Mix-use hospital with
patients' yard, vegetable garden



indigenous landscaping

Nature de-emphasized in healthcare institutions in the West

1800

1860-1864
Saratoga Springs, New York
Shaded outdoor plazas were integral therapeutic adjuncts to the specialized treatment regimen.



green garden

1900

WWI
1914-1918

HOSPITAL WITH NATURE

1861-1865
U.S. Civil War
tent hospitals



openable windows
natural daylight

NIGHTINGALE WARD:
views/courtyards/terraces

WWII
1939-1945

1918-1920
King's Daughters Home
Outdoor heliotherapy veranda.



Late 1930s
St. Thomas' Hospital, London
Patients convalescing on the outdoor terrace.

HEALING WITH NATURE

DEVELOPMENT OF TECHNOLOGY

1960

Megahospital
Interstate system begun.
Patient towers
De-institutionalization



atrium hospitals

1970

1980



indigenous landscaping

therapeutic gardens

1990

Home as clinic/
Clinic as home



simulated views of nature

2000

Interior nature
Images of nature

NATURAL HOSPITAL

5. FUTURE?

Figure 23. Timeline of healing with nature (Stephen, V. 2010, p.102)

Project database

Case studies + case visits

Case studies/ case visit

Case study / case visit is the fundamental part of a research. This part requires collecting relevant data from precedent projects in order to arrive at a comprehensive understanding of the characteristics that people perceive and concise in natural experience. Then, this precedents will be analyzed, selected and classified including completed projects, exhibition devices, giant structures, and architectural facilities, which utilize different structure selection to create natural experience. The accomplished projects database helps to develop the general guidelines or principles for building natural experience.



visual aspect

Visual aspect of structure indicates its form, appearance and scale. This structural representation is understood as structure typifying a physical object, like a tree.



haptic aspect

Haptic aspect of structure is focus on the multi-sensory perception, acoustic, haptic, tactile and olfactory senses. This multi-sensory design concerns all the sense and how they can be influenced.



sensory aspect

Sensory aspect of structure refers to people's sensory perception of the space or atmosphere caused by structure. The research primarily discusses about light and shadow.

literal

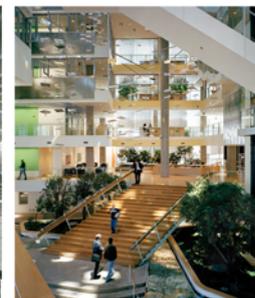
total mimicry	partial mimicry	non-biological analogy	abstraction	inspiration
 Tree House, Kagawa Hironaka Ogawa & Associates, 2015	 Sagrada Familia, Barcelona Antoni Gaudi, 1882	 BCE Gallery, Toronto Santiago Calatrava, 1992	 BCE Gallery, Toronto Santiago Calatrava, 1992	 KAIT Workshop, Kanagawa Junya Ishigami+Associates, 2008
 2000 World Expo, Hanover MVRDV, 2000	 Stuttgart Airport Terminal, Stuttgart VonGerkan, Marg+Partner, 1991	 Oriente Station, Lisbon Santiago Calatrava, 1996	 Oaka stadium corridor, Athens Santiago Calatrava, 1982	 Crematorium Baumschulenweg, Berlin Shutes Frank Architekten, 1982
 Sticks and Stones, Berlin David Chipperfield, 2015	 National Gallery, Singapore StudioMilou, 2015	 Nine Bridges Country Club, Korea Shigeru Ban Architects, 2009	 Palazzo del Lavoro, Turin Pier Luigi Nervi, 1961	 Genzyme Center, Cambridge Behnisch Architekten, 2004
 Tote Restaurant, Mumbai Serie Architects, 2013	 Vietnam Pavilion, Milan VTN Architects, 2015	 Johnson Wax offices, Racine Frank Lloyd Wriah, 1938	 Cave in a dream, Tokyo onishimaki + hyakudayuki, 2009	 Carreau du Temple, Paris StudioMilou, 2014
 RADBOUDUMC, Nijmegen EGM Architects, 2014	 Pancho Aréna, Felcsút Imre Makovecz, Tamás Dobrosi, 2014	 College of Social Sciences, Taiwan Toyo Ito, 2014	 Metropol Parasol, Seville Jürgen Mayer, 2005	 Fondation Cartier, Paris Jean Nouvel, 1994

Figure 24. Category from literal aspect to abstract aspect



form



structure member and array



material



structure and light



Figure 25. Category by nature characteristics

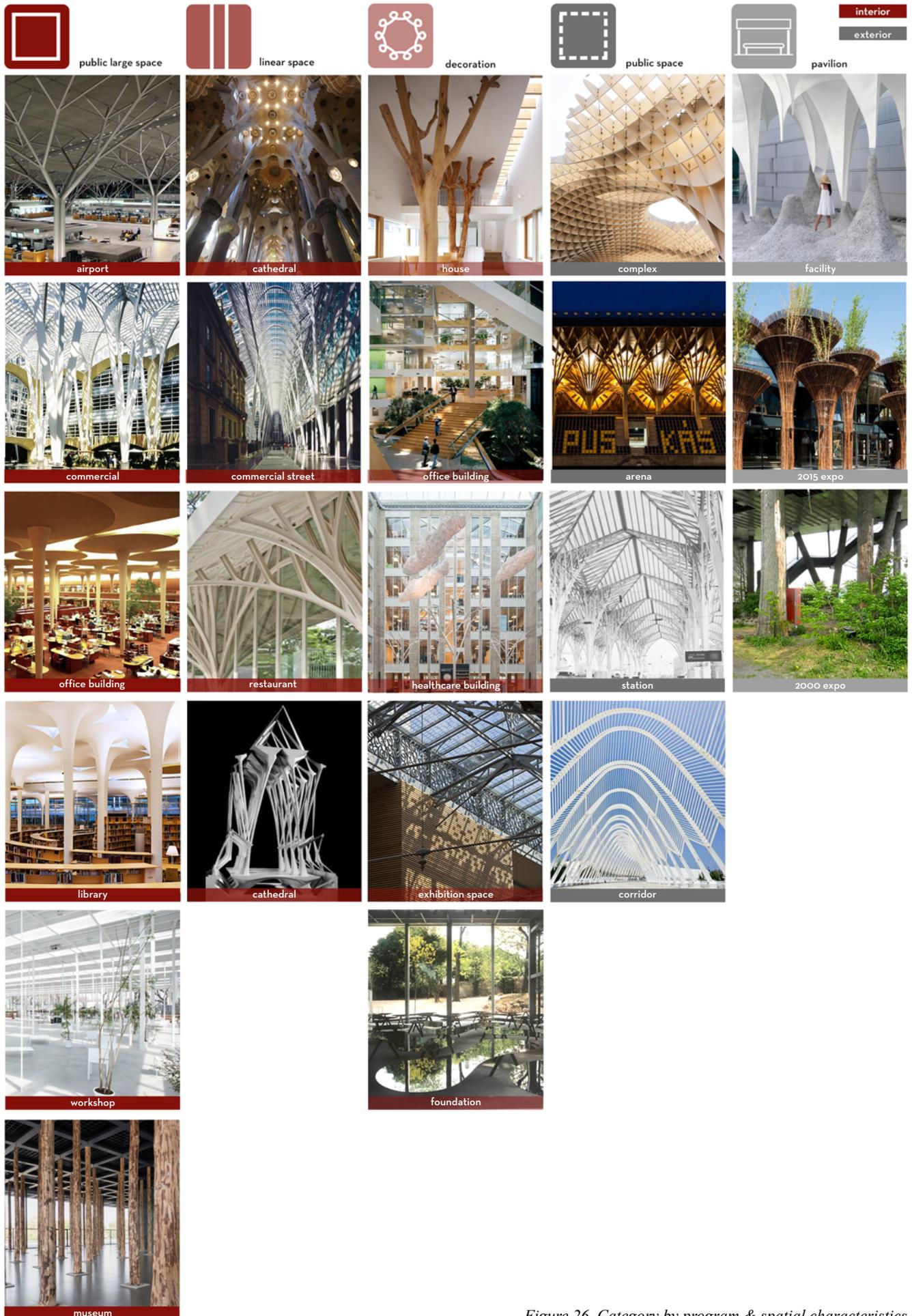


Figure 26. Category by program & spatial characteristics



Stuttgart Airport Terminal
Von Gerkan, Marg+Partner, 1991



CASE STUDY 1: Tree-like Support Structure

Architect: Architecture group Gerkan, Mag and Partners
Location: Kanagawa, Germany
Year: 2011
Program: transportation building
Material: Steel + Glass

case study

DESIGN PRINCIPLES:

1. The use of bio-mimicry in the light weight structural members creates a powerful blend with the built and natural environment giving the entire building an open and inspiring vibe.
2. Effective force system. These "columns" gather all the loads passing down through the branches which are translated into the trunk and then down to the foundation.



Oriente Station, Lisbon
Santiago Calatrava, 1996



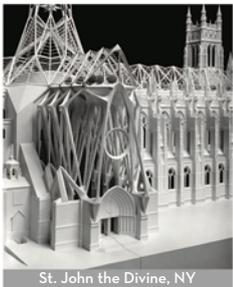
CASE STUDY 2: Dendritic structure

Architect: Santiago Calatrava
Location: Lisbon, Portugal
Year: 1993 - 1998
Program: Urban and transportation
Material: Steel + Glass + Concrete

case visit

DESIGN PRINCIPLES:

1. The station represents the tree in abstracted form, which functions as a structural support for the glazed roof over the train platform.
2. The steel ribbed canopy bears a strong resemblance to a grove of palm trees- an association reinforced by its detailing.
3. The hunched and rounded rib-to-arch connections and the use of sharp-edged and thin sections recall similar properties of palm thongs.
4. With this gesture he creates a direct link with the city, transforming the canopy of trees into a canopy of structure. With these elements Calatrava creates a unified urban composition transporting the public park into the train station itself.



St. John the Divine, NY
Santiago Calatrava, 2005



CASE STUDY 3: Tree-like structure

Architect: Santiago Calatrava
Location: New York, United States
Year: 1991
Program: Cathedral
Material: Stone

case study

DESIGN PRINCIPLES:

1. The plan involved a 'biosphere' garden being planted atop the nave in the giant greenhouse formed by lithely arches.
2. An interpretation of the tripartite section as foliage (roof), trunk (nave), and roots (crypt) is reflected.
3. The new bio-shelter is successfully integrated into the original cathedral's Gothic setting and follows its cross-plan.
4. The use of stone as the structural material and the ways in which light filters through the trees above the nave and transept is considered in this project.



KAIT Workshop, Kanagawa
Junya Ishigami+Associates, 2008



CASE STUDY 4: Random columns

Architect: Junya Ishigami and Associates
Location: Kanagawa, Tokyo, Japan
Year: 2011
Sectors: Education/ Workshop
Material: Steel + Glass

case study

DESIGN PRINCIPLES:

1. Total of 305 pillars are dotted throughout, with differences in size and shape they reference the irregular nature of tree trunks, evoking the sense of wandering through an unknown forest.
2. Reflecting surrounding cherry blossom trees on its glazed facade, they are all glass.
3. The resulting free-forming room both blurs its edges between the numerous internal programs, and also the connection between the inside and outside world.



BCE Gallery, Toronto
Santiago Calatrava, 1992



CASE STUDY 5: Arcade + tree-formed support

Architect: Santiago Calatrava
Location: Toronto, Canada
Year: 1987 - 1992
Program: Commercial/Mixed Use, Retail
Historical Restorations- Preservation of historic buildings
Material: Steel

case study

DESIGN PRINCIPLES:

1. Along the linear corridor, inwardly inclined dendritic supports branch out in a single plane to create a colonnade, which supports the lofty parabolic vaults that rhythmically span the space.
2. The continuous roof structure gives sequential direction to the arcade.
3. The arched and ribbed shade-structure encloses the whole atrium, and people experience its light-filtering qualities. A "corridor of light" covered by a band of radial elements connected by transverse beams.
4. The new structure system has been conceived as a free-standing element between existing buildings.



Sagrada Familia, Barcelona
Antoni Gaudi, 1882



CASE STUDY 6: Double-twisted columns

Architect: Antoni Gaudi
Location: Barcelona, Spain
Year: 1882
Program: Cathedral
Material: Bricks & mud + Venetian glass tiles

case visit

DESIGN PRINCIPLES:

1. It did not copy nature but analyzed the function of its elements to formulate structural and formal designs which he then applied to architecture.
2. It arrived at the revolutionary idea of leaning columns branching out like trees and of using the idea of a forest. Each tree splits into branches and supports part of the vaulting; when one tree falls, the whole forest does not collapse.
3. To achieve greater stability and a slender and more harmonious effect, Gaudi designed all the branching columns as double-twisted columns formed by two helicoidal columns.
4. The space of magical lighting witnesses the changing of time.

Figure 27. Six different representative cases

CASE STUDY 1

STUTTGART AIRPORT

Architect: Architecture group Gerkan, Mag and Partners

Location: Kanagawa, Germany

Year: 2011

Sectors: Workshop

Material: Steel + Glass

In an equally literal example of representation, steel tree-columns transform the interior of Stuttgart Airport Terminal. Structural twigs penetrate the wall glazing at first floor level to support at the interior grove of trees within. Again stick-like and leafless, the branches indicate either an endless winter or death, but their complexity and intricacy more than compensate for their starkness, and they arouse interest and admiration.

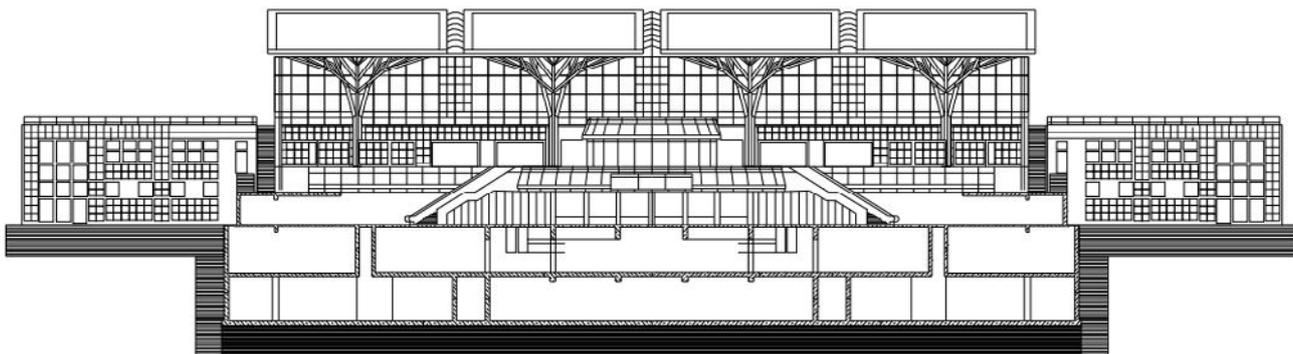
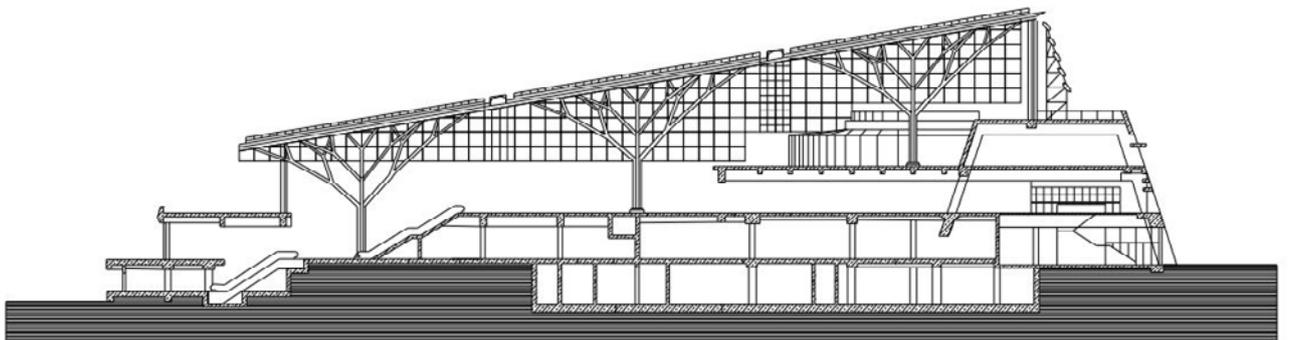
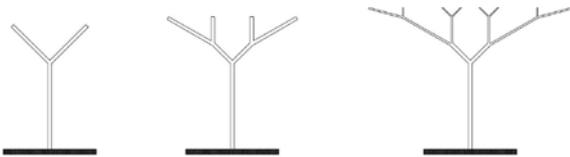
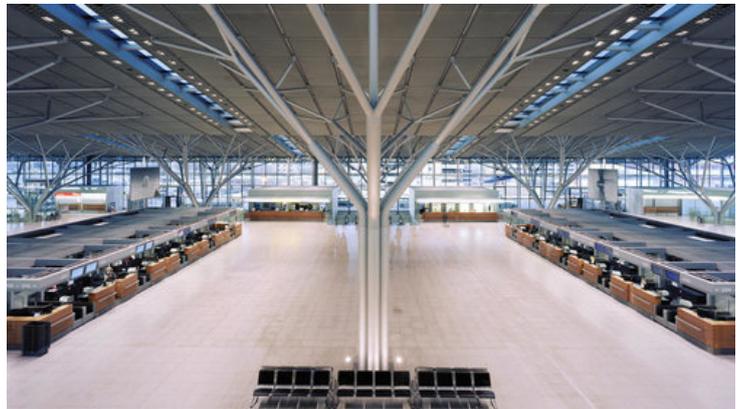


Figure 28. Case study: Stuttgart Airport, Kanagawa, Germany (Architecture group Gerkan, Mag and Partners, 2011)

CASE VISIT 2

ORIENT STATION

Architect: Santiago Calatrava

Location: Lisbon, Portugal

Year: 1993-1998

Program: Urban and transportation

Material: Steel + Glass + Concrete

In his project for Orient Station in Lisbon, Calatrava allows the park across the street to enter the site of the station. Inside, he represents the tree in abstracted form, which functions as a structural support for the glazed roof over the train platform. With this gesture he creates a direct link with the city, transforming the canopy of trees into a canopy of structure.

The train run through the buildings and underneath tree-like structures that support the glass canopy above. With these elements Calatrava creates a unified urban composition transporting the public park into the train station itself.

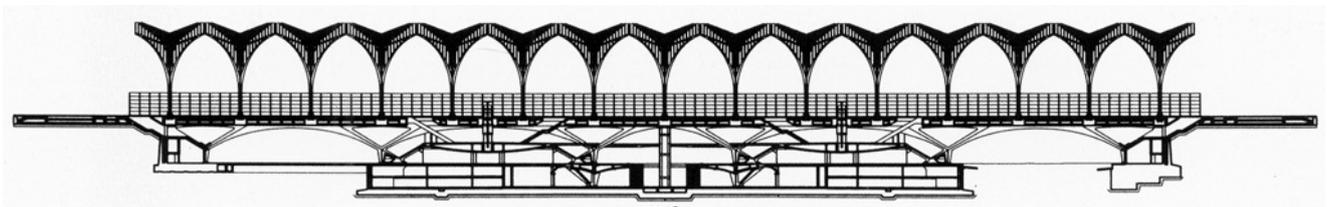
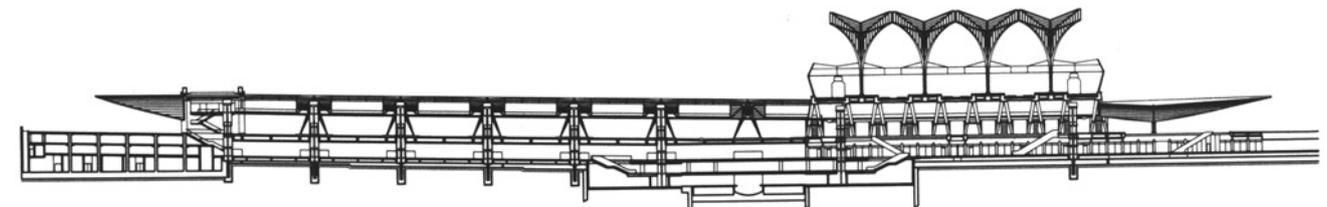
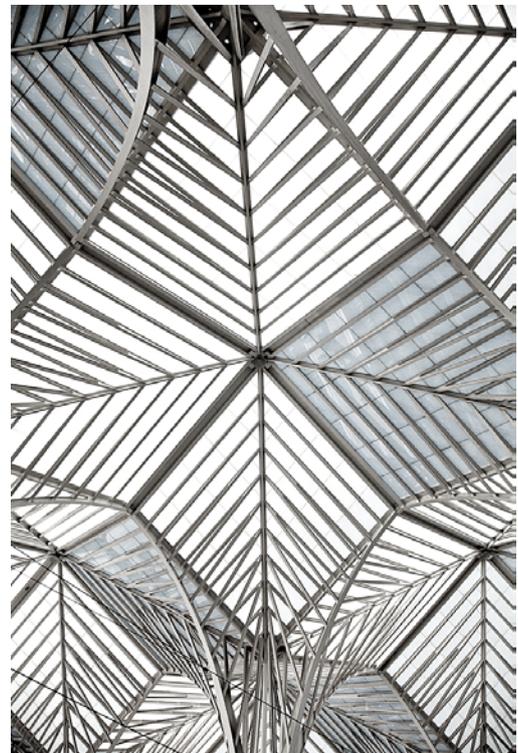
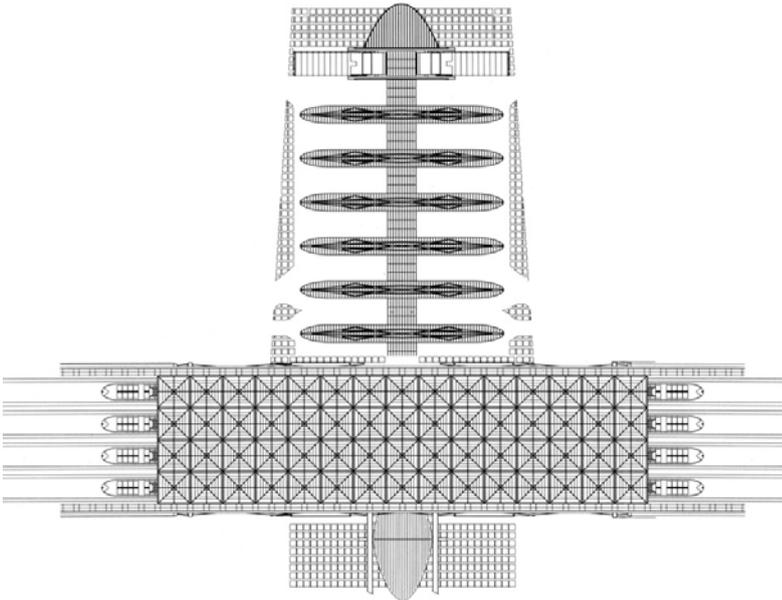
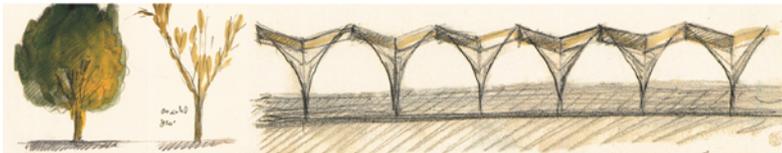


Figure 29. Case visit: Orient Station, Lisbon, Portugal (Santiago Calatrava, 1993-1998)

CASE STUDY 3

ST. JOHN THE DIVINE

Architect: Santiago Calatrava
Location: New York, United States
Year: 1991
Program: Cathedral
Material: Stone

Using the image of a tree as the basic element of composition, Calatrava's bioshelter is successfully integrated into the cathedral's Gothic setting and follows its cross-plan. The bioshelter's placement directly under the roof and in the attic of the present nave dictates that the cathedral will have a new, glazed roof. Important design issues that Calatrava considered include the use of stone as the structural material and the ways in which light filters through the trees above the nave and transept. Just as the cathedral perceives itself to be a microcosm of the city, so Calatrava's addition extends the cathedral's architecture as well as its spiritual and ecological ideals. The plan involved a 'biosphere' garden being planted atop the nave in the giant greenhouse formed by Calatrava's lithely arches.



Longitudinal section along the central axis

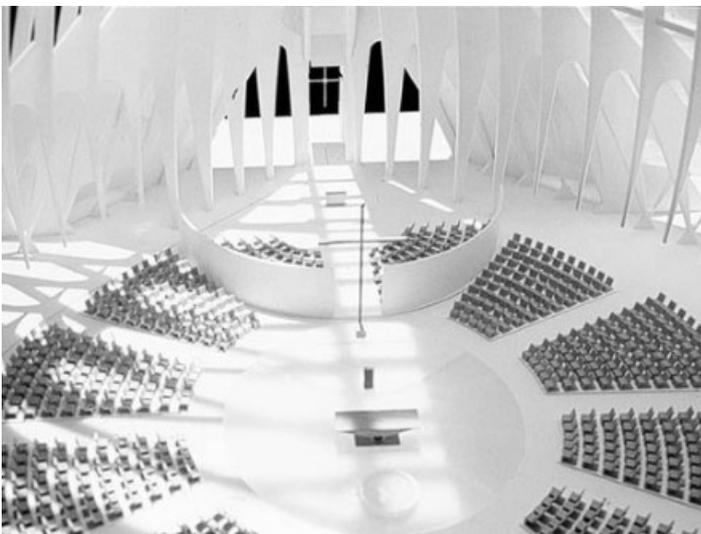
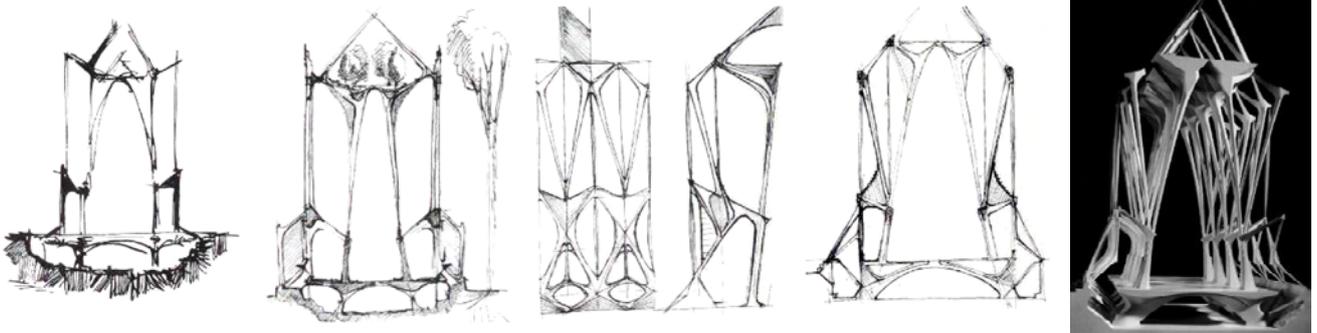


Figure 30. Case study: St. John the Divine, New York, United States (Santiago Calatrava, 1991)

CASE STUDY 4

WHITE FOREST THE KAIT WORKSHOP

Architect: Junya Ishigami and Associates

Location: Kanagawa, Tokyo, Japan

Year: 2011

Sectors: Workshop

Material: Steel + Glass

A white forest in a grey field, Junya Ishigami's university project space in the foothills west of Tokyo is a building designed to almost disappear. The structure presents another round in the architect's ongoing contest with gravity. The forest comprises 305 slender steel 5-m-high columns.

Ishigami explains the evolution of the design as a painstaking investigation of the relationships between the columns. "I wanted to make a space with very ambiguous borderlines, which has a fluctuation between local spaces and the overall space, rather than a universal space like that of Mies" says Ishigami. "This allows a new flexibility to emerge, revealing reality rather than shaping it."

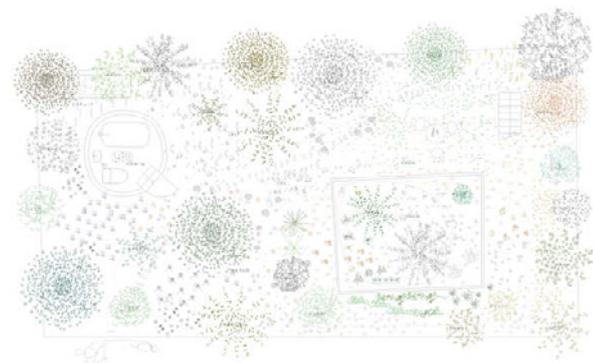
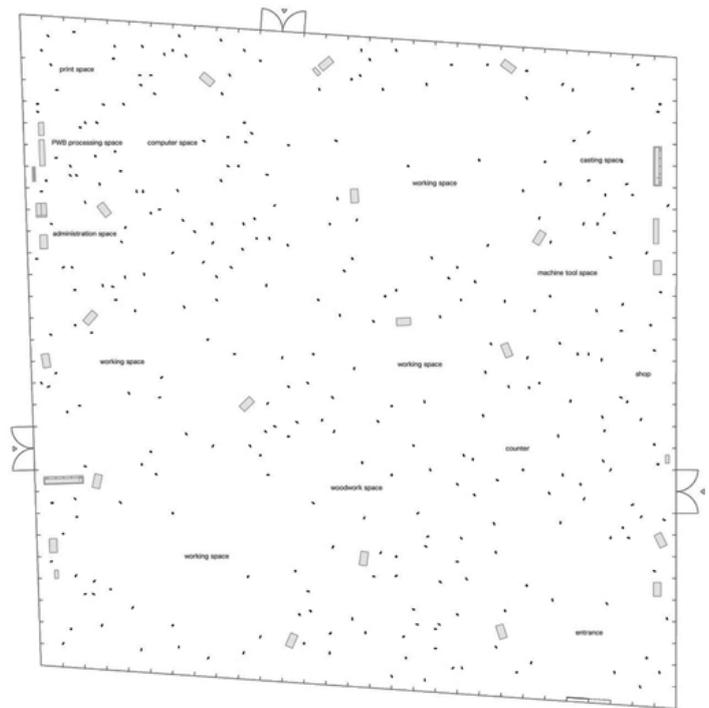
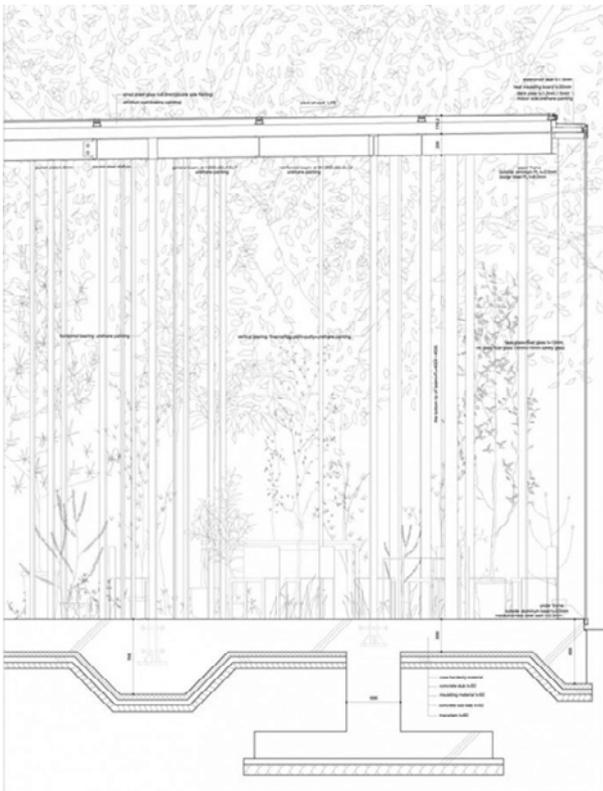


Figure 31. Case study: The KAIT Workshop, Tokyo, Japan (Junya Ishigami and Associates, 2011)

CASE STUDY 5

BCE PLACE GALLERIA & HERITAGE SQUARE

Architect: Santiago Calatrava

Location: Toronto, Canada

Year: 1987 - 1992

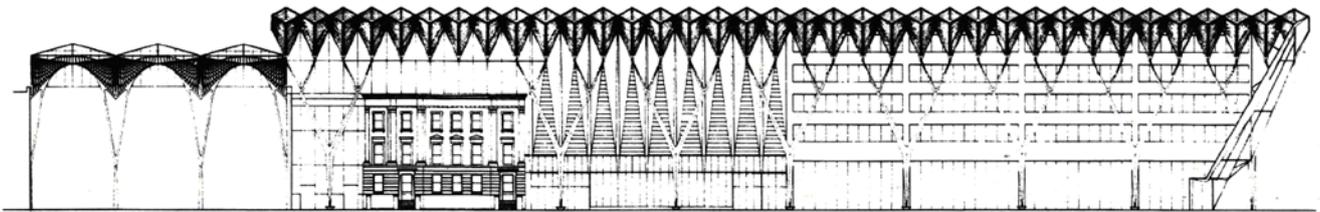
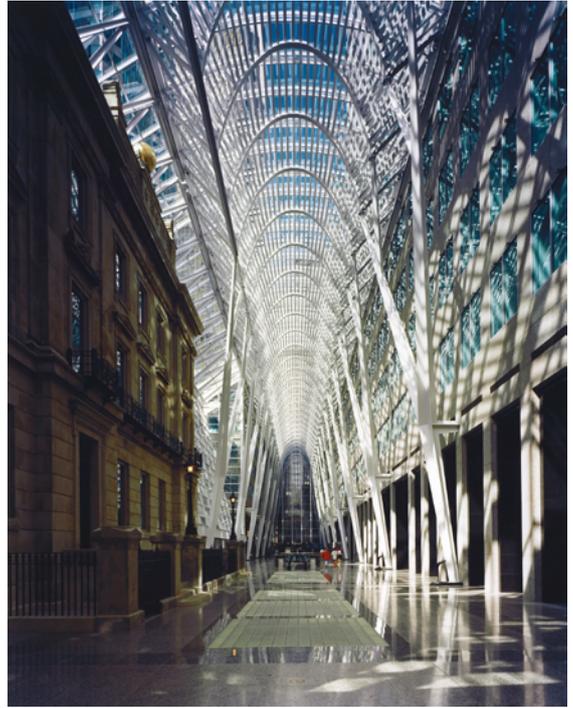
Sectors: Commercial/Mixed Use, Retail

Historical Restorations- Preservation of historic buildings

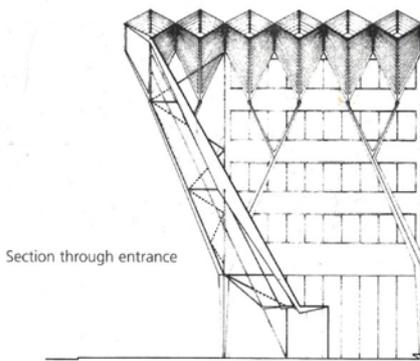
Material: Steel

Over a 30-by-3-meter regular plan, treelike structures rise and support nine intersecting barrel vaults, creating a “forest” effect. The glazed, translucent roof envelops the square below with wide, upturned parabolas. Below, in the center, is a circular fountain of steel tubes, opening like a flower.

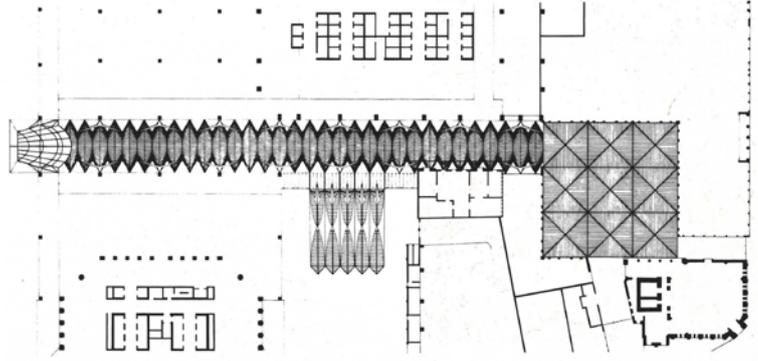
As a building type, the BCE fuses the neo-Victorian arcade with the more modern, urbanistic idea of inserting a garden between the buildings in a central business district. Behind the neo-Victorian precedents are even older models, namely that of the Gothic cathedral’s nave and aisle. Rather than resorting to the imitation of these precedents, however, Calatrava reinterprets them as “forest” of structural “trees”.



Long section through the five-storey-high gallery



Section through entrance



Roof plan

Bay Street elevation

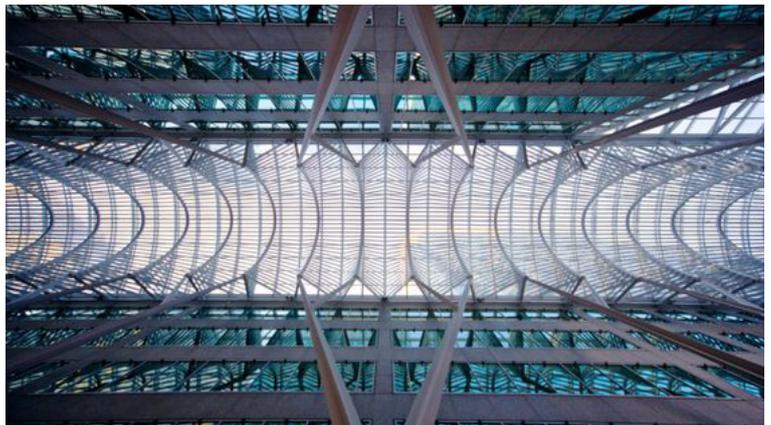
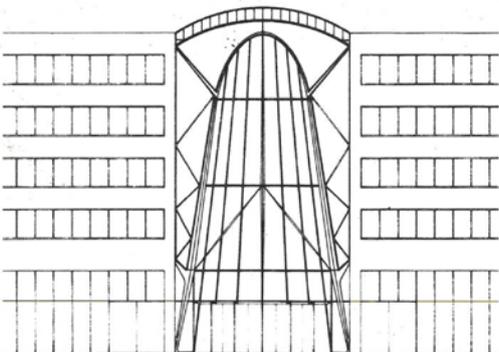


Figure 32. Case study: BCE Gallery, Toronto, Canada (Santiago Calatrava, 1987-1992)

CASE VISIT 6

SAGRADA FAMILIA

Architect: Antoni Gaudi

Location: Barcelona, Spain

Year: 1882-

Sectors: Commercial/Mixed Use, Retail

Material: Bricks & mud + Venetian glass tiles

The central nave soars to a height of 45 meters, and is designed to resemble a forest of multi-hued piers in Montjuïc and granite. The piers change in cross section from base to terminus, increasing in number of vertices from polygonal to circular. The slender, bifurcating columns draw the eye upward, where light filters through circular apertures in the vaults. These are finished in Venetian glass tiles of green and gold, articulating the lines of the hyperboloids. His structural forms mimicked those found in nature thereby providing him with both aesthetic and functional benefits. Columns mirroring trees or human bones, roof structures mirroring leaves, arches mirroring rib cages; all these allowed him to reduce the materials needed to build strong structures because of the supreme functionality gained from reproducing nature's designs.

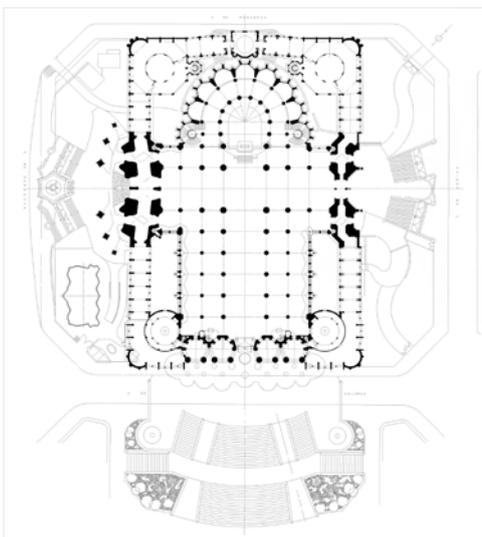
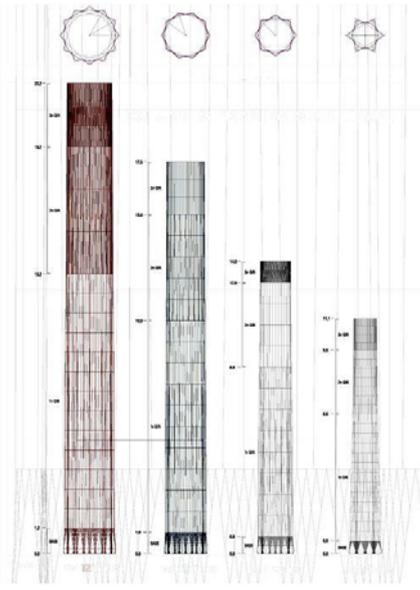
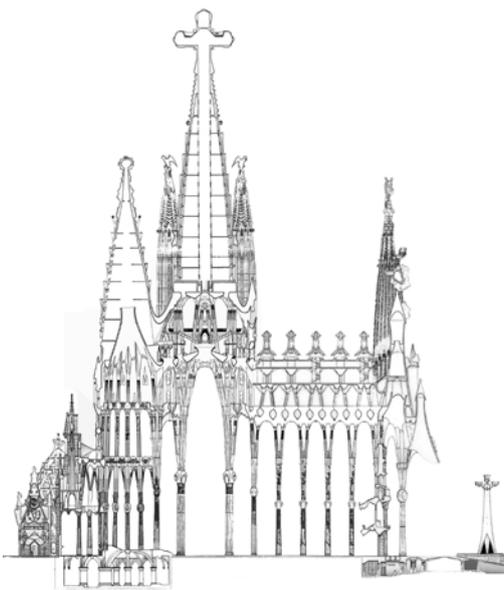
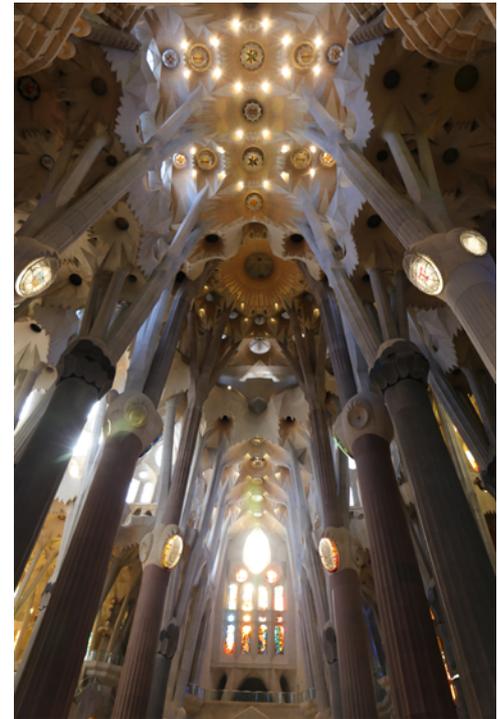


Figure 33. Case visit: Sagrada Familia, Barcelona, Spain (Antoni Gaudi, 1882-)

Simulation

Three-dimensional Physical Model

Physical Modelling 1:50

This part is to verify the previous guidelines or principles in specific context (AMC-Academic Medical Center in the research). The sense of natural experience, simulated by physical model (a full-scale, real-life mock-up), can be effectively investigated. The design strategies concluded in this part will conduct the next design process.

OPTION 1- Form and materials

Dendritic structure



Palm



Tree-like structure



Wood

Figure 34. OPTION 1 - Form, materials of structure

Redesign and apply in AMC

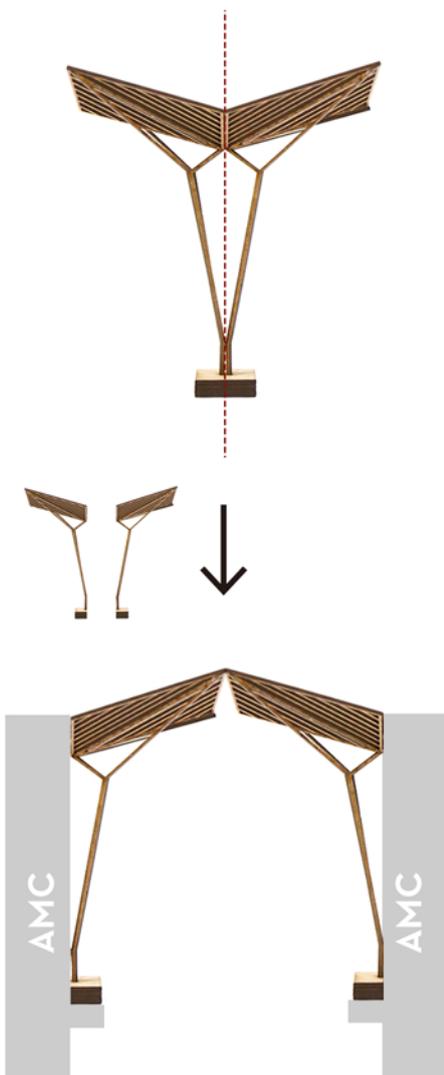


Figure 35. OPTION 1 - Redesign of tree-like structure

OPTION 1- Structure and light

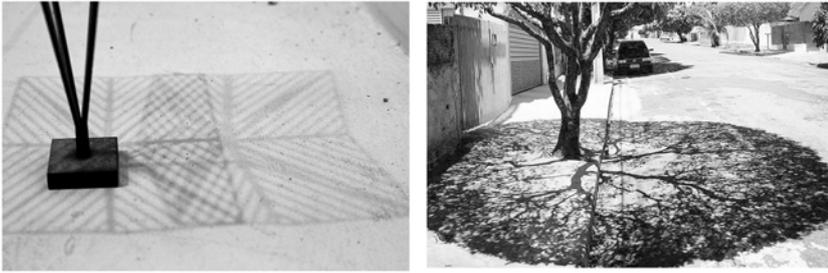


Figure 36. OPTION 1 - Structure and light: shadow of structure and tree

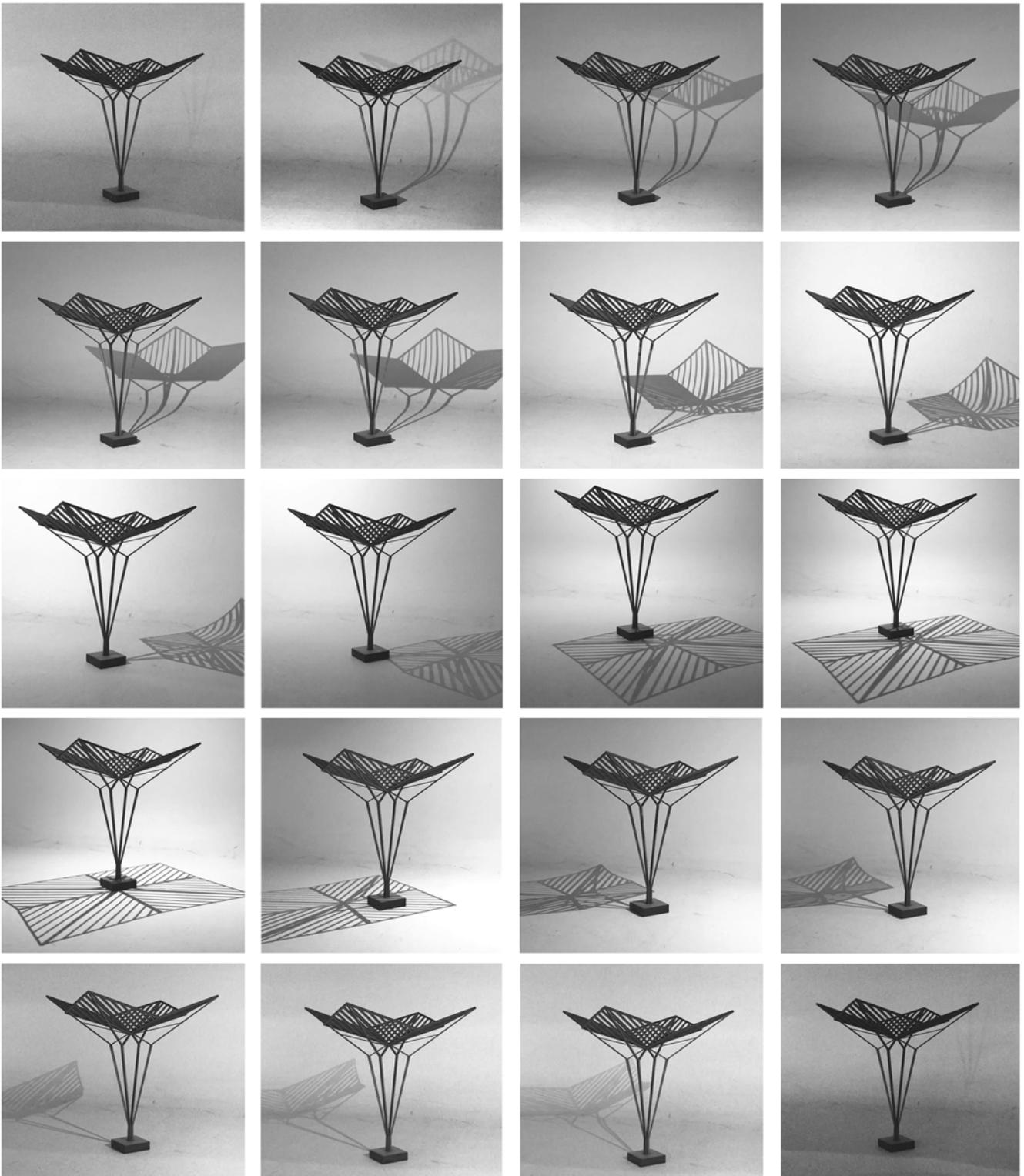


Figure 37. OPTION 1 - Structure and light: light and shadow changes during the course of a day

OPTION 1- Atmosphere (light and shadow)



Figure 38. OPTION 1 - natural lighting in AMC atrium

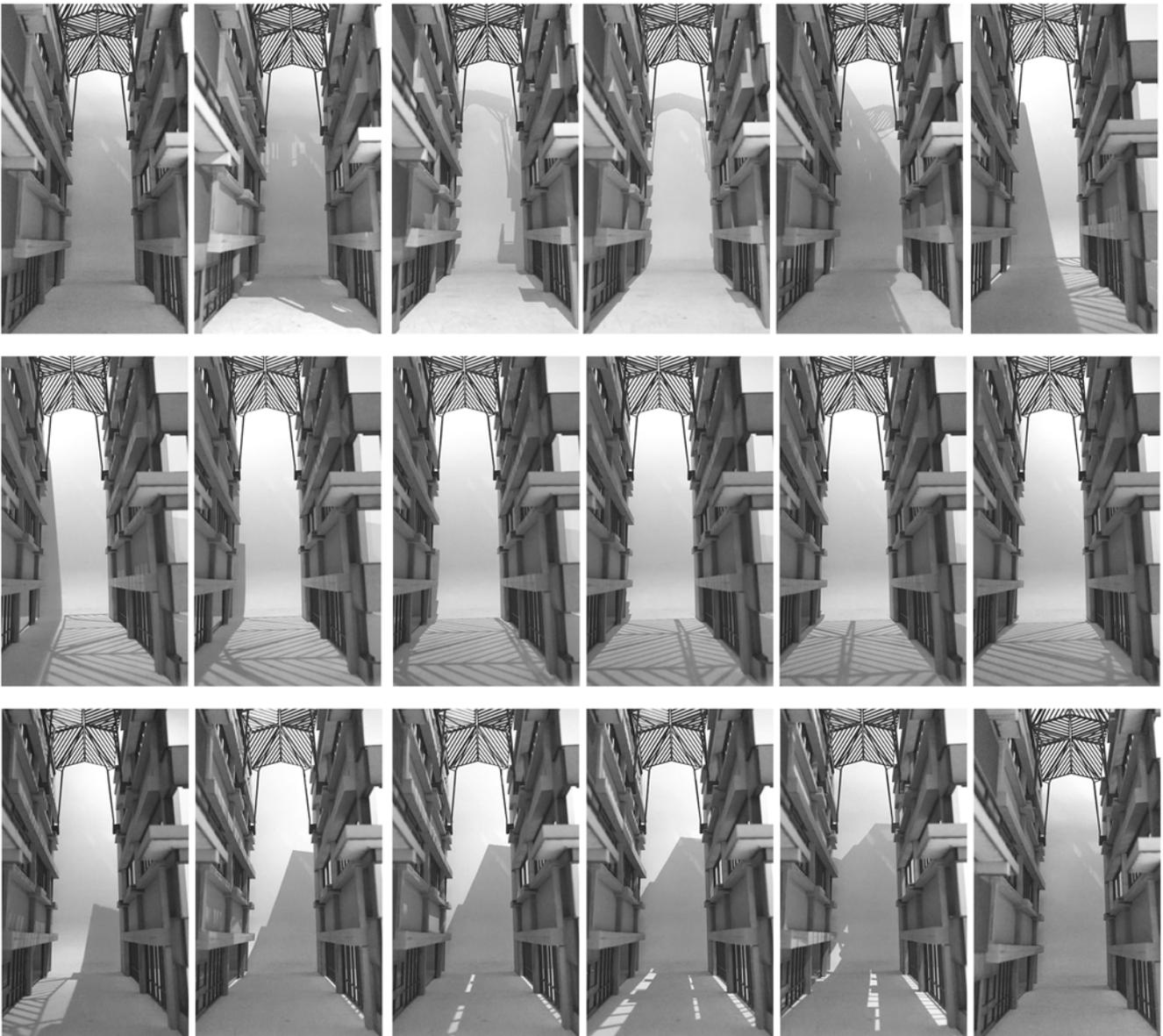
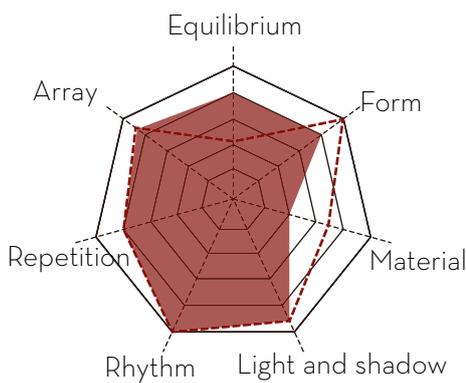


Figure 39. OPTION 1 - Atmosphere: light and shadow changes during the course of a day

OPTION 1- Evaluation



--- Original structure

■ Structure in AMC

Form of evaluation

- ✓ **Form:** Dendritic structure is the most instinct and common way to associate with tree and nature.
- ✓ **Material:** Selection of material in different circumstance considers in terms of color and texture. For example, wood color material is similar with the real trees, coarse-textural material cause imagination of earth or trunk and so on.
- ✓ **Light and shadow:** The play of light and shadow strengthens the natural phenomenon. Depending on the color tones of leaves, bark, soil, and the nature of the foliage and branch structure, a unique pattern of shade is created: short-though-with-light, light, dark, heavy, sharp, soft, colorful, full of contrasts, diffuse. Combination of various materials and this kind of light and shadow can give impression of nature.
- ✓ **Rhythm:** It is necessary to include the same and similar motif -structure selection repeatedly in order to give coherence and harmonious to a space like planting in garden or park. Too many elements will disturb the visual stability. This shows particularly clearly in the thematically differently designs of the public space in AMC.
- ✓ **Repetition:** Structural arrangement of creates a less explicit sense of nature. There are two main ways: one is orderly repetition; the other is random placement. The former one recalls of well-arranged tree-lined street, the latter one evokes a forest.
- ✓ **Array:** The intervals between the structural unit, and the number of units, should be varied, depending on the type and scale of the space.
- ✓ **Equilibrium:** Equilibrium is a common aim of design. It describes a state of balance and harmony between various design components. The form, material, color, scale of the structure should harmonize with the architecture or the available space.

ADVANTAGES

1. Tree form is directly link to nature
2. New structure is attached to the original structure, less pressure
3. Dendritic structure is space structure, which means each member can be slighter.
4. No column in the atrium. It provides one whole space
5. The glazing roof makes the atrium become the lighting tube for buildings on either side.
6. The tree-like structure creates a direct link with the surrounding environment, transforming the canopy of trees into a canopy of structure

DISADVANTAGES

1. The recombinant tree structure may have mechanical problem
2. The joint between new structure and original column is vulnerable part.

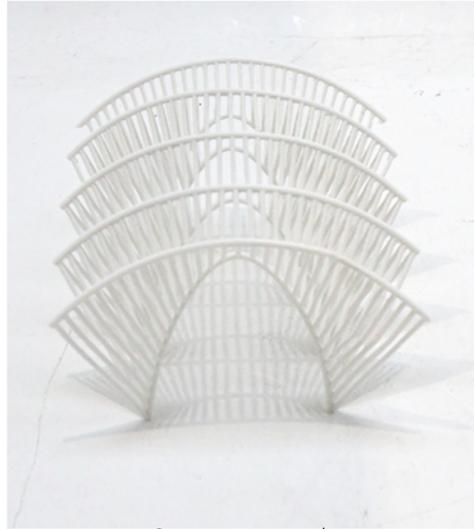
Figure 40. Evaluation of Option 1

OPTION 2- Form and materials

Arcade



Palm leaves



Sequent arcade



White steel

Figure 41. OPTION 2 - Form, materials of structure

Apply in AMC



Figure 42. OPTION 2 - Apply in AMC atrium

OPTION 2- Structure and light

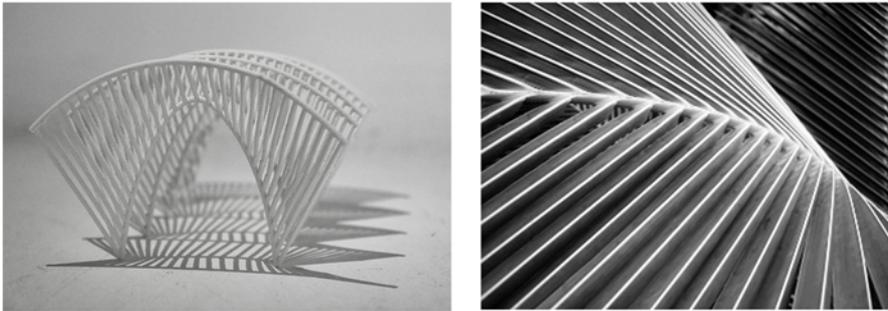


Figure 43. OPTION 2 - Structure and light: shadow of structure and palm leaf

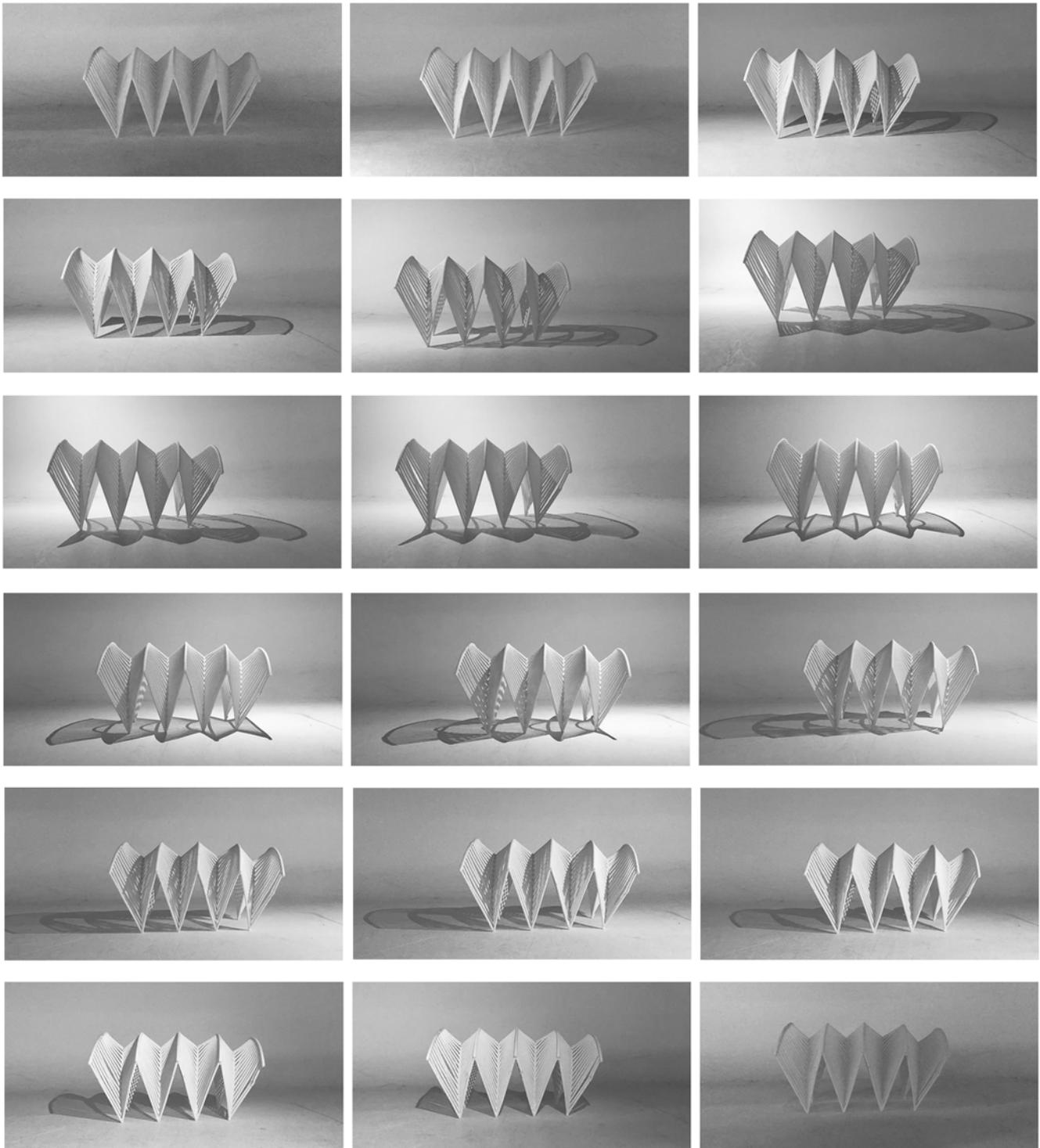


Figure 44. OPTION 2 - Structure and light: light and shadow changes during the course of a day

OPTION 2- Atmosphere (light and shadow)



Figure 45. OPTION 2 - natural lighting in AMC atrium

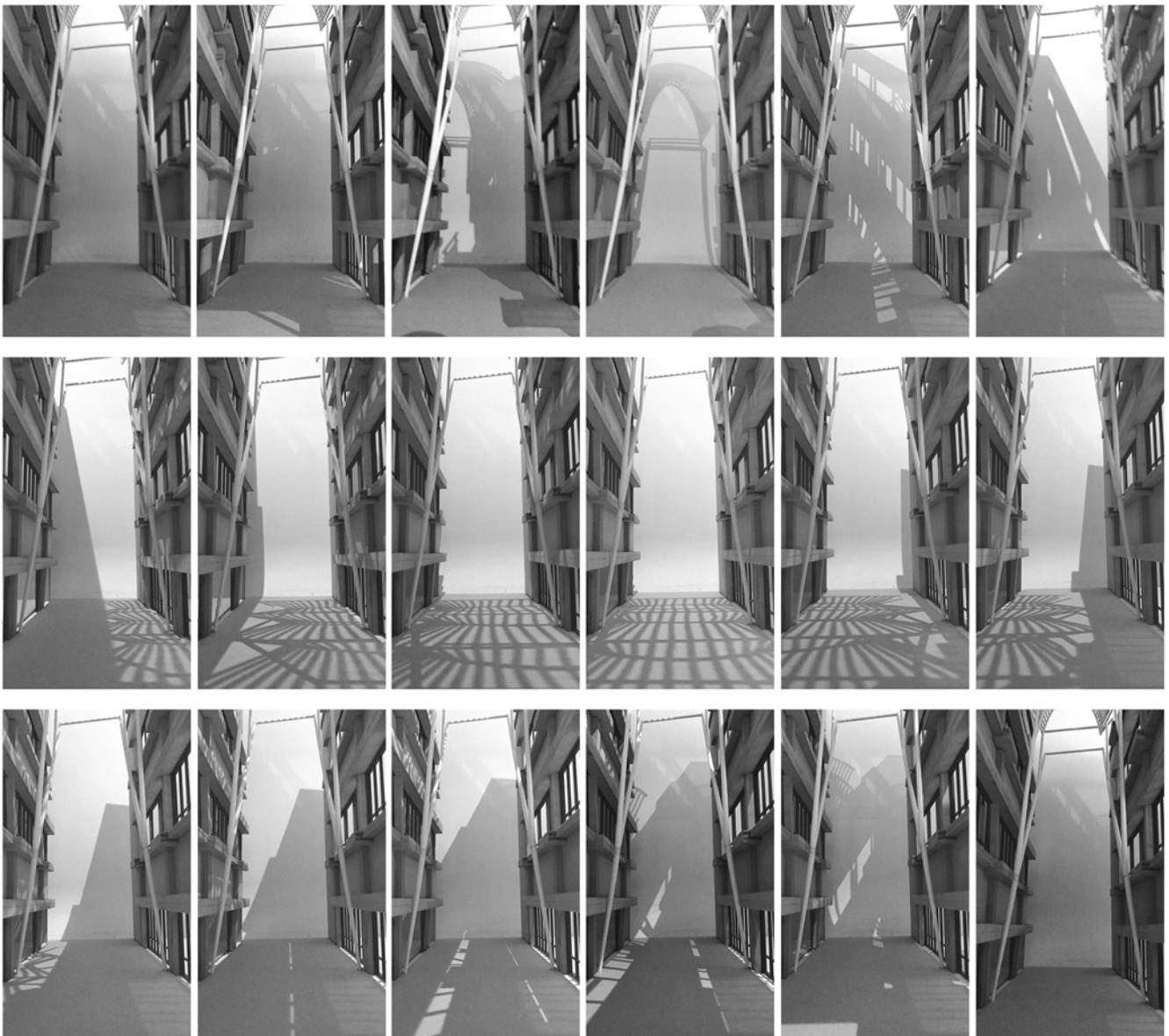
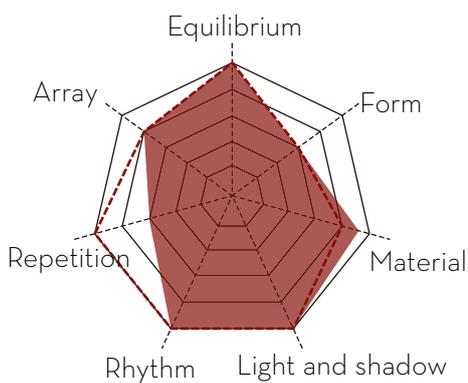


Figure 46. OPTION 2 - Atmosphere: light and shadow changes during the course of a day

OPTION 2- Evaluation



--- Original structure

■ Structure in AMC

Form of evaluation

- Form:** Dendriform structure is the most instinct and common way to associate with tree and nature.
- Material:** Selection of material in different circumstance considers in terms of color and texture. For example, wood color material is similar with the real trees, coarse-textural material cause imagination of earth or trunk and so on.
- Light and shadow:** The play of light and shadow strengthens the natural phenomenon. Depending on the color tones of leaves, bark, soil, and the nature of the foliage and branch structure, a unique pattern of shade is created: short-though-with-light, light, dark, heavy, sharp, soft, colorful, full of contrasts, diffuse. Combination of various materials and this kind of light and shadow can give impression of nature.
- Rhythm:** It is necessary to include the same and similar motif -structure selection repeatedly in order to give coherence and harmonious to a space like planting in garden or park. Too many elements will disturb the visual stability. This shows particularly clearly in the thematically differently designs of the public space in AMC.
- Repetition:** Structural arrangement of creates a less explicit sense of nature. There are two main ways: one is orderly repetition; the other is random placement. The former one recalls of well-arranged tree-lined street, the latter one evokes a forest.
- Array:** The intervals between the structural unit, and the number of units, should be varied, depending on the type and scale of the space.
- Equilibrium:** Equilibrium is a common aim of design. It describes a state of balance and harmony between various design components. The form, material, color, scale of the structure should harmonize with the architecture or the available space.

ADVANTAGES

1. The sequent arcades express classical aesthetics
2. The new structure has been conceived as a free-standing element between existing buildings, while reserve the original interior facade of AMC.
3. The colonnade in the atrium provides two different hierarchy.
4. The colonnade and sequent arcades emphasis the directionality
5. The transparent and light elements consist a "corridor of light"
6. This structure connects buildings on either side, meanwhile link the environment and in-between space

DISADVANTAGES

1. The hierarchy of two space is not obvious due the narrow atrium.

Figure 47. Evaluation of Option 2

OPTION 3- Form and materials

Random columns



Forest



Random columns



White steel

Figure 48. OPTION 3 - Form, materials of structure

Apply in AMC



Figure 49. OPTION 3 - Apply in AMC atrium

OPTION 3- Structure and light



Figure 50. OPTION 3 - Structure and light: shadow of structure and forest

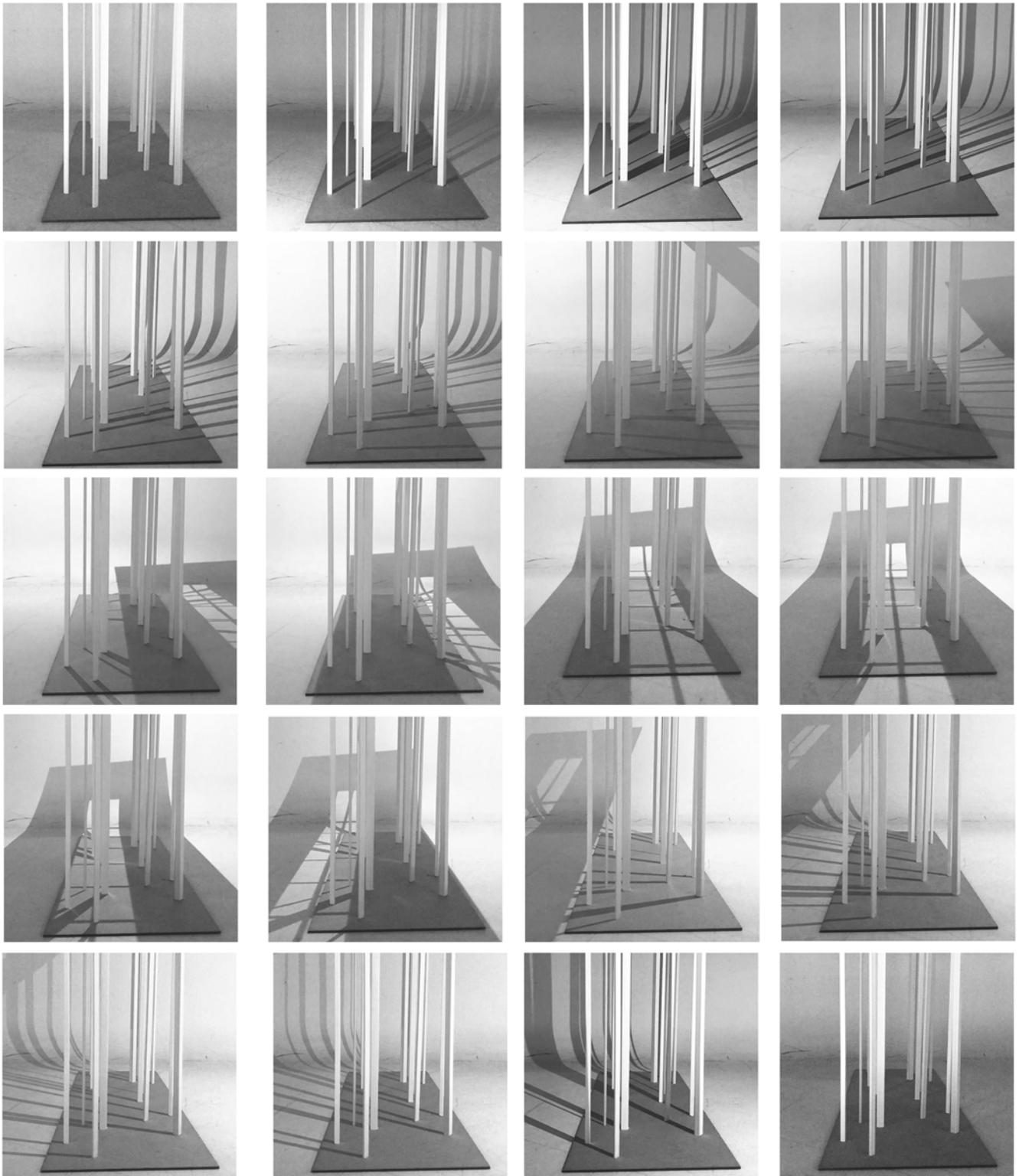


Figure 51. OPTION 3 - Structure and light: light and shadow changes during the course of a day

OPTION 3 - Atmosphere (light and shadow)



Figure 52. OPTION 3 - natural lighting in AMC atrium

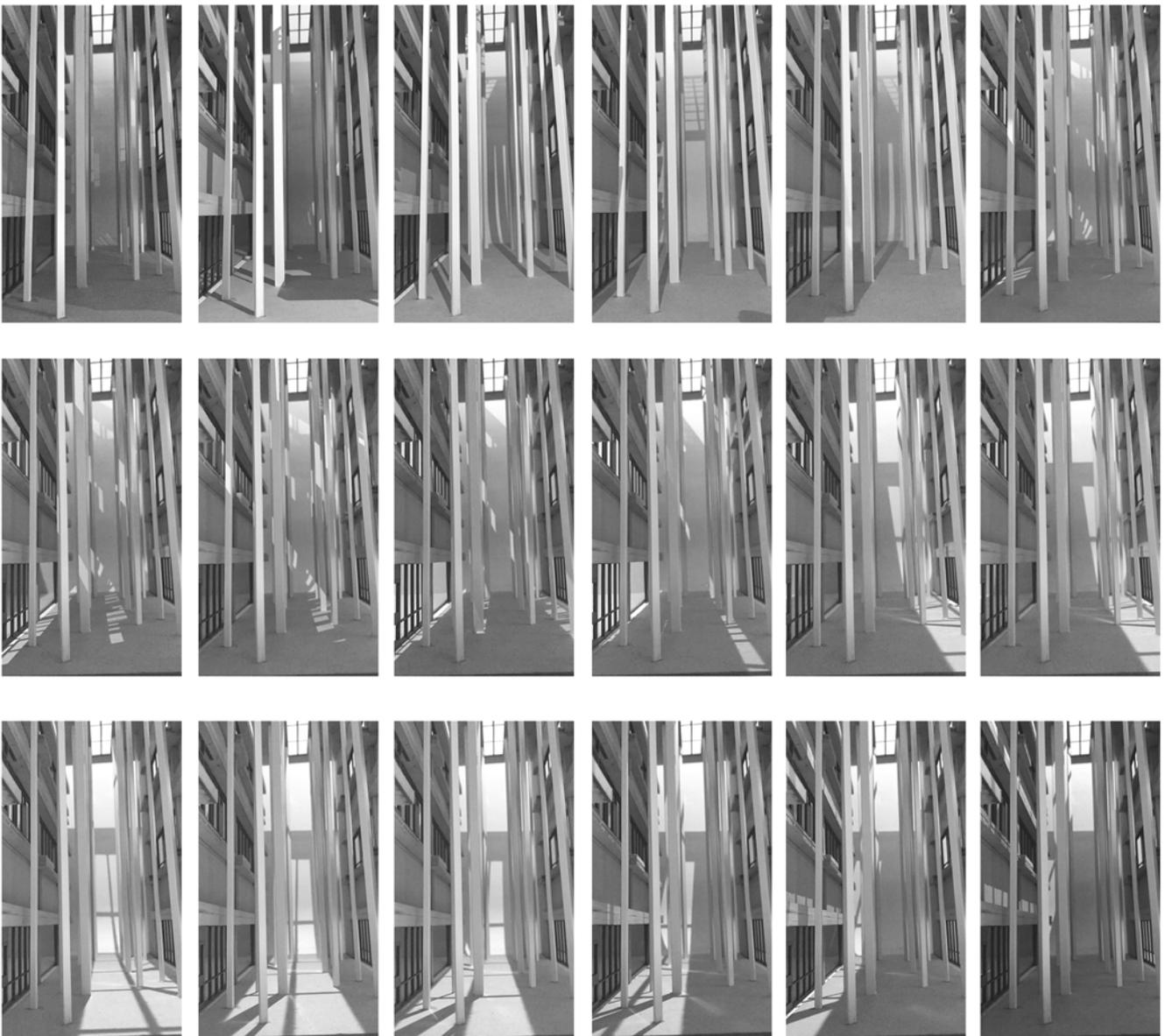
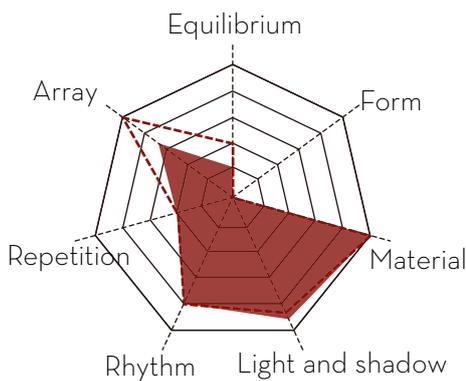


Figure 53. OPTION 3 - Atmosphere: light and shadow changes during the course of a day

OPTION 3- Evaluation



--- Original structure

■ Structure in AMC

Form of evaluation

- Form:** Dendriform structure is the most instinct and common way to associate with tree and nature.
- Material:** Selection of material in different circumstance considers in terms of color and texture. For example, wood color material is similar with the real trees, coarse-textural material cause imagination of earth or trunk and so on.
- Light and shadow:** The play of light and shadow strengthens the natural phenomenon. Depending on the color tones of leaves, bark, soil, and the nature of the foliage and branch structure, a unique pattern of shade is created: short-though-with-light, light, dark, heavy, sharp, soft, colorful, full of contrasts, diffuse. Combination of various materials and this kind of light and shadow can give impression of nature.
- Rhythm:** It is necessary to include the same and similar motif -structure selection repeatedly in order to give coherence and harmonious to a space like planting in garden or park. Too many elements will disturb the visual stability. This shows particularly clearly in the thematically differently designs of the public space in AMC.
- Repetition:** Structural arrangement of creates a less explicit sense of nature. There are two main ways: one is orderly repetition; the other is random placement. The former one recalls of well-arranged tree-lined street, the latter one evokes a forest.
- Array:** The intervals between the structural unit, and the number of units, should be varied, depending on the type and scale of the space.
- Equilibrium:** Equilibrium is a common aim of design. It describes a state of balance and harmony between various design components. The form, material, color, scale of the structure should harmonize with the architecture or the available space.

ADVANTAGES

1. The columns create various spatial experience
2. The pillars with different shapes and size is more like trees in a real forest, and give enjoyment in the space.
3. People can feel the time-changing by observing the direction of shadow.

DISADVANTAGES

1. The scale of column is narrow, which means the structure system is not rational
2. Random column system is more suitable for open space rather than liner space.
3. These spaces separated by columns are too narrow to use.
4. Less natural lighting going through the roof, most of time the space is dark.

Figure 54. Evaluation of Option 3

OPTION COMPARISON

OPTION	ADVANTAGES	DISADVANTAGES
 <p data-bbox="229 790 464 819">Dendritic structure</p>	<ol style="list-style-type: none"> 1. Tree form is directly link to nature 2. New structure is attached to the original structure, less pressure 3. Dendritic structure is space structure, which means each member can be slighter. 4. No column in the atrium. It provides one whole space 5. The glazing roof makes the atrium become the lighting tube for buildings on either side. 6. The tree-like structure creates a direct link with the surrounding environment, transforming the canopy of trees into a canopy of structure 	<ol style="list-style-type: none"> 1. The recombinant tree structure may have mechanical problem 2. The joint between new structure and original column is vulnerable part.
 <p data-bbox="309 1411 395 1440">Arcade</p>	<ol style="list-style-type: none"> 1. The sequent arcades express classical aesthetics 2. The new structure has been conceived as a free-standing element between existing buildings, while reserve the original interior facade of AMC. 3. The colonnade in the atrium provides two different hierarchy. 4. The colonnade and sequent arcades emphasis the directionality 5. The transparent and light elements consist a "corridor of light" 6. This structure connects buildings on either side, meanwhile link the environment and in-between space 	<ol style="list-style-type: none"> 1. The hierarchy of two space is not obvious due the narrow atrium.
 <p data-bbox="240 2031 448 2060">Random columns</p>	<ol style="list-style-type: none"> 1. The columns create various spatial experience 2. The pillars with different shapes and size is more like trees in a real forest, and give enjoyment in the space. 3. People can feel the time-changing by observing the direction of shadow. 	<ol style="list-style-type: none"> 1. The scale of column is narrow, which means the structure system is not rational 2. Random column system is more suitable for open space rather than linear space. 3. These spaces separated by columns are too narrow to use. 4. Less natural lighting going through the roof, most of time the space is dark.

Figure 55. Horizontal comparison of three options