FREE FORM ARCHITECTURE AND INTERIOR SPACE: A CRITICAL ANALYTICAL APPROACH

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ABSTRACT

FREE FORM ARCHITECTURE AND INTERIOR SPACE: A CRITICAL ANALYTICAL APPROACH

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Architecture has been in a period of transformation since the last decade of the 20thcentury. There have been major developments in architecture in terms of the design and realization processes due to the technological advances. The 21stcentury witnesses the domination of Free Form Architecture on the contemporary architectural practices and theories. The use of digital design tools further widens the limits of experimental approaches in architectural design and realization. It is possible to say that formal expression has become one of the focal points of architectural design. In this thesis, it is supported that the overemphasis on formal expression may lead to an undervaluation of the importance of various key characteristics of interior spaces. Since space is of upmost importance in architecture and the interrelations between form and space constitute the dynamics of architectural design, the characteristics of spaces in Free Form Architectural works are selected as the main topic of investigation. This thesis focuses on the impact of formal expression of the building skin on interior spaces, and adopts a critical analytical approach. A number of cases are selected and a thematic categorization is made based on the architectural drawings in order to be able to analyze the current intentions about space characteristics in contemporary Free Form Architecture. The results indicate that the formal expression of the building skin can be very limitedly perceived from the inside. Therefore, the

spatial concerns may have been regarded as secondary design consideration in Contemporary Free Form Architecture.

Keywords: architectural design, architectural form, interior space, free form architecture.

ÖZ

SERBEST BİÇİM MİMARİSİ VE İÇ MEKAN: ELEŞTİREL ANALİTİK BİR YAKLAŞIM

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Mimarlık, 20. yüzyılın son on yılından bu yana bir dönüşüm içerisindedir. Teknolojik gelişmeler mimari tasarım ve uygulama süreçlerinde büyük gelişmelere neden olmuştur. 21. yüzyıl, Serbest Form Mimarisinin çağdaş mimari uygulamalar ve kuramlar üzerinde edinmeye başladığı hakimiyete tanıklık etmektedir. Dijital mimari tasarımın, tasarım sürecinde deneysel yaklaşımların sınırlarını genişletmesiyle, biçimsel ifadenin mimari tasarımın odak noktası haline geldiğini söylemek mümkündür. Bu tezde, biçimsel ifadeye aşırı vurgu yapılmasının, iç mekanların özelliklerinin öneminin zayıflamasına yol açabileceği desteklenmektedir. Mimarlıkta mekanın en önemli unsurlardan biri olduğu ve form ile mekan arasındaki ilişkilerin mimari tasarımın dinamiklerini oluşturması nedeniyle, Serbest Biçim Mimari eserlerde mekanların özellikleri araştırmanın ana konusu olarak seçilmiştir. Bu tez, binanın biçimsel ifadesinin iç mekanlar üzerindeki etkisine odaklanmakta ve kritik bir analitik yaklaşım benimsemektedir. Çağdaş Serbest Biçim Mimarisindeki mekan ve mimari form ilişkisini analiz edebilmek için iç mekânları belirten ortografik mimari çizimlere dayanarak bir dizi mimari örnek seçilip tematik bir sınıflandırma yapılmıştır. Sonuçlar, mimari formun iç mekanlardan algılanabilirliğinin sınırlı olduğunu ve bu nedenle, mekansal kaygıların Çağdaş Serbest Biçim Mimarisinde ikincil tasarım kaygılarından biri olarak düşünülmüş olabileceğini göstermektedir.

Anahtar Kelimeler: mimari tasarım, mimari biçim, iç mekan, serbest biçim mimarlık.

To my family. For their endless love, forbearance and encouragement.

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CHAPTER 1

INTRODUCTION

1.1. Research Motivation

It has been widely argued that architecture has been in a transformation process since the last decade of the 20th century, due to the technological advances. Specifically, the development of digital technologies triggered new developments in architecture in terms of design conception and realization and enabled architects to operate with complex computational tools and methods that support the design process.[1] Although digital media can be used for a wide range of activities including design communication, synthesis and evaluation, its wider implementation in architectural practices has been rather limited to the generation and manipulation of architectural form.[2] For the last two decades, there has been great interest in formal architectural experimentation resulting in the construction of an increasing number of Free Form Buildings.[3] 21stcentury witnesses the rise of the popularity of Free Form Architecture which started to dominate the skyline of some of the major cities around the world.[4] It is possible to say that the visual features of Free Form Architecture have become influential especially in design education and across young architects, and while the

[1] Eekhout, Mick, Barbara Van Gelder, Walter Lockefeer, Martijn Veltkamp, and Karel Vollers. 2015. *Free Form Technology from Delft*. Vol. 14. Amsterdam: IOS Press BV. http://ebooks.iospress.nl/bookseries/research-in-architectural-engineering-series.

[2] Kalay, Yehuda E. 2004. *Architecture's New Media: Principles, Theories, and Methods of Computer-Aided Design*. Cambridge, Massachusetts: The MIT Press.

[3] Pottmann, Helmut, Alexander Schiftner, and Johannes Wallner. 2008. "Geometry of Architectural Freeform Structures." *Internationale Mathematische Nachrichten*, 15–28. http://www.geometrie.tugraz.at/wallner/arch-imn.pdf.

[4] Wong, Joseph F. 2010. "The Text of Free-Form Architecture: Qualitative Study of the Discourse of Four Architects." *Design Studies*31 (3): 237–67. https://doi.org/10.1016/j.destud.2009.11.002.

number of commissions that favor Free Form Architecture to make their signature in the particular locale increased.[5]

Contemporary architectural production has been criticized for its desire to attract attention through its physical appearance aiming to distinguish from the others with what is purported to be an identity of its own.[6] The digital developments have been used as a tool of distinction by providing a set of operations of form generation and manipulation.[7] Experimentation on complex architectural geometry has proliferated by testing boundaries, querying traditional perceptions, and searching for new materials and concepts around the topic of architectural form.[8] These newly introduced possibilities increased the impact of the certain aspects of architecture previously considered secondary, such as surface manipulation and articulation.[9] This change in architectural thinking has led to a displacement of the criteria for judgment, from an evaluation of form toward an assessment of the motivations that lie underneath its conception.[10] Various concerns can guide the process of design and form reasoning in Free Form Architecture such as rationalization and performance. Rationalization can be determinant in terms of form making due to the reliance on structural and materialistic aspects of architectural design. The building performance can be a focal point with respect to environmental concerns. All these determinant forces shape the studies on Free Form Architecture and they focus more on the *building skin*[11] and architectural form. The formal expression of the architectural works in terms of the increased complexity that can be achieved with new design tools leads the conceptualization process.

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[5] Ibid.
[6] Hertzberger, Herman. 2000. *Space and the Architect Lessons in Architecture 2*. Rotterdam: 010 Publishers.
[7] Picon, Antoine. 2004. "The Ghost of Architecture: The Project and Its Codification." *Perspecta*35: 8–19. https://www.jstor.org/stable/1567337.
[8] Schittich, Christian. 2012. "Shell, Skin, Materials." Essay. In *In Detail Building Skins*, 8–27. Basel: Birkhäuser.
[9] Picon op. cit.
[10] Ibid.
[11] 'Building skin' is the term to express the form of the building envelope, which is derived from the analogy of building envelope and human. Please see page 45 for further information.

According to Carlos Marcos, the focus on the outward appearance of the architectural works as the objective of the design process, runs the risk of leading to a banal formalism inconsistent with architecture's own tradition.[12] Herman Hertzberger, similarly, draws attention to the common focus on the building appearance by stating:

> Architecture photographers are inclined to capture buildings as objects isolated from their surroundings, each time seen from an exterior viewpoint. This is evidently how architects want their work to be seen, in independence, as a self-sufficient creation they themselves regard at arm's length, and that is the image that travels the world.[13]

During the act of architectural design, form and space can be regarded as a *means* to solve a problem in response to conditions of function, purpose, and context.[14] It is important to note that creativity plays an important role in architectural design thinking, as working in the three-dimensional forms demands the architect to act more than just a problem solver.[15]

According to Herman Hertzberger, designing is basically a question of finding the appropriate concept for the task at hand and this concept can be defined as the idea translated into space.[16] A concept must be challenging in terms of leaving room for interpretations by asserting as little as possible about form, and concentrating all the more on the space.[17] "As space begins to be captured, enclosed, molded, and organized by the elements of mass, architecture comes into being."[18] According to Edmund Bacon, the essence of design is the interrelations between the two basic ingredients of architectural design, which are mass and space, and since form is the point of contact between these two, the quality of architecture is determined by the skill of the designer

[12] Marcos, Carlos L. 2011. "New Materiality: Digital Fabrication and Open Form. Notes on the Arbitrariness of Architectural Form and Parametric Design." *International Conference on Innovative Methods in Product Design*, 1037–46.
[13] Hertzberger 2000, op. cit.
[14] Ching, Francis D. K. 2014. *Architecture Form, Space, & Order*. 4. ed. New Jersey: John Wiley & Sons, Inc.
[15] Abdelhameed, Wael. 2004. "Visual Design Thinking in the Design Process as Impacted by Digital Media."
[16] Hertzberger 2000, op. cit.
[17] Ibid.
[18] Ching, op. cit.

in using and relating the elements of form, both in interior spaces and in the open spaces around buildings.[19] The relation between form and space can be provided by designing from the outside in, as well as, the inside out.[20] Regardless of the method adopted, architecture brings new spatial discoveries exhilarating spatial idea not encountered in that form before.[21] So, architecture is an act of defining spaces, as Edmund Bacon states: "This is architecture, not to look at, but to be in."[22]

In contrast, Free Form Architecture usually prioritizes building form and building skin as the focal point of architectural design. Moreover, spaces and their basic qualities provided by Free Form Architecture are usually considered as secondary or subordinate to complex forms. Although Free Form Buildings can be designed focusing on constructional or performative concerns, or as an exploration of the digital possibilities by using from the outside in approach, the question of architectural spaces as the primary concern of architectural design remains. The studies on Free Form Architecture generally covers the topics of digital architectural design, representation, rationalization and performative design. As most of the Free Form Architectural works derive their motive from form reasoning through these considerations, the characteristics of interior spaces are rather neglected. Therefore, this research approaches the relationship between complex architectural form and interior spaces in contemporary Free Form Architecture as the research problem. As Herman Hertzberger claims: "An essential aspect is that space is always present in what we do, as a permanent challenge."[23]

This research focuses on the impact of formal expression of the building skin on interior space and aims to explore the intentions of Free Form Architecture in spatial characteristics. This exploration is carried out by investigating architectural drawings of Free Form Architectural works. Simon Unwin also considers, the plans and sections

[19] Bacon, Edmund N. 1967. *Design of Cities*. London: Thames and Hudson.
[20] Venturi, Robert. 1992. *Complexity and Contradiction in Architecture*. 2. ed. New York: The Museum of Modern Art.
[21] Hertzberger 2000, op. cit.
[22] Bacon, op. cit.
[23] Hertzberger 2000, op. cit.

as the means of expressing spatial ideas in architecture.[24] The horizontal and vertical spatial relations can be determinant in defining the relationship between the building form and interior spaces. Simon Unwin indicates the importance of analysis in architectural practice as:

> The word 'analysis' comes from the Greek αναλυση (analyein), which means 'to break apart' or 'to unloose'. To analyse something is to release, to unloose, to expose for assimilation its constituents and workings – its powers. The purpose of analysing architecture, as any other creative discipline, is to understand its underlying constituents and workings, so that their powers may be assimilated and acquired.[25]

This thesis adopts a comparative analytic approach to discover the relationship between the building skin and interior space in Free Form Architectural works.

1.2. Research Questions

Considering the discussion in the previous sections, this research addresses the following research question:

- What is the relationship between the formal expression of Free Form Architecture and interior spaces?

In order to answer this main question, a number of sub-questions have been addressed in the chapters of this thesis, which are listed as following:

Chapter II:

- What is Free Form Architecture?

Chapter III:

- What are the determinant factors in architectural space definition?
- What is the role of building skin in interior space definition?
- What are the principles for visual perception of the building skin from interior space in Free Form Architectural works?

[24] Unwin, Simon. 2014. *Analysing Architecture*. 4. ed. London: Routledge.
[25] Ibid.

Chapter IV:

- What relationships exist between the building skin and interior space in Free Form Architecture?

1.3. Research Methodology

This thesis aims to explore the relationship between the building form and interior space focusing on the architectural space defining elements, spatial organization and relationships, and visual perception with respect to the design objectives and processes of Free Form Architecture.

This research adopts two methods. The first method is based on a literature review aiming to benefit from the previous knowledge and theories in this field. This part of the research aims to study a wide range of sources in order to be able to define a ground for discussion and construct the considerations that will guide the research. The second method adopts the principles of case study research. In architectural research, as Simon Unwin also claims, exploration and explication through examples is an effective way of architectural research.[26] This thesis examines existing cases in architectural practice aiming to generate a point of view towards contemporary Free Form Architectural practice. Robert Yin provides the following definition in one of the most frequently cited books on case study research: "A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident."[27] Case studies can be applied both in case of quantitative and qualitative research. In this thesis, they are used as a qualitative research on architectural phenomena. With the visual examination of the orthographic architectural drawings of the cases, a thematic categorization is made to be able to analyze the current intentions about the characteristics of interior spaces in Contemporary Free Form Architecture.

[26] Unwin, op. cit.
[27] Yin, Robert K. 2003. *Case Study Research: Design and Methods*. 3. ed. London: Sage Publications.

The research process can be organized into two main phases. The first one focuses on the literature review while the second one is case studies. Each phase has sub-phases as follows:

Literature Review

- The first phase contains a literature review on Free Form Architecture covering its definition and the common studies about it in architectural field.
- The second phase includes a literature review about form and space indicating architectural space definition, space-boundary relationship and visual perception.

Case Study

- In the first phase a number of cases are examined and a categorization is done to be able to provide a framework for systematic evaluation.
- The second phase includes the representative cases of the categories in order to comprehend better the interaction of the categories and the relationship between the building skin and interior space.

1.4. Chapter Outline

Chapter II: Free Form Architecture

This chapter aims to discuss the definition of Free Form Architecture and the common study fields about it in architectural domain.

Chapter III: Form and Space

This chapter aims to discuss architectural space definition, space-boundary relationship and visual perception by providing considerations for the case study research.

Chapter IV: Case Study

This chapter presents case studies to be able to understand the form and space relationship in Free Form Architecture

Chapter V: Conclusion

Chapter V is the conclusion of this thesis which summarizes the research findings and the implications of the research.

CHAPTER 2

FREE FORM ARCHITECTURE

2.1. Defining Free Form Architecture

Architecture has been in a transformation period since the last decade of the 20th century. There have been major developments in the architectural field in terms of conception and construction due to the technological advances. The liberation of the formal expression and organization could be defined as the emergence of a new approach to form-making in architecture.[28] With the new opportunities in form generation, architects embraced the independency on the simple geometries and rectilinear forms.[29] The development of computer tools for 3D modeling enabled architects to design volumes out of the classical vocabulary of Cartesian grid, which they could deform, stretch and manipulate.[30] Eekhout and Wichers link the technological developments in architectural tools and the emergence of Free Form Architecture in their book, in 2015, by stating:

> In a sense, the evolution of free form architecture is a direct consequence of architects and engineers being driven by the urge to explore new opportunities that the latest generation 3D design computer programs provide them with. Progression in 3D programs is now allowing designers to design geometrically complicated virtual 3D buildings, which are always 'one-off s' in shape and usually composed of non-repetitive components.[31]

[28] Wong, op. cit.
[29] Mosoarca, Marius, Anthimos Anastasiadis, and Kampouris Apostolos. 2014. "Are Free Form Architecture Ecological Buildings." *Journal of Environmental Protection and Ecology*15 (1). http://www.jepe-journal.info/vol15-no-1-2014.
[30] Eekhout, et al., op. cit.
[31] Eekhout, Mick, and Sieb Wichers. 2015. *Lord of the Wings: The Making of Free Form Architecture*. Vol. 12. Amsterdam, The Netherlands: IOS Press. http://ebooks.iospress.nl/volume/lord-of-the-wings-the-making-of-free-form-architecture.

There does not yet exist any consensus on the definition of Free Form Architecture among architects.[32] Different terms are used to define Free Form, such as, 'Blob'[33], 'Liquid Design'[34], or 'Non Standard'[35]. Similarly, different definitions are adopted to describe the characteristics of Free Form Architecture. In *The Text of Free-Form Architecture*, Wong describes Free Form Architecture as a new approach to form generation that is characterized by a dynamic juxtaposition of volumes expressing separation, fragmentation and distortion, and a free-flowing expression that seeks to simultaneously reflect and reconcile the inevitability of a diversity of forces influencing architectural design.[36] The expression of Free Form Architecture in unbuilt form is termed as 'visionary architecture'[37] by Wong. In contrast, in the same article, Wong supports the idea of an architecture that tests the boundaries of preconceived architectural formal conventions that predate the Free Form Architecture, instead of being constrained by the limitations of conventional construction techniques and materials.[38] While this explanation emphasizes the liberation of form-making and form reasoning process from the orthogonal forms, there are also other definitions that focus on the visual features of the architectural design artifacts. "Random curves and tilts, in which buildings often seem to be exploding or collapsing, as opposed to conventional vertical walls and right angles"[39] can be listed as one of them. Eekhout and Wichers focus more on the digital generation process and they interpret Free Form Architecture as:

> […] the beautiful art of seemingly freely formed geometries, non-definable by any regular mathematical formula and which are mainly driven by

[32] Vermeij, Peter. 2006. "Parametric Associative Design for Free Form Architecture." Dissertation. Delft University of Technology. . http://resolver.tudelft.nl/uuid:531aaab8-daf8-4c50-81f8-e5dbf89abe7f.
[33] Eekhout and Wichers, op. cit
[34].Ibid.
[35]Mennan, Zeynep. 2008. "The Question of Non Standard Form." *METU JFA*25 (2). http://jfa.arch.metu.edu.tr/archive/0258-5316/2008/cilt25/sayi_2/171-183.pdf.
[36] Wong, op. cit.
[37] Spiller, Neil. 2006. *Visionary Architecture: Blueprints of the Modern Imagination*. London: Thames & Hudson.
[38] Wong, op. cit.
[39] Vermeij, op. cit.

> increasing capacity of contemporary computers combined with the desire of designers and engineers to give unique identities to their creations.[40]

Technological advances and digital capabilities lie at the heart of Free Form Architecture, therefore digital architecture is the key to understand and to be able to come up with a definition of it. Within digital architecture, a new formal abstraction architecture has emerged.[41] Different from traditional tectonics, digital architecture not only takes into account the interaction between architecture, environment and people, but also reflects it in a dynamic structure, allowing the building to posse a body with life.[42] This change is possible if only the complexity level of the design is increased. Digitalization of the design process enables designers to manage highly complex geometries. As complexity moves contemporary architecture forward, it also poses new questions to be answered. The advanced design tools set architects free to explore the limits and since this exploration is generally based on pure aesthetics, it often results in awkward and out of scale structures or very costly constructions.[43] Architects and engineers are imposed intense challenges from the design stage to construction, leading to the need of developing new approaches to design and fabrication.[44] As digital design defines a certain order in application of the procedures, and it aims to provide desired improvement in problematic aspects, it is possible to say that a new architectural paradigm has been achieved in digital architecture which is based on both, new conception and new production standards.[45]

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[40] Eekhout and Wichers, op. cit

[41] Marcos, Carlos L. 2011. "New Materiality: Digital Fabrication and Open Form. Notes on the Arbitrariness of Architectural Form and Parametric Design." *International Conference on Innovative Methods in Product Design*, 1037–46.

[42] Gao, Wan Ping. n.d. "Tectonics? A Case Study for Digital Free-From Architecture." https://www.researchgate.net/publication/30876047_Tectonics_A_Case_Study_for_Digital_Free-Form_Architecture.

[43] Brandt-Olsen, Cecilie Sos. 2015. "Harmonic From-Finding for the Design of Curvature-Stiffened Shells." Dissertation. University of Bath. https://researchportal.bath.ac.uk/en/studentTheses/harmonic-form-finding-for-the-design-of-curvature-stiffened-shell.

[44] Chen, Zi Ru, Chor Kheng Lim, and Wei Yen Shao. 2015. "Comparisons of Practice Progress of Digital Design and Fabrication in Free-Form Architecture." *Journal of Industrial and Production Engineering*32 (2): 121–32. http://dx.doi.org/10.1080/21681015.2015.1023853.

[45] Marcos, op. cit.

Following the brief effort to define Free Form Architecture, the first part of this section will be focusing on the historical references in terms of both structural and theoretical aspects of the topic.

2.1.1. Precedents of 21st Century

Although Free Form Architecture gained its popularity and established itself around the turn of the millennium, it is possible to say that it has structural, inspirational and theoretical connections with the past. It would be beneficial to point out these connections in order to better understand the current state of the 21st century.

If free-form is traced back in history, it is even possible to reach the Viking boats reflected the possibilities of free-form based only on the technology of the time.[46] However, since this is a rather wide perspective resulting in endless examples, this section mainly focuses on the references and influences in the history of architecture namely 20thcentury, in which three main influential factors can be listed but not limited to: Thin Shell Structures (formal/structural), Sydney Opera House (inspirational), Deconstructivist Architecture Exhibition at the MoMA (theoretical). The first one is the structural system which could be regarded as the precedent of Free Form Architecture in terms of its conceptual and structural features. The second one is the building that signaled a new age due to the inspiration it created among the architects.[47] And the final one is the theoretical break-through where architectural form was subjected to a relentless semiotic critique.[48]

[46] Baldassini, Niccolo, Helmut Pottmann, Jacques Raynaud, and Alexander Schiftner. 2010. "New Strategies and Developments in Transparent Free-Form Design: From Facetted to Nearly Smooth Envelopes." *International Journal of Space Structures*25 (3): 185–97. https://journals.sagepub.com/doi/abs/10.1260/0266-3511.25.3.185.
[47] Mosoarca, Anastasiadis and Apostolos, op. cit.
[48] Horn, Bradley. n.d. "Meaningless Form / Formless Meaning: Architecture, Language, and the Computational Turn." *Seeking the City*, 515–19.

Free Form Architecture could be regarded as the renaissance of the shell structures because of its impact on the construction industry.[49] Pastore and Corrao explains further the relationship between Free Form Architecture and Shell Structures:

> One of the first structural system adopted for free form buildings was the shell typology, whose technology, limitedly developed in the Thirties by Franz Dischinger, found its great expression through the works of architects such as Eero Saarinen, Heinz Isler, Felix Candela and Pier Luigi Nervi. Shell structures are able to withstand and transfer loads with minimal thickness and rely on their three-dimensional curved geometry and correct orientation and placement of supports for their adequate performance. In fact, by their nature, shell structures are supported at their perimeters. Although any associated structural elements, such as ribs, that might increase its strength, their structural configuration doesn't allow to significantly reduce the inner space. This is the reason why not only such structural systems generate dynamic and expressive buildings but are also used to better organize the internal functions, sometimes creating innovative impressing spaces. Such a system has a wide application, for example, for free-flowing interior spaces buildings: auditoriums, sport facilities, public infrastructures and so on.[50]

Thin shell structures emerged in 1930s, with the desire to cover wide spans in an efficient manner.[51] A general definition of thin shell structures, which often referred as concrete shell structures as well, consists of a curved surface which affects its strength and stiffness, and relatively small thickness as compared to its other dimensions.[52] In terms of tectonics there is a certain parallelism between Free Form Architecture and concrete shell structures due to their complete understanding of structural continuity. The thin shell structure needs to be structurally continuous, and

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[49] Eekhout and Wichers, op. cit

[50] Pastore, Luisa, and Rossella Corrao. 2010. "Filigree Constructions vs Solid Constructions. The Relationship Between Structure and Architecture in the Contemporary Age." In *Structures and Architecture*.
https://www.researchgate.net/publication/272500613_Filigree_constructions_vs_solid_constructions_The_relationship_between_structure_and_architecture_in_the_contemporary_age.

[51] Huijben, Frank, Frans van Herwijen, and Rob Njsse. 2011. "Concrete Structures Revisited: Introducing a New 'Low-Tech' Construction Method Using Vacuumatics Formwork." https://www.researchgate.net/publication/254902140_Concrete_Shell_Structures_Revisited_Introducing_a_New_and_'Low-Tech'_Construction_Method_Using_Vacuumatics_Formwork.

[52] Asmaljee, Zaahir. 2013. "Form-Finding of Thin Shell Structures." Dissertation. University of the Witwatersrand. . http://wiredspace.wits.ac.za/bitstream/handle/10539/13732/Form-Finding of Thin Shell Structures - Zaahir Asmaljee.pdf?sequence=2&isAllowed=y.

this continuity requires that the forces within the surface of the shell should be able to be transmitted in a number of different directions.[53]

There were different methods to design and calculate the shells. Between 1930-1950, design process of the shell structures was mainly based on mathematically defined geometries.[54] Anton Tedesko, Eduardo Torroja and Pier Luigi Nervi are well-known engineers who designed and calculated extremely elegant concrete shells in early 20th century. The Spanish architect Felix Candela is considered as the master of thin reinforced concrete shells.[55] Los Manantiales Restaurant can be shown as most well-known and successful example of this approach (*Figure 2.1*).

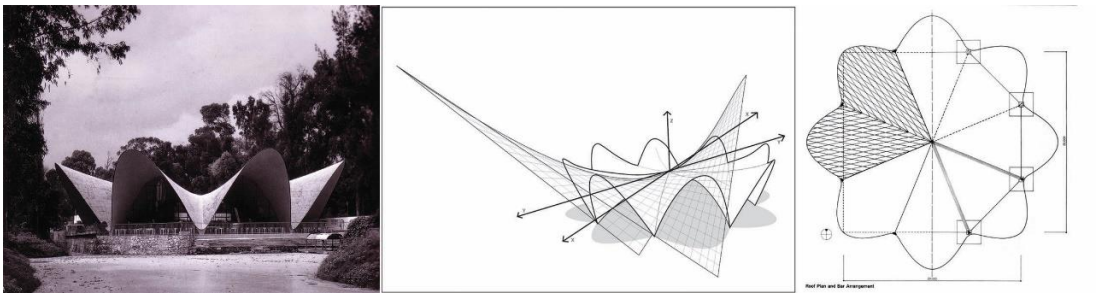

Figure 2.1. Los Manantiales Restaurant in Xochimilco Mexico City by Felix Candela

Source: https://www.archdaily.com/496202/ad-classics-los-manantiales-felix-candela

In the 1950s, the well-known engineer Heinz Isler followed a different approach for designing thin shell structures that was based on physical experiments rather than using mathematical calculations (*Figure 2.2*), which was most widely used in form making of tennis and sports halls.[56] His approach is explained in detail by Huijben, van Herwijen and Nisse as follows:

[53] Ibid.
[54] Huijben, van Herwijen and Nisse, op. cit.
[55] Chilton, John, and Chu Chun Chuang. 2017. "Rooted in Nature: Aesthetics, Geometry and Structure in the Shells of Heinz Isler." *Nexus Nerwork Journal*, November, 763–85. https://doi.org/10.1007/s00004-017-0357-5.
[56] Ibid.

> In the spirit of Antonio Gaudi's hanging models, [Isler] successfully applied several 'natural' phenomena, like air pressure, gravity and material flow, to design thin concrete shells. Due to the experimental character of his approach, these shapes can be referred to as 'Experimental Forms'. Structural calculations were made by conducting load tests on small-scale models which were interpreted for the design of the full-scale concrete structure.[57]

Figure 2.2. Isler's Experimental Forms, based on air pressure, gravity and material flow[58]

By the end of 1950s, the interest in concrete thin shell structures suddenly waded. In the late 1960s, complex timber shell structures appeared especially by the works of German architect Frei Otto.[59] In general it is possible to say that shell structures in the first half of the 20th century were structure based building skins dominating the architectural expression, whose three dimensional form was generally determined by the engineer rather than the architect.[60]The rapidly escalating development in technology brought a new approach to the concept of the shell in the 1990s often referred as sculptural forms whose concern was form and aesthetics, more than structural efficiency.[61]

The evolution of the shell topologies resulted in complex architectural geometries consisting of different structural systems in the contemporary age.[62] The fact that in 20thcentury, shell structures were generally designed for single space requiring functions, aiming to cover wide spans, makes a research required on the contemporary Free Form Architecture's space organization and spatial characteristics aspects. Thin

[57] Huijben, van Herwijen and Nisse, op. cit.
[58] Ibid.
[59] Pastore and Corrao, op. cit.
[60] Chilton and Chuang, op.cit.
[61] Huijben, van Herwijen and Nisse, op. cit.
[62] Pastore and Corrao, op. cit.

shell structures can be defined as the precedent of the Free Form Architecture despite the evident scale and program differences between them.

The second influential factor listed is Sydney Opera House by Jorn Utzon (*Figure 2.3*). It is also one of the most significant architectural works of the advancing technology and consideration of aesthetics in the late 20thcentury, as mentioned above. The most important impact of Sydney Opera House is announcing the opportunity of realizing the potential future of the architecture. It showed that a new stage of architecture was emerging.[63]

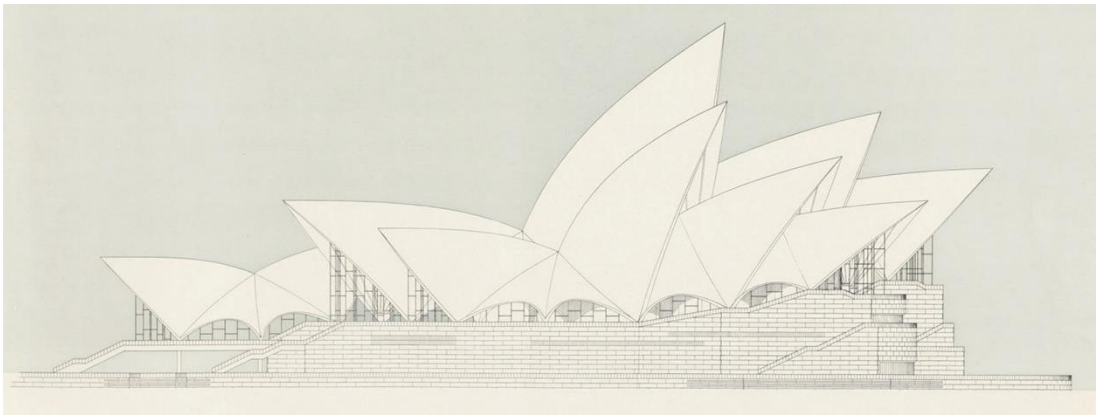

Figure 2.3. Elevation Drawing of Sydney Opera House[64]

The conception and construction process of the master piece was a journey starting form late 1950s to 1970s. It was no doubt a difficult and collaborative engineering work. From the very beginning it was apparent that it had the opportunity of being one of the world's great buildings with regard to the mathematically systematic design approach which lies behind its provocative appearance (*Figure 2.4*).[65] In terms of conception it was incredibly innovative, however, the construction period was

[63] Mosoarca, Anastasiadis and Apostolos, op. cit.
[64] Utzon, Jorn. 1958. *Sydney National Opera House*.
[65] Murray, Peter. 2004. *The Saga of Sydney Opera House the Dramatic Story of the Design and Construction of the Icon of Modern Australia*. London: Spon Press.

conflictive and expensive.[66] Baldassini and Potmann point out the importance and difficulties of Sydney Opera House as follows:

> Concerning modern architecture, if we want to pinpoint the beginning of free-form design, we have to refer to the Sydney Opera House, a case that also demonstrated the difficulties of coupling architectural expression with structural and technological constraints. That difficulty is well represented in the long evolution of the shape, the endless site and the constantly increasing budget.[67]

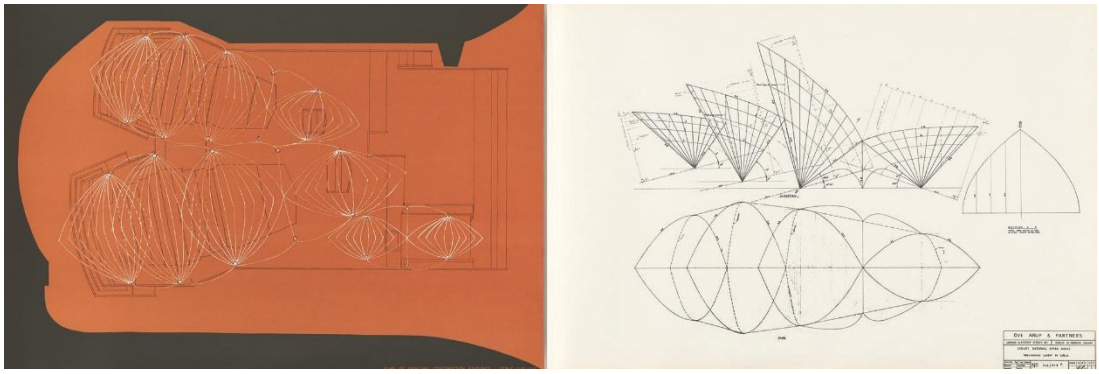

Figure 2.4. Principle Construction Drawings of Sydney Opera House[68]

These rationalization and construction difficulties are indicative of the future problems of Free Form Architecture in terms of construction.

Another important influential characteristics of Sydney Opera House is its 'iconic value'. The iconic value here refers to a meaning related to fame, symbolism and aesthetic quality.[69] When it is combined with the innovation, it is not a surprise for Sydney Opera House to become an icon. After the construction it shortly became a landmark, and serves as a symbol for both Sydney and Australia.[70] Since the most significant feature of 21st century is to be unique and iconic, Sydney Opera House can be regarded as precedent of the signature architectural understanding.

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[66] Ibid.
[67] Baldassini and Pottmann, op. cit.
[68] Utzon, op. cit.
[69] Sklair, Leslie. 2006. "Iconic Architecture and Capitalist Globalization." *City*10 (1). http://dx.doi.org/10.1080/13604810600594613.
[70] Colbert, François. 2003. "The Sydney Opera House: An Australian Icon." *International Journal of Arts Management*5 (2): 69–77. http://neumann.hec.ca/artsmanagement/articles/06 Colbert.pdf.

The third and the final influential factor is the Deconstructivist Architecture Exhibition at the MoMA. At the MoMA exhibition, in June 1988, the term 'Deconstructivist' was introduced to describe the works of the participant architects - Frank O. Gehry, Daniel Libeskind, Rem Koolhaas, Peter Eisenman, Zaha Hadid, Coop Himmelblau and Bernard Tschumi - who are strikingly different from each other and moving in different directions.[71] The reason behind their communality was the reaction against the dominance of pure forms.[72] What was established in MoMA under the name of Deconstructivist Architecture was not a new style.[73] According to Philip Johnson: "Deconstructivist architecture represents no movement; it is not a creed. It has no "three rules" of compliances. It is not even "seven architects"."[74]Therefore, Free Form Architecture means not only a description of the geometric characteristics of architectural form but also a symbolic act of freeing architecture from the limitations of pure form.[75] Horn argues further by saying:

> Cut to the mid-nineties. With the 'Decon' show at the MoMA now history and the digital revolution lurking on the horizon, architecture occupied a tenuous position between a recent past that relieved it of "the burden to mean" and a future where new technologies promised to make the expression of almost anything possible. It is at this moment when, in the vacuum created by the postmodern project, and for the first time in history, a form was created that appeared to be completely a-signifying.[76]

The architects named above have expanded beyond the field of architecture and have become influential figures in global art and culture.[77] Their works have shaped the current state of contemporary Free Form Architecture.

[71] Wong, op. cit.
[72] Ibid.
[73] Johnson, Philip, and Mark Wigley. 1988. *Deconstructivist Architecture*. New York: Eastern Press. https://www.moma.org/documents/moma_catalogue_1813_300062863.pdf.
[74] Ibid.
[75] Wong, op. cit.
[76] Horn, op. cit.
[77] Ibid.

Figure 2.5. Guggenheim Museum by Frank Gehry, in Bilbao

Source: https://www.archdaily.com/422470/ad-classics-the-guggenheim-museum-bilbao-frank-gehry

In 1997, a Free Form building was designed and realized: Guggenheim Museum of Frank O. Gehry in Bilbao (*Figure 2.5*). The impact of the building could be expressed by saying "Although architecture critics on the work of Gehry could have expected this type of building, its extreme contrast in form and prominent location just outside the 19th and 20th century city of Bilbao shook the world of Architecture."[78] The museum is located in an industrial city which was rather insignificant at that time. The very contrast between the building form and existing built environment was notable.[79] This architectural work of Frank Gehry demonstrated the possibilities and brought them to the wide public attention.[80] The courageous, innovative and unique formal features of the building made it a symbol of the city. In this sense the iconic value of the building expended worldwide, even contributing to a term called 'Bilbao effect' to the literature of architecture.

Overall, after studying different periods and different events of the last century, it is possible to say that 20thcentury gave birth to a new formal expression in architecture.

2.1.2. Current State of 21st Century

[78] Eekhout, et al., op. cit.
[79] Ibid.
[80] Terzidis, Kostas. 2005. *Expressive Form. A Conceptual Approach to Computational Design*. Spon Press. https://epdf.tips/expressive-form-a-conceptual-approach-to-computational-design.html.

In the 21st century, Free Form Architecture has started to dominate both the practice and education of architectural design.[81] Complex free form structures can be regarded as one of the most striking features in contemporary architecture.[82]

The technological advances in digital design tools have also gained pace. Formal liberation in architecture was interpreted as a liberation from semantics, history, and culture and this radical ambiguity of meaning became unbearable by architects.[83] The absence of reasoning was quickly filled in by organic, biological and process based design approaches by courtesy of digital advances.[84] Consequently, there arose a need to generate new languages for architectural design. Islami explains further:

> In this era of digital and technological advancement, architects are beginning to examine notions of boundary, with specific attention given to the architectural surface. While in early twentieth century, modernists sought to convey deep space through the use of transparent materials, today, architects attempt to compress allusions to the depth of the interior into the surface of a building. Such shifts in architectural practice are the result of two related factors: the changing attitude towards binary oppositions in philosophy and architectural theory, and more importantly, the development of new technologies for architectural design and construction.[85]

Contemporary architecture is becoming a process of surfacing.[86] The virtual space, one of the contributions of computer based technologies, has allowed the experimentation on extraordinary complex geometries and the increasing flexibility in generation of computer based surfaces.[87] Most of these geometries' design considerations were not based on constructability. This is because digital tools advancing faster that the construction techniques required to realize the designed architectural forms. This resulted in a gap between the conception and production of

[81] Wong, op. cit.
[82] Pottmann, Schiftner, and Wallner, op. cit.
[83] Silvetti, Jorge. 2003. "The Muses Are Not Amused: Pandemonium in the House of Architecture." *Harvard Design Magazine*19.
[84] Ibid.
[85]Islami, Yahya S. n.d. "Digital Surfacing," 263–67. https://e-pub.uni-weimar.de/opus4/frontdoor/deliver/index/docId/1334/file/islami_pdfa.pdf.
[86] Islami, Yahya S. 2007. "Surface-Driven Architecture. Moving Beyond the Ornament/Structure Opposition," 671–82.
[87] Marcos op. cit.

free forms.[88] As the realization process is more difficult and expensive as compared to simpler architectural forms, Free Form Designs posed many challenges in terms of architecture, engineering, manufacturing and contracting.[89] So, architecture mainly focused on narrowing the gap between conception and construction.

2.2. Common Study Fields on Free Form Architecture

It is evident that the use of digital tools has an enormous influence on the 21st century Free Form Architecture. The relationship between information and conceptualization of design defines the process from idea to form.[90] Digital advances offered architects endless opportunities in terms of geometric configurations, surface expression and the temporal aspects of design.[91] However, the existing construction methods and technologies could not yet cope with the highly complex geometries.[92] The gap mentioned in the previous section was most apparent during the construction of Guggenheim Museum in Bilbao. The Guggenheim was built with conventional construction techniques and materials but following the other designs generated with the digital tools and desires, the need of the development of Free Form Technology became apparent.[93] In the early stages Free Form Designs caused many problems in the construction phase, therefore among builders they had the popular nickname 'Free Form Nightmares'.[94]

Following the realization of the gap, digital tools have evolved to bring solutions to the problem of production. CAD/CAM technologies provided new opportunities for

[88] Eekhout, et al., op. cit.
[89] Ibid.
[90] Kızılcan, Egemen Berker. 2015. "Complexity Management and Mutuability in Architectural Form Conception: Form-Blindness and Softform." Dissertation. Middle East Thechnical University. . http://etd.lib.metu.edu.tr/upload/12619094/index.pdf.
[91] Islami "Digital Surfacing", op. cit.
[92] Hu, Yongheng, and Qinying Li. 2014. "Integrating the Tectonics in Architectural Design. A Study on the View of Structural Performance Design Work-Flow for Agent-Based Architecture," 433–42. http://anzasca.net/wp-content/uploads/2014/12/09_34_86.pdf.
[93] Eekhout, et al., op. cit.
[94] Ibid.

production and construction of complex forms.[95] So, it is possible to say that technological advances and digital tools are used for both conceptualization (digital design process) and realization (construction process) of the architectural products. According to Wong: "[…] there are two types of digital architect: those who use the computer to generate form and those who use the computer to rationalize form."[96]

With the increase in the importance of structure and materials, digital design evolved into digital tectonics which has led to the synthesis of architecture and structural engineering.[97] The development of digital tools and the concerns about production and materiality brought a change of paradigm which is not based on material itself but a conceptual revolution about a construction aware design process.[98] Balinski and Januszkiewicz explains this change as:

> These new architectures emerging from new kinds of industrial production and design tools require new thinking and conceptions of architecture both from the perspective of the designer and the person experiencing the built environment. Growing out of the analogue digital tectonics becomes the primary factor in modern thinking, designing and constructing buildings. One can only expect its impact to bring new materials, technologies and design tools, and even more interesting buildings.[99]

The architectural works of 21st century proves that computer based digital architecture techniques are not only a tool for design but also a new inspiring way of creative thinking by means of producing the logic behind even more complex forms.[100]

In light of all these developments and changes in Free Form Architecture, the surveys, works, and researches mainly focus on the use of digital tools. The works and

[95] Balinski, Grzegorz, and Krystyna Januszkiewicz. 2016. "Digital Tectonic Design as a New Approach to Architectural Design Methodology." *Procedia Engineering*161: 1504–8. https://www.sciencedirect.com/science/article/pii/S1877705816328466.
[96] Wong, op. cit.
[97] Balinski and Januszkiewicz, op. cit.
[98] Marcos, op. cit.
[99] Balinski and Januszkiewicz, op. cit.
[100] Gao, op. cit.

researches of architectural field mostly gathers around the two parts of the Free Form Architecture: digital design, representation, rationalization, and performance.

2.2.1. Digital Architectural Design in Free Form Architecture

20th century architecture has witnessed a transition to a more complex design approach in terms of exploration and representation.[101] This transition increases the importance of digital technologies operationalized during the design process. Architectural design complexity has been dependent on the virtual space and 3D modelling offered by digital media.[102] With accordance to this, it is possible to say that computation forms the basis of the digital activities of contemporary architecture. As Gürsel Dino notes:

> Computational systems have emerged as a fundamental keystone in architectural design during the last decades, marking the rise of a new area of study that engages with design cognition, computation and generative principles in contemporary design practice.[103]

Such a computational practice in architectural domain finds itself a formation called Digital Design. In order to make a definition of digital design one can address the explanation of Oxman:

> By the year 2003 with the Non-Standard Architectures Exhibition at the Pompidou Center in Paris, the concept of non-standard, non-normative, non-repetitive design had become a major theoretical focus of this new phenomenon - recognized today as digital design.[104]

She also defines the components of digital design as representation, generation, evaluation, and performance.[105]

The role of digital design is not only related with the architectural end product. The word ‘design’ covers both the act of designing an object and the end result of the act

[101] Abdelhameed, op. cit.
[102] Marcos, op. cit.
[103] Gürsel Dino, İpek. 2012. “Creative Design Exploration by Parametric Generative Systems in Architecture.” *METU Journal of the Faculty of Architecture*29 (1): 207–24. https://doi.org/10.4305 / METU.JFA.2012.1.12.
[104] Oxman, Rivka. 2006. “Theory and Design in the First Digital Age.” *Design Studies*27 (3): 229–65. https://doi.org/10.1016/j.destud.2005.11.002.
[105] Ibid.

of design simultaneously.[106] Since digital design covers the generation process also, understanding of computational design along with the computational tools requires an evolution of designing not only the end product but also designing the process.[107]

By the use of computer software, a great control over the special and logical manipulation of design can be achieved.[108] In the manipulation of the computational models, new interfaces between different domains and the use of mathematics play a crucial role requiring algorithmic thinking and parameterization skills for the designer.[109] The new and innovative mode of design thinking with a certain set of operations and parameters which are algorithmically based, offers an increased computational control over design geometry during design activity.[110] Parametric approaches are based on defining relationships between elements and groups of elements, and assigning values of expressions to organize and control those definitions through programming and coding.[111] Gürsel Dino indicates further: "Their adaptability and responsiveness to changing design criteria and requirements make parametric models especially useful for design exploration in complex and dynamic design settings."[112]

Since the basis of digital design is the technological advances, it is important for architects to be up to date. Technology progresses every day. It is possible to say that there is a growing amplitude of issues and subjects in digital design.[113] Moreover, there is a certain demand about the computational thinking in architectural domain requiring more attention.[114] In the new design possibilities as represented by dramatic

[106] Gürsel Dino, op. cit.
[107] Sorguç, Arzu Gönenç, and Semra Arslan Selçuk. 2013. "Computational Models in Architecture: Understanding Multi-Dimensionality and Mapping." *Nexus Network Journal*, August. https://doi.org/10.1007/s00004-013-0150-z.
[108] Gao, op. cit.
[109] Sorguç, op. cit.
[110] Gürsel Dino, op. cit.
[111] Chen, Lim and Shao, op cit.
[112] Gürsel Dino, op. cit.
[113] Oxman 2006, op. cit.
[114] Sorguç, op. cit.

form-generative potential, a high level of publication on the subject has occurred.[115] A significant portion of architectural studies and researches are based on the digital advances.

2.2.2. Representation

> The nature of the task of representing architecture alters to reflect the state of architecture at each period of time. In simulating architecture, the necessary conversion from that which is inhabitable, experiential, functional, and at times, indescribable to an abstraction in an entirely different media is often an imperfect procedure that centers on its translation rather than the actual design.[116]

Traditionally, the main application of architectural representation has been representing the form of the architectural work for the dual purpose of explaining the cognitive and conceptual processes and communicating design ideas.[117] Achieving a situational awareness that allows for meaningful criticism of the design is the objective in visualizing any architectural work.[118] For the last decades CAD modelling systems are the most used representation tools based on the axonometric drawing and parallel projection rules. While CAD drawings are efficient for design communication, it is not the same for the representation of the cognitive processes. CAD modelling produces definitive geometric forms striping away ambiguity while creating a contrast to the indeterminacy of physical based activities and artifacts.[119]

It is evident that use of computer technologies has expanded its boundaries of operation beyond traditional production drawings.[120] Digital three dimensional

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[115] Oxman 2006, op. cit.
[116] Kalisperis, Loukas N., and Anastasia Pehlivanidou-Liakata. 1998. "Architectural Design Studio: Digital and Traditional." https://www.researchgate.net/publication/30871435_Architectural_Design_Studio_Digital_and_Traditional.
[117] Koutamanis, Alexander. 2000. "Digital Architectural Visualization." *Automation in Construction*9: 347–60.
[118] Kalisperis and Pehlivanidou-Liakata, op. cit.
[119] Shelden, Dennis R. 2002. "Digital Surface Representation and the Constructibility of Gehry's Architecture." Dissertation. Masachusetts Institute of Technology. .
[120] Uddin, Saleh. 2000. "Beyond Mere Representation: The Changing Perspective of Computer Use in American Architecture." In *Architectural Computing: The Rendered Image*, 511–18.

visualization technology contributed new representation techniques to the world of architecture. Computer aided design applications provide the ability to design intension and conceptual features without recourse to two dimensional representations.[121] They offer unattainable qualities such as motion, texture, and real-time shadows to further enhance situational awareness.[122] In this manner, visualization has a significant role in understanding and controlling of complex processes.[123] Since Free Form Architecture is constitute of complex design processes resulting in complex geometries, it must be represented three dimensionally. In order to represent the expression of the spatial relationship between the various elevations, three dimensional models are essential.[124] When the spatial information of the complex geometries are delivered through suitable tools, it can simulate depth which is one of the most important component of spatial cognition.[125] Another outstanding characteristic of Free Form Architecture is the notion of expression and emotion. When free form is represented in a digital environment three dimensionally, it can be full of emotion using a very active and direct method to affect immediate changes and thus displaying emotion in design.[126] As a result dynamic visualization can be presented as the pinnacle of architectural representation.[127]

Architectural representation is a constantly evolving area as architectural design itself. As explained above, different eras, different design methods, and different design products require different representation techniques. As the quality of design that is wanted to be presented increases the previous method would remain insufficient. Thus, it brings endless opportunities to evolve and progress the techniques.

[121] Shelden, op. cit.
[122] Kalisperis and Pehlivanidou-Liakata, op. cit.
[123] Koutamanis, op. cit.
[124] Chen, Lim and Shao, op. cit.
[125] Kalisperis and Pehlivanidou-Liakata, op. cit.
[126] Gao, op. cit.
[127] Koutamanis, op. cit.

2.2.3. Rationalization

The previously mentioned gap between the conceptualization and realization of Free Form architecture has led to a new area of research and experimentation for both architects and engineers. In order to tackle the problems regarding the rationalization of free forms, rational and systematic approaches and a full understanding of architectural geometry is necessary.[128] Since architectural works made up of highly complex geometries are often unique solutions, their structural solutions become as unique as the design itself. Complex forms typically require custom structural systems and building systems in a one-project setting: Non-repetitive and arbitrary curved forms increase the cost, time, effort and waste during the processes of architectural and structural design, manufacturing, optimization and construction.[129] Moreover, these unique design solutions are often very difficult to operate and expensive. So, as design conception changed with the technology, it forced a change with respect to materiality and construction as well.[130]

Realizing Free Form Architecture often requires the transfer and adaptation of technologies used by other industries also.[131] But the most important thing would be to make use of modern technologies for further implications. "[…] the use of modern technology means considering how to use new techniques, new materials and new building methods to produce structural harmony […]."[132]

There are two aspects of this issue: structure and material. From the structural part, it is possible to say that with Free Form Architecture established a new way of construction. As mentioned in the previous sections, free forms have evolved to an architecture of surface. The structural difference that has been brought by free forms is that a main structural system depending on surface geometry in contrast to the

[128] Wallner, Johannes, and Helmut Pottmann. 2011. "Geometric Computing for Freeform Architecture." *Journal of Mathematics in Industry*1 (4): 1–19. https://doi.org/10.1186/2190-5983-1-4.
[129] Veltkamp, Martijn. 2007. "Free Form Structural Design: Schemes, Systems & Prototypes of Structures for Irregular Shaped Buildings." Dissertation, Delft University Press. Delft University. .
[130] Marcos, op. cit.
[131] Eekhout and Wichers, op. cit
[132] Gao, op. cit.

conventional frame approach of construction.[133] The most common attitude toward realization of Free Form Architecture is the rationalization of the form for construction which is completely independent from the conception process. However, what is more evolutionary from producing solution to the already design buildings is that the involvement of load calculation principles via digital tools to the design process. Marcos indicates further:

> […] computers have also allowed calculating enormously complex systems of loads and stresses, and computerized robots have been able to manage the positioning and assembly of the customized constructive elements. We can refer to digital consciousness as the awareness on digital computing enhancements applied to architectural design. Thus, digitally conscious architectural design challenges modernist paradigm and proposes a new grammar in accordance with digital culture.[134]

There is an evolving methodology called 'digital tectonics' which aims to integrate use of design software with traditional construction methods. With this methodology, computer aided fabrication techniques serve as an integral part of design process, allowing architects and engineers to comprehend the behavior of load bearing surfaces, and to generate new architectural forms.[135]

From the materiality point of view, with the experimental conceptions and the realization of complex geometries draw attention more than ever to new materials and concepts.[136] In terms of the relationship between material and architectural design realization there are two types of approaches: designing the material in order to reduce the dependency of architecture to material, and designing according to the material properties. In the former, which is less common, the building process shifts from the building site to the factory.[137] It is also referred as info-material revolution, in which

[133] Ibid.
[134] Marcos, op. cit.
[135] Balinski and Januszkiewicz, op. cit.
[136] Schittich, op. cit.
[137] Schittich, Christian, Werner Lang, and Roland Krippner. 2012. "Materials in the Building Skin – From Material to Construction." Essay. In *In Detail Building Skins*, 60–69. Basel: Birkhäuser.

designers of material plays a central role.[138] The latter, which is more commonly used especially in digital tectonics, focuses on the role and applications of materials and technology in creation of contemporary architecture.[139] This approach opens the door for a material-based design understanding which can be defined as "[…] a computational informing process that enhances the integration between structure, material, and form within the logic of fabrication technologies."[140]

Oxman explains further the evolution of the approaches towards material and tectonics as follows:

> The growing affinity between the interest in the role of materials in design and in the relationship to tectonics has produced a "new materiality". The emerging new synthesis of material in design is resulting in the formulation of conceptual principles of the formal, structural and material in new digital orders. Furthermore, the logic of these structural and material principles is recently becoming integrated within the rationale of emerging fabrication technologies, thus enriching the possibility of the potential integration of design with fabrication and production.[141]

Realization of an architectural design could be defined as the last and one of the most important stages of designing process. Complex geometries always carry the risks of construction and cost efficiency. Since rationalization is the most problematic part of the Free Form Architecture, the most significant density of studies and researches appears on this aspect of the issue.

2.2.4. Performance Based Architectural Design and Free Form Architecture

The interrelations of an architectural work with its surrounding environment and conditions have been one of the major aspects of the architectural design process. Considering the great human contribution to the global warming and climate change in terms of building industry, it becomes impossible to remain indifferent to the

[138] Lorenzo-Eiroa, Pablo, and Aaron Sprecher. 2013. *Architecture in Formation, On the Nature of Information in Digital Architecture*. https://www.taylorfrancis.com/books/9781134502837.
[139] Schittich, Lang and Krippner, op. cit.
[140] Oxman, Rivka. 2012. "Informed Tectonics in Material-Based Design." *Design Studies*33 (5): 427–55.
[141] Ibid.

environmental issues from the perspective of architects and engineers. Towards the end of the 20th century, the concept of sustainability is introduced to both the consciousness of architects and the discourse of architecture, representing a revised conceptualization of architecture in response to a myriad of contemporary concerns about the effects of human activity.[142] Sustainability in architecture aims to indicate not only sustainability as a discipline but also a product of the discipline.[143] As the building industry, including architecture, engineering and construction, embraces the awareness of sustainable and low-carbon era, the notion of performance in architecture has drawn more attention than ever.[144] Performance as a concept evolved out of a series of intellectual efforts commenced in the 1940s and 1950s brought a paradigm shift in the humanities referred to as the 'performative turn'.[145] The current interest in building performance as a design paradigm related to the emergence of sustainability, is framed within an expansive context including financial, spatial, social and cultural, and purely technical realms.[146] In this context, it is possible to say that the understanding of good architecture has shifted to the notion of a building that is sensitive to its environment.[147] Achieving high performance level in buildings has become a major challenge. In this new understanding, building designers are encouraged to design buildings that fulfil user expectations with regard to the quality of the indoor climate and environment contributing to a sustainable development.[148] So, the potentials and opportunities of performance oriented architectural concerns for

[142] Williamson, Terry, Anthony Radford, and Helen Bennetts. 2004. *Understanding Sustainable Architecture*. London: Spon Press. https://www.researchgate.net/publication/236854170_Understanding_Sustainable_Architecture.
[143] Ibid.
[144] Shi, Xing. 2010. "Performance-Based and Performance-Driven Architectural Design and Optimization," 512–18. https://doi.org/10.1007/s11709-010-0090-6.
[145] Hensel, Michael U. 2010. "Performance-Oriented Architecture. Towards a Biological Paradigm for Architectural Design and the Built Environment." *Form Akademisk*3 (1): 36–56. https://www.researchgate.net/publication/282770255_Performance-oriented_Architecture_-_Towards_a_Biological_Paradigm_for_Architectural_Design_and_the_Built_Environment.
[146] Kolarevic, Branko. 2004. "Back to the Future: Performative Architecture." *Internatinal Journal of Architectural Computing*2 (1): 43–50. https://pdfs.semanticscholar.org/aa6a/c70006e5269545bb71f3e55b2abcfd51c6ba.pdf.
[147] Williamson, Radford and Bennetts, op. cit.
[148] Peterson, Steffen, Jacob Bryder, Kristian Levinsen, and Jon Strunge. 2014. "Method for Integrating Simulation-Based Support in the Building Design Process," 83–89.

reducing the negative environmental impact and improving the energy efficiency of the built environment is on focus in many architectural researches.[149]

The rise of the concept of performance in architecture proposes that computer based architecture transforms notions in the architectural discourse towards performance.[150] The developments in the theory and technology of digital architectural design plays a great role in the emergence of performative design.[151] Oxman explains further the term performative:

> The term performative may represent a synthesis of two of the essential characteristics of digital design. Digital design processes support transformation and generation of a geometrical model and they support analytical evaluation of environmental performance based upon simulating physical conditions such as solar or structural loadings. It is the potential of an integration of evaluative simulation processes with digital 'form generation' and 'form modification' models that is implied by the term Performative Design. The term further implies that performance can in itself become a determinant and method for the creation of architectural form.[152]

In terms of digital architectural design, computation, in analytical and generative modes, has a key role in both the logics of how material constructions are made and the way they will interact with environment.[153] "Today, digital quantitative and qualitative performance-based simulation represents the technological foundation of the emerging performative architecture described earlier."[154] The quantitative evaluations of specific design propositions can be qualitatively assessed by courtesy of the developments on graphic output and visualization techniques.[155] Although

[149] Gürsel Dino, İpek. 2010. *CLIP: Computational Support for Lifecycle Integral Building Performance Assessment*.TU Delft
[150] Grobman, Yasha J., and Eran Neuman. 2012. *Performalism: Form and Performance in Digital Architecture*. Routledge.
[151] Oxman, Rivka. 2008. "Performance-Based Design: Current Practices and Research Issues." *International Journal of Architectural Computing*6 (1).
[152] Ibid.
[153] Hensel, Michael, and Achim Menges. 2008. "Inclusive Performance: Efficiency Versus Effectiveness. Towards a Morpho-Ecological Approach for Design ." *Architectural Design*78 (2): 54–63. https://doi.org/10.1002/ad.642.
[154] Kolarevic, op. cit.
[155] Ibid.

designers can assess certain performative aspects of their projects with digital analytical tools, after the initial design is developed these tools would not be helpful in terms of providing dynamic generative capabilities that could open up new territories for conceptual exploration in architectural design.[156] Therefore, designers need to integrate the assessments and digital evaluations to the early design phases by knowing how potential design decisions would affect the quality of the indoor climate and environment as well as energy performance.[157]

Performative architecture should not be regarded as a problem solving method to be applied on already existing design proposals. Form generation process based on performative strategies of design that are grounded in quantifiable and qualifiable performative aspects of building design is the main objective here.[158]

As Grobman and Neuman states: "[…] with the advent of digital media technologies and the ability to conceptualize, express and produce complex forms using digital means, the question of the status of the architectural form is once again under consideration."[159] Performative architecture establishes a main change in architectural conception by using building performance as a guiding design principle. Therefore, performative architectural design approach and its form generative methods can be used to answer the questions concerning the method of form expression in contemporary Free Form Architecture. Thus, a great portion of architectural research focuses on performative architecture in terms of the form generation principles of Free Form Architecture.

2.3. Research Ground

Regarding Free Form Architecture as a new approach to form generation, form reasoning process gains importance. As can be derived from the common study fields on Free Form Architecture, various approaches can be applied to design process

[156] Ibid.
[157] Peterson et. al., op. cit.
[158] Kolarevic, op. cit.
[159] Grobman and Neuman, op. cit.

concerning various aspects of architectural design. These approaches can be based on aesthetical characteristics of the architectural works by benefiting and exploring the possibilities of digital architectural design, or they can be concerning tectonic solutions and be based on rationalization process of architectural design, or they can be focusing on the performative aspects, since aesthetics, tectonics, and performance are integral parts of architectural design. On the other hand, while the progress and opportunities is valuable, the question about the space characteristics that have been provided by Contemporary Free Form Architecture remains. Since architecture is an act of creating space, space is of upmost importance in architecture. So, as this thesis aims at exploring the relationship between the building skin and interior spaces, it would be necessary to explore the spatial characteristics on Free Form Architectural works. The following chapter will be focusing on this issue starting from architectural space generation to the space-boundary relationship.

CHAPTER 3

FORM AND SPACE

Architecture expresses itself with spatial means.[160] Space is such an integral part of architectural thinking that architects are practically incapable of thinking about it at all without putting the main emphasis on the spatial displacement of the subject in time.[161] Moreover, Edmund Bacon defines architecture as the articulation of space.[162] Such articulation is achieved through formal expression. The interrelation of form and space composes the dynamics of architecture. Thus, form and space are the critical aspects of architecture, not regarded as ends in themselves but as means to solve an architectural problem.[163] Form is the primary identifier of a volume and it describes the boundaries of the volume through the interrelations of the planes and surfaces.[164] So, architectural form is the point of contact between mass and space and can be defined as the expression of philosophical interactions of the forces of mass and space.[165] Form suggests reference to both the internal structure and the external form indicating not only the three dimensional mass or volume but also the configuration of the contours that delimit the architectural space.[166] In terms of space definition and space quality of an architectural work, the features of the bounding form are as important as the form itself. In Edmund Bacon words:

> Architectural forms, textures, materials, modulation of light and shade, color, all combine to inject a quality or spirit that articulates space. The quality of the architecture will be determined by the skill of the designer in using and

[160] Hertzberger, 2000, op. cit.
[161] Frampton, Kenneth. 1995. *Studies in Tectonic Culture: The Poetics of Construction in Nineteenth and Twentieth Century Architecture*. Chicago, IL: Graham Foundation for Advanced Studies in the Fine Arts.
[162] Bacon, op. cit.
[163] Ching, op. cit.
[164] Ibid.
[165] Bacon, op. cit.
[166] Ching, op. cit.

> relating these elements, both in the interior spaces and in the spaces around buildings.[167]

The term space articulation comprises both interior and exterior space defined by the architectural mass. As this thesis particularly focuses on interior spaces, this chapter aims to study the relationship between the form defined by the building skin and the characteristics of interior spaces in terms of space definition and perception.

In order to be able to analyze the relationships mentioned before, this chapter firstly explores how architectural space can be defined with respect to the space defining elements, aiming to provide a perspective towards the form of the building skin as a defining element of the interior space by considering surface articulation, functional differences of spaces, and internal spatial relationships of architectural spaces. Secondly, the performative aspects of the building skin will be discussed since performative concerns plays a great role in the design process of the building skin including surface articulation and configuration. The final aspect that will be covered in this chapter is the visual perception of the building skin, which is critical in defining a relationship between the skin and interior space. With accordance to the issues that will be discussed, this chapter aims to identify research considerations regarding the analysis of the relationship between the form of the building skin and interior space.

3.1. Architectural Space

Space can be defined as a self-contained entity, infinite of finite, an empty vehicle, ready and having the capacity to be filled with things.[168] The Platonic idea of space indicates a nothingness existing as an entity in the outer world and without the object it could hold space would still exist, as an empty, boundless container.[169] Physically, space is shaped by either what it is that surrounds it, or by the objects within it, as long as they are perceivable.[170] In other words, space is defined by the extension of material

[167] Bacon, op. cit.
[168] Arnheim, Rudolf. 2009. *The Dynamics of Architectural Form: Based on the 1975 Mary Duke Biddle Lectures at the Cooper Union*. Berkeley: Univ. of California Press.
[169] Ibid.
[170] Hertzberger 2000, op. cit.

bodies or fields bordering on each other.[171] Martin Heidegger provides another definition for space as follows:

> A space is something that has been made room for, something that is cleared and free, namely within a boundary, Greek peras. A boundary is not that at which something stops, but, as the Greeks recognized, the boundary is that from which something begins its presencing […] Space is in essence that for which room has been made, that which is let into its bounds.[172]

In the case of architectural space, the bounding material bodies are typically created by the contributions of architects. In architecture, a volume can be regarded as both a portion of space defined by the surfaces and quantity of space displaced by the mass of an architectural work.[173] So, space is both the medium and the outcome of the architectural design operations. The term *surface* means more than just a two dimensional geometry; it is essential the architectural element defining the boundary of a three dimensional void.[174] The primary purpose of existence of an architectural enclosure is the separation of interior from exterior space.[175]

The separation of interior from exterior space is only possible by space-defining architectural operations. At this point, it is important to focus on the ways in which space can be defined. As Simon Unwin indicates: "Often the materials and the way they are put together impose or suggest geometry. And the geometry of buildings conditions the shapes of the spaces they define."[176] In terms of space defining architectural elements, Francis Ching introduces three generic types of planes to define space: overhead plane, wall plane and base plane.[177] "The properties of each plane as well as their spatial relationship to one another ultimately determine the visual

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[171] Arnheim 2009, op. cit.
[172] Heidegger, Martin. 2001. "Building Dwelling Thinking." Essay. In *Poetry, Language, Thought*, 1. ed. Perennial Classics.
[173] Ching, op. cit.
[174] Ibid.
[175] Schwarzer, Mitchell W., and August Schmarsow. 1991. "The Emergence of Architectural Space: August Schmarsow's Theory of 'Raumgestaltung.'" *Assemblage*15 (August): 48–61. http://www.jstor.org/stable/3171125 .
[176] Unwin, op. cit.
[177] Ching, op. cit.

attributes of the form they define and the qualities of the spaces they enclose."[178] These three generic planes can be regarded as both exterior building envelope and interior partition elements. The formal manipulation of these planes contributes the characteristics of the space as long as they are perceivable by the user.

Similarly, Simon Unwin explores the space defining elements in his book *Analysing Architecture*. Unwin introduces the terms 'wall' and 'roof'[179] operating in a parallel logic with the planes of Ching, to explain and analyze building envelope. According to Unwin, wall is used to divide and contain acting as a barrier, and roof defines space beneath by providing a shelter from the forces of sky.[180] Walls (barriers) and roof (shelter) can be combined to form an enclosure by establishing a clear inside differentiated and separated from the outside.[181] The combination and manipulation of the planes introduced by Ching and elements used by Unwin is affected by the technical and digital opportunities of the architects.

As explained in the previous chapter, the use of digital technologies has widened the vocabulary of space defining elements and operations with which they can be realized. It is widely argued that the contemporary architecture has a tendency to define the building enclosure through geometrically complex building skins.[182] In this case these surfaces can be regarded as the combinations of planes defined by Ching. In the following sections, the functional differences of spaces, their organizational interrelations and the categorization of spatial forms will be examined.

3.1.1. Public, Private and In-Between Spaces

Every architectural work is associated with a certain program and utility requirement to a certain extent. "The first consideration of decisive importance in designing a space is what the space is intended for and what not, consequently what the proper size, is

[178] Ibid.
[179] Unwin, op. cit.
[180] Ibid.
[181] Ibid.
[182] Eekhout and Wichers, op. cit.

to be."[183] It is the architectural program and activities that primarily give rise to spatial differentiation in architecture.[184] Along the same line, it can be argued that different activities require different levels of privacy.

The concept of 'public' and 'private' can be regarded as corresponding to the spatial terms of 'collective' and 'individual'.[185] Private spaces are those that can be accessed by one person or a small group of people.[186] The exclusiveness of private spaces are established through patterns of use, creating a sense of belonging and promoting territorial behavior.[187] Public space, in contrast, is accessible to everyone at all or most of the times.[188] So, accessibility is the key to determine the privacy level of an architectural space. The functional distinctions and thresholds provides the key to transition and connection of spaces with different definitions.[189]

While private and public spaces represent two ends of a spectrum, a transitional concept is also present: 'in-between space'. Hertzberger explains further as such:

> The in-between concept is the key to eliminating the sharp division between areas with different territorial claims. The point is therefore to create intermediary spaces which, although on the administrative level belonging to either the private or the public domain, are equally accessible to both sides, that is to say that it is wholly acceptable to both that the 'other' makes use of them.[190]

Simon Unwin widens the definition of 'in-between space' by adding the transitionary means of it between outside and inside, and secular and sacred to between public and private.[191] Unwin defines in-between space as dynamic routes that people follow by

[183] Hertzberger, Herman. 2001. *Lessons for Students in Architecture*. 4. ed. Rotterdam: 010 Publishers.
[184] Bacon, op. cit.
[185] Hertzberger 2001, op. cit.
[186] Ibid.
[187] Madanipour, Ali. 2005. *Public and Private Spaces of the City*. London: Routledge.
[188] Hertzberger 2001, op. cit.
[189] Ibid.
[190] Ibid.
[191] Unwin, op. cit.

establishing hierarchies. But he also does not deny that an 'in-between' space can be a place in its own right, a zone not just for passing through but to stop.

The character of the spaces related to required privacy levels are determined and provided by the space defining architectural elements, which are previously mentioned. The features of the space enclosure would determine and be determined by the privacy level. The notion of privacy plays a crucial role in space articulation, the relationship of the space and boundary, and space organization. Spatial organization and interrelations of spaces are determined by the functional requirements of the program, privacy levels of spaces, and formal considerations.

3.1.2. Spatial Relationships

Space, as Hertzberger argues, should be articulated to create places, spatial units in appropriate dimensions and correct measure of enclosedness accommodating the pattern of relations of those who will use it.[192] Architecture can be regarded as a series of linked spaces, each possessing particular quality and each related to the other.[193]

Francis Ching introduces four main types of the spatial relationships: space within a space, adjacent spaces, interlocking spaces, and spaces linked by a common space.[194] A smaller space can be contained within the volume of a larger space indicating a space-within-a-space relationship. The containing space provides a ground for the contained one's relationship to the exterior environment. Such a distinction can only be perceivable if the differentiation in size is clearly perceivable. The distinction can indicate a symbolic importance or domination of the contained space. In the case of adjacent spaces, two space are completely separated and defined by the planes introduced in the previous section. This relationship allows each space to be clearly defined and respond to the functional requirements of the program. The visual and perceptional continuity of the spaces depends on the features of the space defining

[192] Hertzberger 2001, op. cit.
[193] Bacon op. cit.
[194] Ching op. cit.

elements. An interlocking spatial relationship occurs when two spatial units overlap and create a zone of shared space. The shared space may remain as a part of the two overlapping spaces or generate its own integrity as a space that links the two overlapping ones. The latter shows a similar character with the spatial relationship called spaces linked by a common space in which spaces are separated by distance and related to each other by a third intermediate space.

The four types of spatial relationships that are introduced by Ching mainly focuses on the horizontal relationships. However, Simon Unwin analyzes vertical spatial organizations of buildings under the term of 'stratification' in his book *Analysing Architecture*.[195] He approaches the vertical spatial relationships with regard to the organization of cellular spaces and attic spaces, and he also focuses on the relationship of these spaces with the form of the building skin. He explains his point of view towards the issue as such: "Stratification is more about the differences in experience it provides at the different levels of a building than it is about appearance."[196]

One of the many cases examined in Unwin's book is a small house designed by the Italian architect Marco Zanuso and built near Lake Como in 1981. Unwin mentions the use of gallery space as one of the main vertical spatial relationships by indicating the section drawing of the house shown in *Figure 3.6*. In this case sleeping area is located above ground which is directly under the pitched roof remaining a visual continuity with the rest of the building. He explains attic space in the section drawing of another case which is an agricultural laboratory designed by a Swedish architect – Fredrik Blom – in 1837 (*Figure 3.7*). Similar to the sleeping space of the previous case the attic space is also directly under the roof. In both cases the shape of the spaces is affected by the geometry of the roof structure.[197] While the sleeping area of the first case has a direct physical reference to the pitched roof, in the attic space of the second

[195] Unwin, op. cit.
[196] Ibid.
[197] Ibid.

case the triangular section of the roof has been translated into a curved ceiling by the presence of a secondary skin.[198]

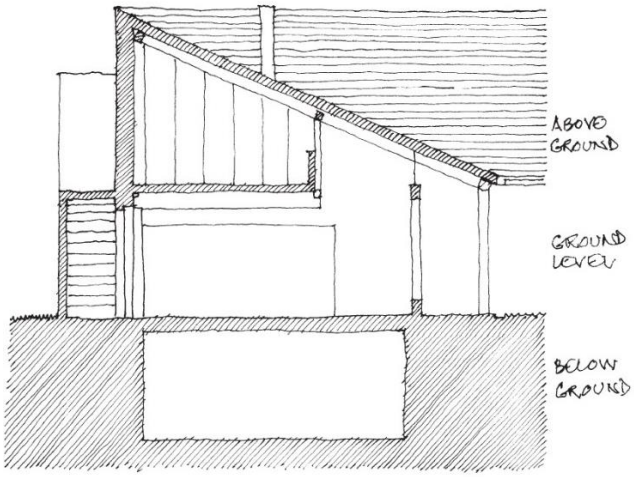

Figure 3.1. Section drawing of the house by Marco Zanuso[199]

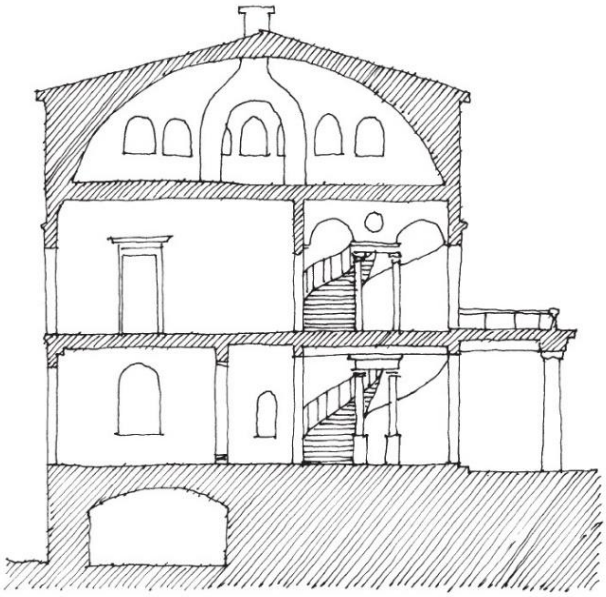

Figure 3.2. Section drawing of the agricultural laboratory by Fredrik Blom [200]

[198] Ibid.
[199] Ibid.
[200] Ibid.

3.1.3. Categorization of Spatial Forms

So far space defining elements and the organizational relationships of the architectural spaces have been discussed. The relationship of form and space can be better understood by analyzing spaces with accordance to their impact on formal expression. "The form and enclosure of each space in a building either determines, or is determined by, the form of the spaces around it."[201] Ching defines three categories of spatial forms using a diagrammatic representation on the plan drawings of the Theater in Seinäjoki by Alvar Aalto as can be seen in *Figure 3.8*.[202]

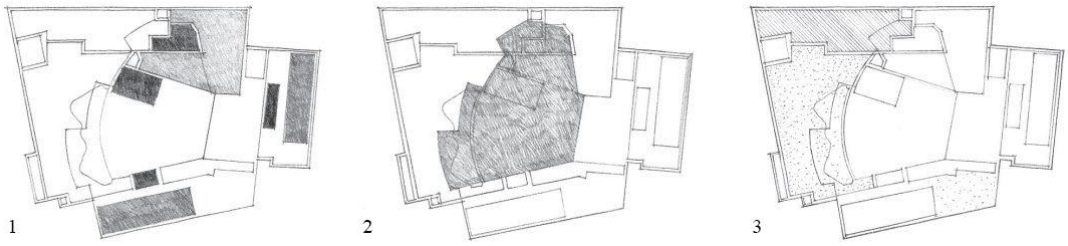

Figure 3.3. Illustrations of Ching sowing the three type of spatial forms[203]

The first category consists of spaces that have specific and similar functions requiring specific and similar formal articulations such as offices. They can be grouped into singular, linear or clustered forms. Their formal organization is not flexible on their own but the flexibility can be provided with the formal organization of the clusters. The second category contains spaces that have specific functional and technical requirements such as concert halls, directly determining their specific forms which will affect the forms of spaces around them. The third category stands for spaces that are flexible in nature such as foyers and therefore their form can be determined freely by the spaces around them or the building skin itself.

Different from these categories, Robert Venturi introduces another type which he calls the 'Residual space'.[204] Residual space is basically the left over space inflected toward

[201] Ching, op. cit.
[202] Ibid.
[203] Ibid.
[204] Venturi 1992, op. cit.

something more important beyond itself. It can occur between outside and inside, between one space and another.[205] When the formal expression of exterior and interior of a building differs, a distinction occurs. Venturi refers to this distinction as an additional space between the lining and the exterior wall as indicated in *Figure 3.9*.

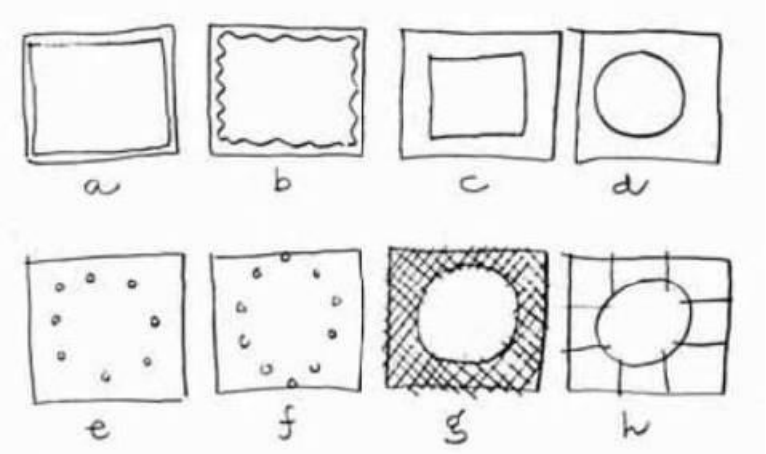

Figure 3.4. Venturi's diagrams showing the distinction of the exterior and interior[206]

The notion of flexibility in terms of formal expression, as indicated the categories of spatial forms by Ching, is closely related with design methods and approaches of the architect. The modernist way of architectural thinking claims that a building grows from the inside out.[207] With accordance to this topic Le Corbusier has written: "The plan proceeds from within to without; the exterior is the result of an interior."[208] This understanding indicates that functions of spaces and their interrelationships are determinant in the formal expression of the building form. On the other hand, when the architectural design intentions focus primarily on the building form and the form dictates the spatial form of the spaces related to it, the building can be said that it grows form the outside in. Designing from the outside in as well as the inside out,

[205] Ibid.
[206] Ibid.
[207] Ibid.
[208] Le Corbusier. 1985. *Towards a New Architecture*. New York: Dover Publications.

according to Venturi, is so crucial that it gives rise to a critical tension that, constitutes the center of architectural production.[209]

3.2. Space – Boundary Relationships

3.2.1. Building Envelope as a Performative Skin

Creating and articulating space necessitates, among other things, creating and articulating surfaces. Architecture comes into being with respect to an act of surfacing.[210] It stands up to deal with natural conditions but the way it handles and builds an skin may differ with accordance to the developments of its time.[211] Exchanging energy and information with the environment and defining architectural character are some important responsibilities of the building skin.[212] Therefore, the building skin can be defined as a transition between inside and outside, providing protection from the external conditions and privacy.[213]

The term 'building skin' comes from the analogy of building envelope and human skin. Beyond the layer of clothing as a 'second skin', architecture is often referred to as a 'third skin', delivering shelter and space for human activity since the function of skin and other outer hulls in nature bears many analogies to the function of building envelope in architecture.[214] The primary analogy between skins and building envelopes is the creation of a difference which is the establishment of an internal environment.[215] Gruber and Gosztonyi explains the analogies further:

> Interaction between inside and outside takes many forms between total closure and total openness to matter and energy flows. Protection from mechanical influences, radiation, unwanted substances and other organisms

[209] Venturi 1992, op. cit.
[210] Islami, op. cit.
[211] Eisenman, Peter. 2013. "Visions Unfolding: Architecture in the Age of Electronic Media." Essay. In *The Digital Turn in Architecture 1990-2010*, 15–27. Wiley.
[212] Gruber, P., and S. Gosztonyi. 2010. "Skin in Architecture: Towards Bioinspired Façades." *Transactions on Ecology and the Environment*138: 503–13. https://doi.org/10.2495/DN100451.
[213] Schittich, op. cit.
[214] Gruber and Gosztonyi, op. cit.
[215] Ibid.

> is one of the most important functional aspects linking skin and building facades. But the border between inside and outside also has to provide mechanisms for exchanging matter and energy needed to maintain metabolism - permeability of some kind to air, water and nutrients is a precondition for life, and for providing an internal environment with today's comfort standards.[216]

Developments in digital technologies and tools in architecture have facilitated unprecedented exploration into surface expression and articulation.[217] In this era of digital and technological advancement, examining the notion of boundary with a certain amount of attention given to the architectural surface has become common among architects.[218] Most recently, architectural surfaces defined through digital tools and their architectural tectonic qualities have become a focus of architectural investigation.[219] The possibilities of building skins is ever expanding given the experimentation including testing boundaries, querying traditional perceptions, and searching for new materials and concepts.[220]

There must be some certain criteria in designing building skins. Werner Lang defines them by asking four main questions:

> 1. Function: What is the practical purpose of the building / the building skin?
>
> 2. Construction: What are the elements/components of the building/the building skin and how are these elements assembled into a whole?
>
> 3. Form: What does the building/the building skin look like?
>
> […]
>
> 4. Ecology: What is the energy consumption of the building / the building skin during construction, use and demolition?[221]

These questions form the foundation of the approaches towards designing building skins. Although the architect may value one over another, it is certain that building

[216] Ibid.
[217] Gao, op. cit.
[218] Oxman 2006, op. cit.
[219] Schittich, op. cit
[220] Ibid.
[221] Lang, Werner. 2012. "Is It All 'Just' a Façade? The Functional, Energetic and Structural Aspects of the Building Skin." Essay. In *In Detail Building Skins*, 28–47. Basel: Birkhäuser.

skin has some functional and performance requirements to serve. In case of functions of the building skin, it is possible to make an analysis starting from the existence of human kind. Throughout the history, the very basic purpose of the act of building is to have a shelter from the elements, wind and rain, cold or excessive heat and to draw a line around the property creating a private sphere.[222] Another challenge is the introduction of natural light in the sheltered space. Daylight use is one of the fundamental tasks of the building skin and is an increasingly important subject both in terms of the comfort and satisfaction of the users.[223] The articulation and relation between opaque and transparent surfaces in the building skin is one of the primary themes in designing the external skin in architecture.[224] One of the main tasks of building skin is to ensure comfortable condition in the interior by regulating the prevailing conditions in the surrounding exterior atmosphere.[225] So, architecture can be regarded as the visible manifestation of the overcoming of natural forces such as gravity and weather.[226] In addition to the mentioned ones Lang compiles functions of building skin as a building envelope in an inclusive way as lighting, ventilation, protection from humidity, insulation against heat and cold, wind protection, sun protection, glare protection, visual protection, visual contact and transparency, safety and security, prevention of mechanical damage, noise protection, fire protection, energy gain.[227]

Besides the functional and performative aspects of building skin, questions related to design and visual appearance are in the foreground in the structural execution of the building skin since construction and design are inseparably linked and the structural design of the building skin determines the visual appearance of a building.[228] Surfacing as a design method for creating building skin allows much more creativity

[222] Schittich, op. cit
[223] Lang, op. cit.
[224] Schittich, op. cit
[225] Lang, op. cit.
[226] Eisenman 2013, op. cit.
[227] Lang, op. cit.
[228] Ibid.

and productivity.[229] It results of a more dynamic and environmentally and structurally responsive skins. The question of building skin and spatial characteristics remains the same as the core of this study.

3.2.2. Building Skin and Interior Spaces

One of the most important aspects of architecture is the fact that the physical manifestations of architecture accommodate human activity by defining, articulating and arranging spaces and forms.[230] In the case of the building skin, spaces also respond to the need to form visual relationships between the outside and inside as elements of the same conception.[231] Therefore, the process of surfacing becomes the focal point of the architectural investigation.[232]

The interaction of architecture and the building occupant is closely related to the space quality of the architectural work as well as the visual perception of it. Architectural space's visual form, its dimensions and scale, and the quality of its light are some of the factors determinant in space characteristics and are determined by the boundary of space.[233] The shape of the space enclosure defines the form of the space. But the relationship between space and structure is not always simple and straightforward; it is open to different approaches as one may either choose and allow a structural strategy to define the spaces one wishes to create, or one can decide on places and force the physical structure of a building to cope with them.[234] Dimensions are determinant in the proportion and scale of the space. Scale refers to the size of something relative to oneself – human scale. The experience of a place is radically affected by its scale.[235] Configuration of the architectural elements leads to definition of space. Light from sky is the medium through which sighted people experience the products of

[229] Islami 2007, op. cit.
[230] Ching, op. cit.
[231] Arnheim, op. cit.
[232] Islami 2007, op. cit.
[233] Ching, op. cit.
[234] Unwin, op. cit.
[235] Ibid.

architecture and can be manipulated by design to identify spaces and to give a particular character to a space by the surface articulation of the building skin.[236]

The only concern of a building skin cannot be its visual appearance since it acts not merely a shell but rather a physicality that accommodates spatial configurations and activities.[237] Building skins are determinant in characteristics of space and the interaction of interior and exterior.[238] Since perceptually and practically, the worlds of outside and inside are mutually exclusive, building skin stands for as a border creating and separating spaces.[239] Building skin molds interior space and simultaneously shapes exterior space and describes form, massing and image of building in space.[240]

It is important to remember the fact that a building skin defines the border between the spaces it interacts both in plan and section plane.[241] With the technological advancement of architectural design tools, building skin has the potential to generate dynamic and complex formal expressions.[242] The ability of generating dynamic and free forms leads architects to question, examine and explore the notion of boundary in terms of building skin.[243] Therefore, the impact of the building skin on the characteristics of interior spaces is an issue that necessitates more attention than the physical skin itself. Bacon explains the quality of architecture as follows:

> Architectural forms, textures, materials, modulation of light and shade, color, all combine to inject a quality or sprit that articulates space. The quality of the architecture will be determined by the skill of the designer in using and relating these elements, both in the interior spaces and in the spaces around his buildings.[244]

[236] Ibid.
[237] Hertzberger 2001, op. cit.
[238] Ching, op. cit.
[239] Arnheim, op. cit.
[240] Ching op. cit.
[241] Lorenzo and Sprecher, op. cit.
[242] Pastore and Corrao, op. cit.
[243] Schittich, op. cit.
[244] Bacon, op. cit.

Building skin's primary impact on spaces is visual, in that the building skin must be perceivable form the inside as well. This situation introduces a concern about visual perception of the building skin from interior spaces.

3.3. Visual Perception of the Building Skin

Visual perception of architectural formal expression from the outside is what draws attention the most but as Bacon has mentioned; "This is architecture, not to look at, but to be in."[245] So the visual perception of its spatial configuration and formal expression form the inside deserves the same attention. Since this study mainly focuses on the characteristics of interior space aspect of the topic, this section is constructed around the visual perception of the building skin form the interior. In order to understand the visual perception of the building skin, it is essential to define vision and study the realm of perception of the visual space.

Vision can be defined as a way of organizing space and elements in space or as a way of looking at, defining the relationship of a subject and an object.[246] Peter Eisenman defines vision in a more specific way as such:

> In architecture, vision refers to a particular category of perception linked to monocular perspectival vision. The monocular vision of the subject in architecture allows for all projections of space to be resolved on a single planimetric surface.[247]

Perception of the visual space can be related to the vision as well as cognitive psychology. According to Paul Linton, visual perception relies upon the optical cues, psychological cues and pictorial cues.[248] Optical cues would refer to binocular disparity which can be defined as the difference between the two retinal images.[249] The sense of depth can be generated by the combination of the information from the

[245] Ibid.
[246] Eisenman 2013, op. cit.
[247] Ibid..
[248] Linton, Paul. 2017. *The Perception and Cognition of Visual Space*.
[249] Ibid.

left and the right eyes.[250] Psychological cues can be regarded as accommodation and vergence, in other words the focal distance of the eyes and the angle between the eyes.[251] Pictorial cues on the other hand, are related to perspective and shading, and the content may not be geometrically specified until the visual system can attributes meaning to them.[252] So, it is possible to approach to visual space perception as a set of interactions between the observer and the physical world in terms of optical, psychological and pictorial aspects.

In the case of architecture, space perception is experienced through the interaction with the space defining elements.[253] Sight is the initial mode of interaction and surfaces are the first place of contact with architecture.[254] "Just like words and sentences, forms depend on how they are "read" and which images they are able to conjure up for the "reader"."[255] The perception of the boundary of the space is often partial.[256] It is possible to see and perceive only a certain part of a surface from a given perspective at a given moment.[257] But of course moving around in an architectural environment and seeing the surfaces from different viewpoints can help perceiving in a more comprehensive way.[258] Experiencing architectural works involves movement from outside to inside, or through the serial stages of a route.[259] The perception of the given portion depends on some properties of vision. Notion of memory, visual continuity of the spaces, and dimensions of the spaces are the main important aspects of visual perception of the architectural spaces.

[250] Parker, Andrew J. 2007. "Binocular Depth Perception and the Cerebral Cortex." *Nature Reviews Neuroscience* 8: 379–91.
[251] Linton op. cit.
[252] Ibid.
[253] Arnheim, op. cit.
[254] Islami, Yahya Sayed. 2009. "The Architecture of Surface The Significance of Surficial Thought and Topological Metaphors of Design." Dissertation. The University of Edinburgh. .
[255] Hertzberger 2001, op. cit.
[256] Arnheim, op. cit.
[257] Islami 2009, op. cit.
[258] Arnheim, op. cit.
[259] Unwin, op. cit.

The notion of memory plays an important role in visual perception of architectural spaces. Arnheim explains the connection between perception and memory as follows: "An interior permits comparison with other places only through the visitor's memory or anticipation. He can perceive its size or shape in relation to what he has seen before or expects to see later."[260] Similarly, Unwin also mentions such a relationship by saying that: "We are constantly placing ourselves: we have a sense of where we are and of other places around us; we weigh up where we might go next."[261] The user or observer constructs an image or a framework in memory creating expectations with accordance to the idea of interiority as a hierarchy between inside and outside.[262] Since visual perception and imagination are not limited to a range of optical images on which they rely, visual perception of an architectural space organizes, completes, and synthesizes a structure in the observers mind.[263]

Visual continuity is an important aspect in perception of an inner space. Spatial continuity and visual continuity are not the same thing. Ching explains the difference between them in his diagrammatic representation in *Figure 3.13*. As it can be seen in Figure 3.13, spatial continuity can be interrupted but visual continuity can remain with accordance to the architectural design. Going from up to down in the diagram the interruption of spatial continuity occurs and visual continuity remains until the situation at the very bottom.

[260] Arnheim, op. cit.
[261] Unwin, op. cit.
[262] Eisenman 2013, op. cit.
[263] Arnheim, op. cit.

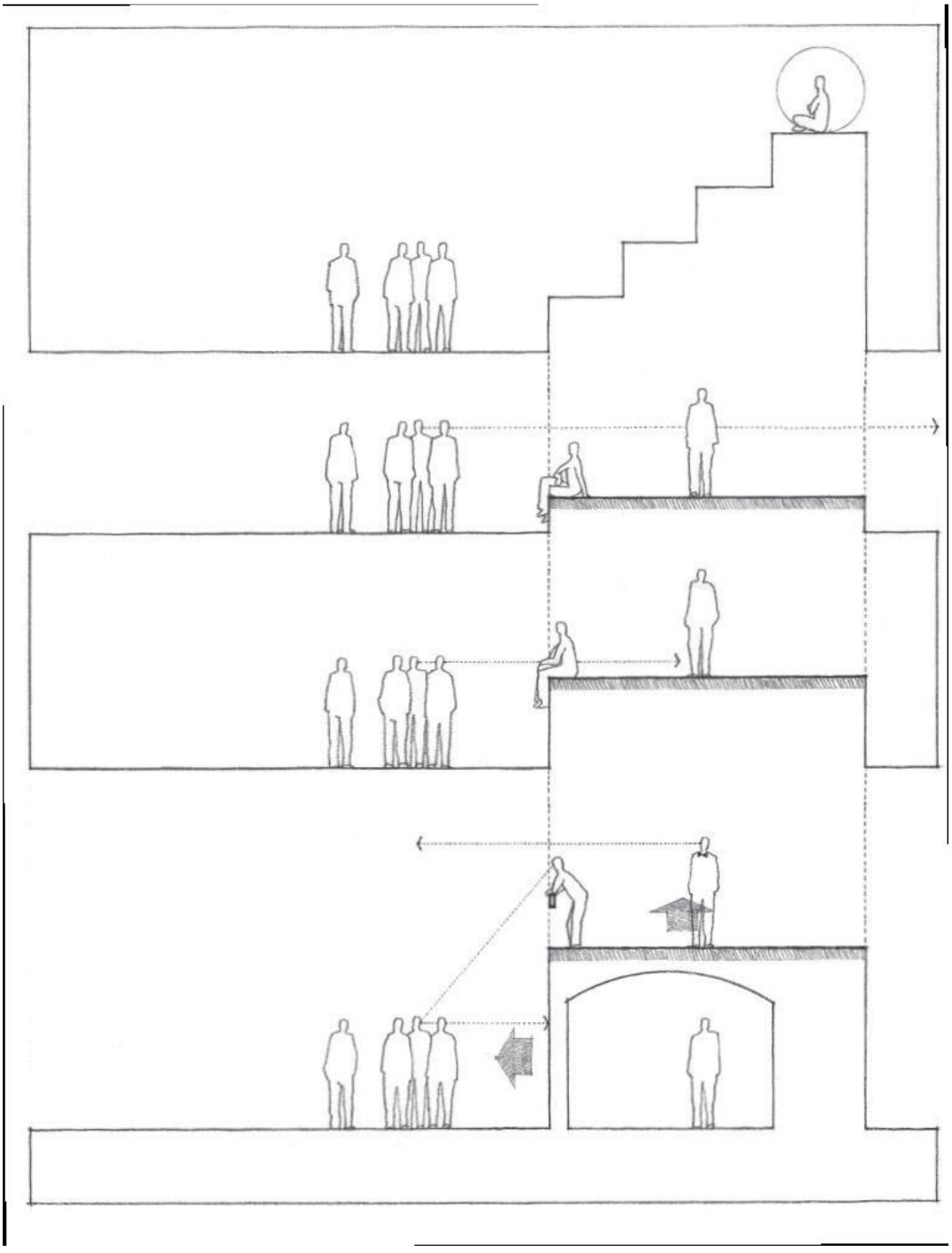

Figure 3.5. Diagram showing the visual and spatial continuity[264]

[264] Ching, op. cit.

The dimensions, proportion and scale of a space play an essential role in visual perception of the building skin. While width and length of a space defines the distance of an observer from the building skin, height defines the scale of the space.

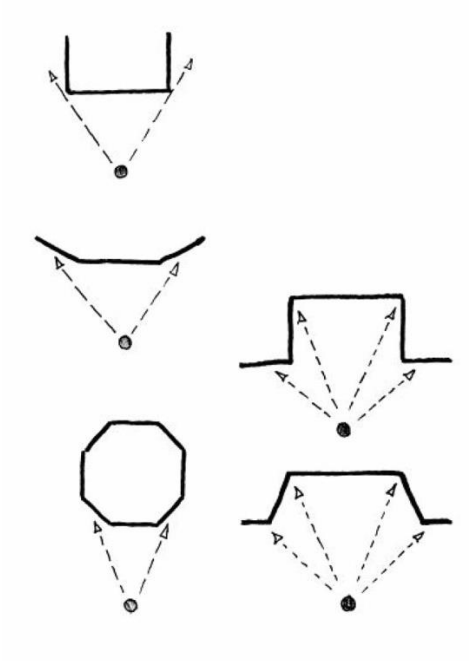

Figure 3.6. Diagrams showing distance and surface perception relationship[265]

Perception of a surface, especially a complex surface, requires distance. As shown in the *Figure 3.14*, distance in this case length or width of a space is determinant in the perception of the building skin. Height, on the other hand has a greater effect on the scale of the space.[266] In *Figure 3.15*, it is possible to see the difference between the perception of the bounding surfaces on the left hand side and right hand side due to the height differences.

[265] Arnheim, op. cit.
[266] Ching, op. cit.

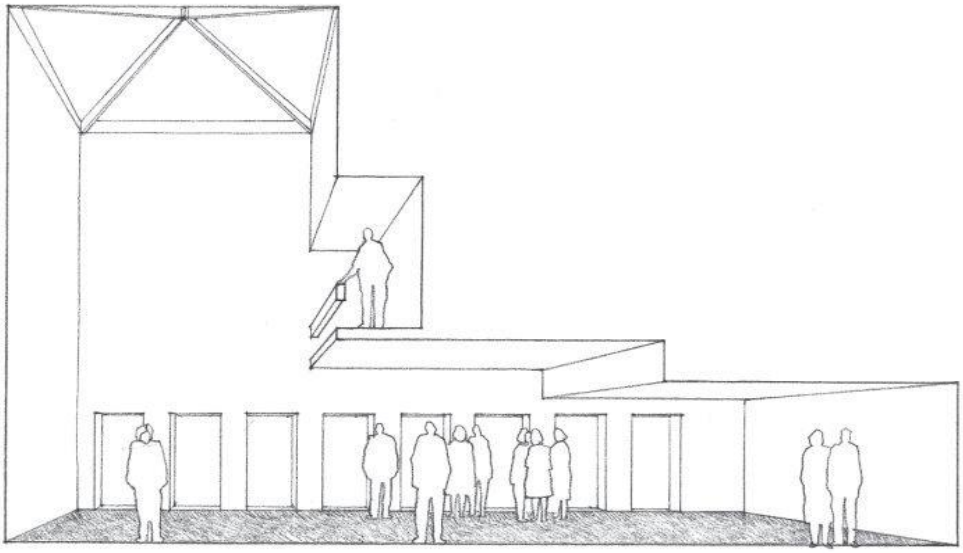

Figure 3.7. Diagrams showing height and surface perception relationship[267]

In order a building skin to contribute to the characteristics of interior space, the skin must be perceivable. If the complex characteristics of the skin cannot be perceived from the interior spaces it interacts, the complexity would not be a feature of the interior of the building. Then, the building skin would serve only to the outside observer, to the city.

The approach *from the outside in* shapes the current state of Free Form Architecture and raises questions about the contribution of the formal expression of the building skin on the characteristics of interior space. The attention of the contemporary Free Form Architecture on the formal expression of the building skin indirectly gives indication on the instability of the relationship between the creator of the form, the designer and the users.[268] With regard to the issues discussed in this chapter, this thesis aims to explore the intentions of the Free Form Architecture towards the relationship between the building skin and interior space. This exploration can be achieved through a comparative analysis of the built works of Free Form Architecture as the following chapter will indicate.

[267] Ibid.
[268] Hertzberger 2001, op. cit.

CHAPTER 4

CASE STUDY

4.1. Case Study Research

This study aims to understand and explain the relationship of the formal expression of Free Form Architectural works and interior space they define. As explained in the previous chapters, design criteria and objectives in Free Form Architecture varies according to the design method of the architects. The impact of the building skins, which are produced by various digital tools in different design methods, on the characteristics of interior space is the main concern of this study.

As explained in Chapter two, the contemporary studies on Free Form Architecture may focus on other issues related to architectural design and realization processes. This research can be regarded as an exploration process of the stance of Free Form Architectural works related to interior space characteristics. Therefore, principles of case study research are adopted in order to be able to develop a certain perspective towards the issue.

In general, case study research is conducted when 'how' or 'why' questions are posed.[269] In case of this study the investigated question would be: How does the building skin interacts with interior spaces in Free Form Architecture? The case study method is useful when the focus of the study is on a contemporary phenomenon within some real-life context.[270] With case study research, it is possible to express the developed framework by the relationships between the observed phenomenon and the real situations.[271] Case studies can describe both the phenomenon and the real-life

[269] Yin, op. cit.
[270] Ibid.
[271] Souza, Renato Cesar Ferreira. 2015. "Case Studies as Method for Architectural Research," January. https://doi.org/: 10.13140/RG.2.2.15768.19207.

context in which it occurs and are descriptively helpful in the illustration of certain topics within an evaluation.[272] Therefore, case study research principles are adopted to be able to evaluate the current state of Free Form Architecture through the examination of contemporary works.

In this chapter, a case based critical analysis will be presented using the case study method. Twenty-eight cases, mostly selected from 21st century, are examined with respect to the research considerations derived from the principles explained in Chapter Three. Thematic categorization will be carried out with respect to the cases with the aim of examining and discussing the spatial characteristics in Free Form Architecture. In order to evaluate in detail, the relationships of the categories, four representative cases are finally selected and analyzed in detail.

4.2. Research Considerations

The examination of the cases requires certain considerations in terms of defining the relationship between the building skin and indoor spaces. Such considerations derive themselves from the third chapter with accordance to the notions they contain about space definition and building skin perception.

The previous chapter indicates how architectural space can be defined with respect to the space defining elements and aims to provide a ground for evaluation of building skin as a defining element of the interior space. Therefore, it focuses first on the issues of surface articulation, functional differences of spaces with respect to their degree of accessibility, and internal spatial relationships of architectural spaces; such as space within a space, adjacent spaces, interlocking spaces, and linking spaces. Considering these relationships of spaces and the contributions of the space defining elements to space characteristics, it is possible to use the categorization of spatial forms introduced by Ching[273] which also creates the foundation of the categorization of the relationships between the building skin and architectural form that this study aims to propose. The

[272] Ibid.
[273] Ching, op. cit.

second aspect that the previous chapter focuses on is the performative functions of building skin to remind that there are performative design criteria that plays a great role on the creation of the building skin as well and the surface articulation and configuration that are the results of such design thinking affects the interior space characteristics as well. The final aspect that is covered in the third chapter is the visual perception of the building skin, since it is one of the key factors of the relationship of the building skin and interior space.

With respect to the space definition and building skin perception it is possible to define considerations that will guide the case study research:

- Form
- Proportion and Scale
- Accessibility (public/private/in between)
- Visual continuity
- Spatial continuity

Form, is the primary determinant of the building skin and space. The ways in which the form of the building skin affects the form of the interior space will be the main focus. It is important to question the degree of influence that the building skin has on the form of the interior space.

Proportion, of the interior spaces that are in physical contact with the building skin is determinant in the visual perception of the skin as explained further in the previous chapter.

Scale, can be approached in two ways. The first one would be the scale of the building, which is closely related to the program of the building. The buildings should be evaluated with accordance to their programmatic complexity and scale. The second way that scale can be considered is the scale of the interior spaces that interact with building skin since it has an important role in the visual perception of the building skin.

Accessibility, of the interior spaces largely defines their privacy level. The relationship between a space and the building skin differs with respect to its level of privacy, since they have different spatial needs and levels of enclosure. This differentiation is also closely related with the scale differences between public and private spaces.

Visual continuity and *spatial continuity*, are key factors in visual perception of the building skin from interior spaces. Visual continuity and spatial continuity between spaces that interact with the building skin can change the perception of the skin and the spatial characteristics of these spaces.

4.3. Cases

In order to understand the relationship between the building skin and interior space in Free Form Architecture, twenty-eight cases are selected to be examined with respect to the considerations introduced in the previous section.

As mentioned in the first section of the second chapter, many significant examples of Free Form Architecture were realized during the 1950s as thin shell structures. The first eight of the cases are selected from the representative architects of the thin shell structures form 20thcentury, and the other twenty of the cases are from 21stcentury examples of Free Form Architecture. Correspondingly, a comparative analysis would be possible. Due to the increasing complexity (both programmatic and formal) and scale of the buildings from 1950s to the early 21stcentury, examining the ways in which architectural works have been interpreting such change through architectural expression of space becomes also increasingly important.

Only built works are included in the study since they have impact on the architectural evolution more than designs that exist only on paper. The cases are not selected from a specific building type since in the case of global scale, conceptualization of Free Form Architecture is not dependent on the type or specific functions accommodated in the building. So, various types of buildings can be selected as examples to examine. The full list of the cases:

1. Kresge Auditorium, 1955, Eero Saarinen, Massachusetts, US
2. Palazzetto dello Sport, 1956, Annibale Vitellozzi, Pier Luigi Nervi, Rome, Italy
3. Los Manantiales, 1958, Felix Candela, Mexico
4. Ingalls Rink, 1958, Eero Saarinen, Connecticut, USA
5. TWA Flight Center, 1962, Eero Saarinen, NYC
6. Yoyogi National Gymnasium, 1964, Kenzo Tange, Tokyo, Japan
7. St. Mary Cathedral, 1964, Kenzo Tange, Tokyo, Japan
8. Sydney Opera House, 1973, Jørn Utzon, Sydney, Australia
9. SEC Armadillo, 2000, Norman Foster, Glasgow, Scotland
10. Auditorium Parco della Musica, 2002, Renzo Piano, Rome, Italy
11. City Hall, 2002, Foster & Partners, London, UK
12. Selfridges Department Store, 2003, Future Systems, Birmingham, UK
13. Walt Disney Concert Hall, 2003, Frank Gehry, California, USA
14. The Hinzert Museum and Document Center, 2005, Wandel Hoefer Lorch + Hirsch, Halle, Germany
15. Chengdu Contemporary Art Centre, 2007, Zaha Hadid, Chengdu, China
16. London Aquatics Centre, 2008, Zaha Hadid, London, UK
17. Novartis Pharma A.G. Campus, 2009, Frank Gehry, Basel, Switzerland
18. Guangzhou Opera House, 2010, Zaha Hadid, Guangdong, China
19. Ordos Art & City Museum, 2011, MAD Architects, China
20. Soumaya Museum, 2011, FR-EE/ Fernando Romero Enterprise, Mexico City, Mexico
21. Dalian International Conference Center, 2012, Coop Himmelb(l)au, Dalian, China
22. Galaxy SOHO in Beijing, 2012, Zaha Hadid, Beijing, China
23. Heydar Aliyev Center, 2013, Zaha Hadid, Baku, Azerbaijan
24. Fondation Louis Vuitton, 2014, Frank Gehry, Paris, France
25. Harbin Opera House, 2015, MAD Architects, Heilongjiang, China
26. Paris Phillarmonie, 2015, Jean Nouvel, Paris, France

27. Elbphilharmonie Hamburg, 2016, Herzog & de Meuron, Germany
28. Phoenix International Media Center, in progress, BIAD, Beijing Shi, China

These twenty-eight cases are examined both in plan and section drawings in order to understand the various types of relationships between the building skin and the interior spaces. Categories of the relations, which will be explained in the following section, is derived from this analysis. The cases can be seen in the *Figure 4.1* and it is possible to reach further and more detailed visual materials and technical drawings of the cases from Appendix A.

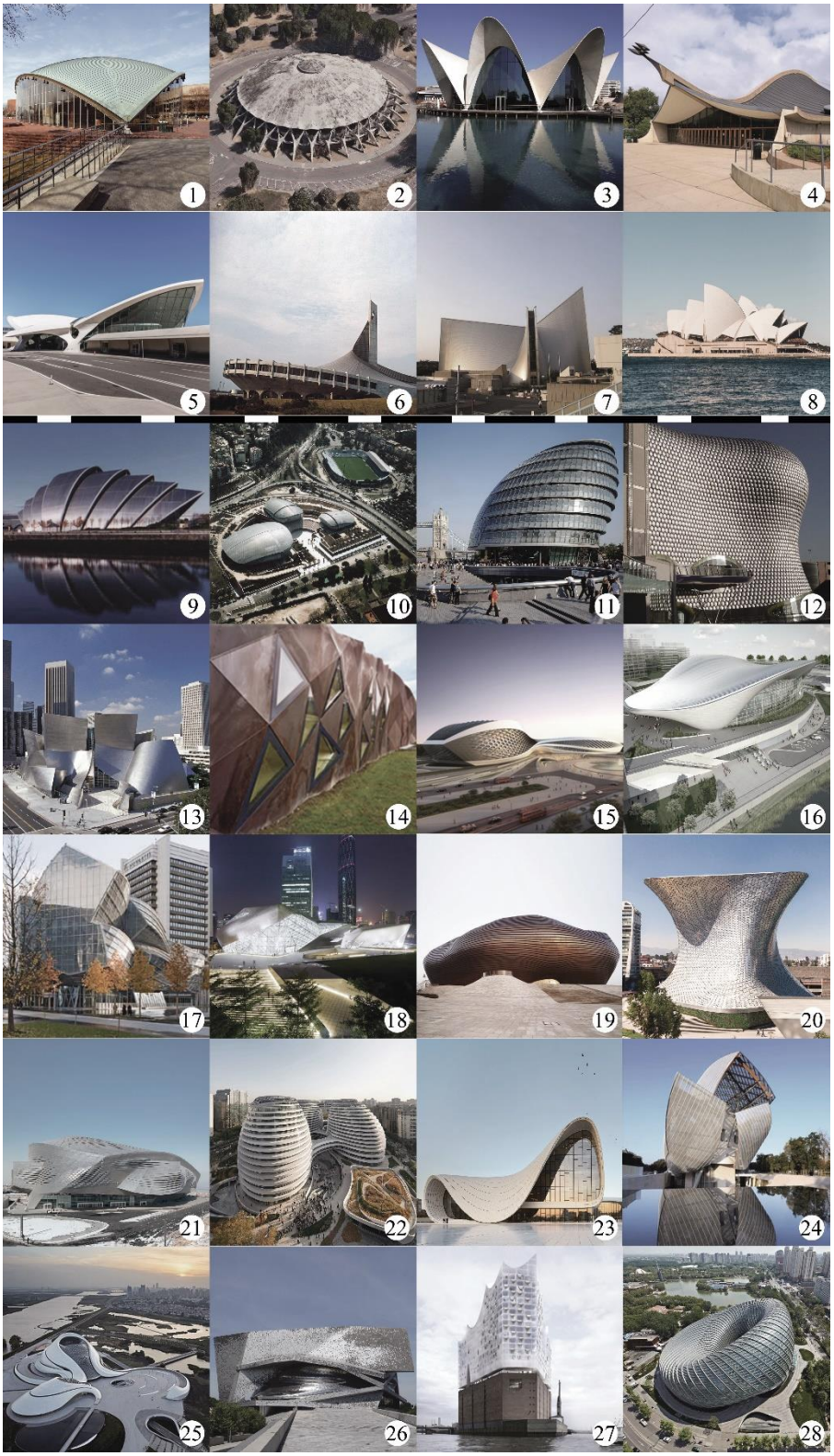

Figure 4.1. External visuals of all cases

4.4. Categories of the Spaces Interacting with Building Skin

Since this study aims to explore the relationship of building skin with interior spaces, it is important to investigate the spaces that interact with the building skin. In this study, the primary medium for analyzing architectural works is drawings.[274] Simon Unwin emphasizes the importance of architectural drawing in expressing ideas as follows: "The plans and sections are particularly important because, since architecture is primarily a spatial art, that is where spatial ideas are most clearly apparent."[275]

In the first stage of the analysis, the technical drawings, containing both plans and sections, have been examined with respect to the considerations of the analysis to discover the types of spaces that interact with the building skin. Following this examination, some certain categories concerning the horizontal relations of spaces are obtained from the plan drawings. However, when the same categorization is attempted to apply on vertical relations with the examination of the sections drawings, a different approach towards categorization is followed. Due to the approach *from the outside in*, the spatial categories derived from plan drawings may end up in different vertical relations with the building skin in cross sectional views. Thus, a different categorization has been made for the vertical relations of spaces with building skin. The categories that are identified after a careful visual examination of a number of cases will be presented with accordance to the horizontal and vertical spatial organization.

4.4.1. Categories Obtained from Horizontal Spatial Organization

Through the investigation of plan views of the cases, it is possible to regard the building skin as (semi-)vertical space-defining element. In this approach, the way the skin defines spaces or influences the spatial organization is important in terms of categorization. In some cases, it defines the boundary of spaces itself. In some other cases, it may define the configuration of the organization of spaces, and in some other

[274] Unwin, op. cit.
[275] Ibid.

cases the form of the building skin can be defined by the space and its specific technical requirements. So, the investigation of the plan views of the cases points out three main categories of spaces which are parallel to Ching's spatial forms[276]: clustered spaces, form defining spaces, and flexible spaces. The first one indicates the spaces which are organized as clusters and can act flexibly when they are aggregated. The second category consists of spaces that have specific functional and technical requirements which are determinant in the form of the building. The last one indicates the spaces that are flexible in nature and therefore can be defined by the formal expression of the building skin. The differentiation between the categories is not strictly defined; the categories represent the spaces that interact with the building skin coexisting in space configuration of the architectural work with respect to the spatial arrangement proposed by the architect.

It is possible to see how the categories apply to the cases in *Figure 4.2*, and the images can be found separately in Appendix B.

[276] Ching, op. cit.

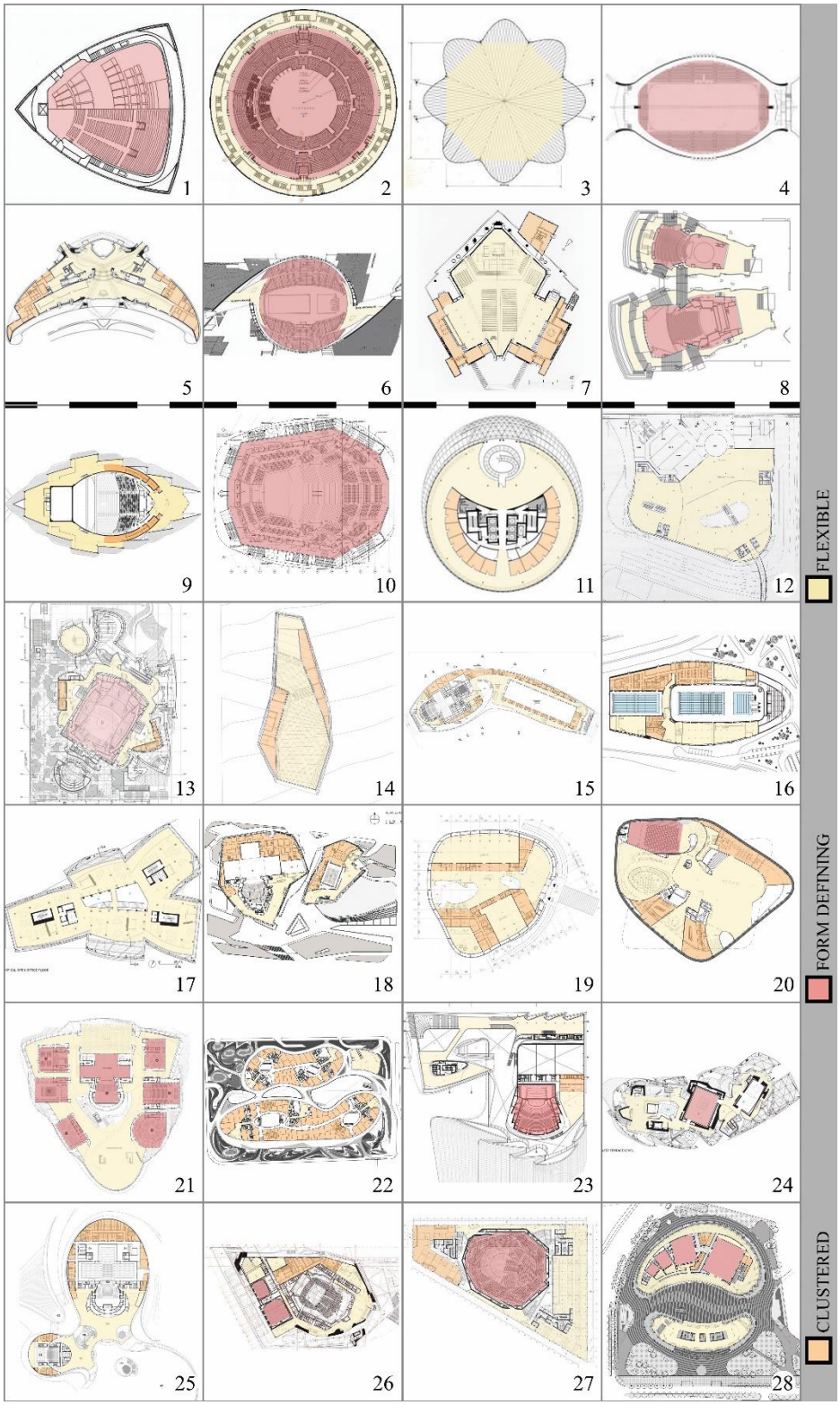

Figure 4.2. Categorization of spaces in plan views

4.4.1.1. Clustered Spaces

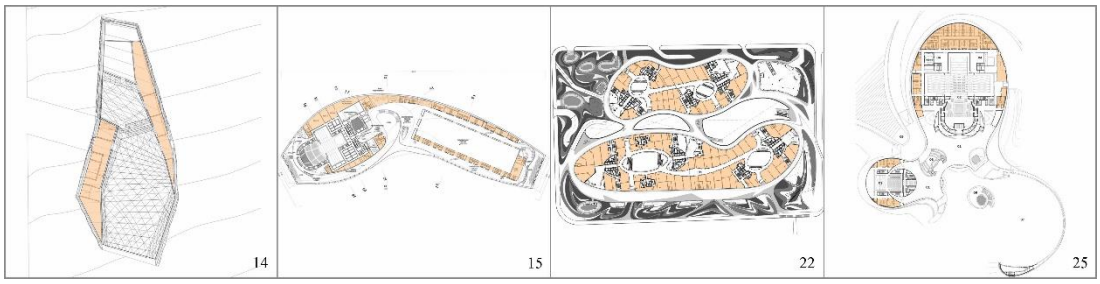

Figure 4.3. Cases exemplifying clustered spaces

Clustered spaces (*Figure 4.3*), Ching's first category of spatial forms, are typically small-scale spaces that have specific but similar functions, such as office units and they can be organized as groups.[277]

After a visual examination of the cases it is possible to expand upon Ching's definition. Clustered spaces are not individually flexible, but they can act flexibly when they are aggregated. The form and organization of the cluster can be defined by the form of the building skin. As it can be seen in the cases 5, 7, 13, 14, 15, 16, 18, 19, 20, 22, 25, 26, and 27; they are often adjacent spaces or they can be linked with another space. With respect to their accessibility level, they are usually private or semi-private spaces. Thus, visual and spatial continuity between spaces can be limited or absent depending on the accessibility level and the organization of the spaces.

On one extreme, it is possible to organize whole building with clustered spaces whose formal organization is determined by the formal expression of the building skin as in the case 22 which is Galaxy SOHO Beijing by Zaha Hadid Architects as can be seen in *Figure 4.3*. Alternatively, a more common way of using clustered spaces is to organize a limited portion of the building as in the cases 5, 7, 13, 14, 15, 16, 18, 19, 20, 25, 26, and 27. Regarding the cases 7, 15, 16, 18, and 25, it is possible to say that clustered spaces can function as the service spaces of form defining spaces such as auditoriums and sports halls and they can be positioned between these form defining

[277] Ibid.

spaces and building skin. Therefore, the form of the clusters can be defined both by the form defining spaces and the building skin. They can be organized along the building skin in a linear way as in the case 15 which is Chengdu Contemporary Art Centre by Zaha Hadid Architects or they can fill in between the building skin and a form defining spaces as in the case 25 which is Harbin Opera House by MAD Architects as both of the cases can be seen in *Figure 4.3*.

Since clustered spaces are small-scale spaces, when they are organized adjacent to the building skin, this interaction between the space and skin is rather limited. As a result, the visual perception of the whole skin is not possible due to the proportional features of the spaces. Therefore, the building skin acts mainly as a physical boundary between the inside and outside, and also as a means of introducing day-light. As a result of their small scale and their low level of interaction with the rest of the building due to the difference in spatial proportions, it is possible to say that the potential for visual perception of the building skin from these spaces is rather limited.

4.4.1.2. Form Defining Spaces

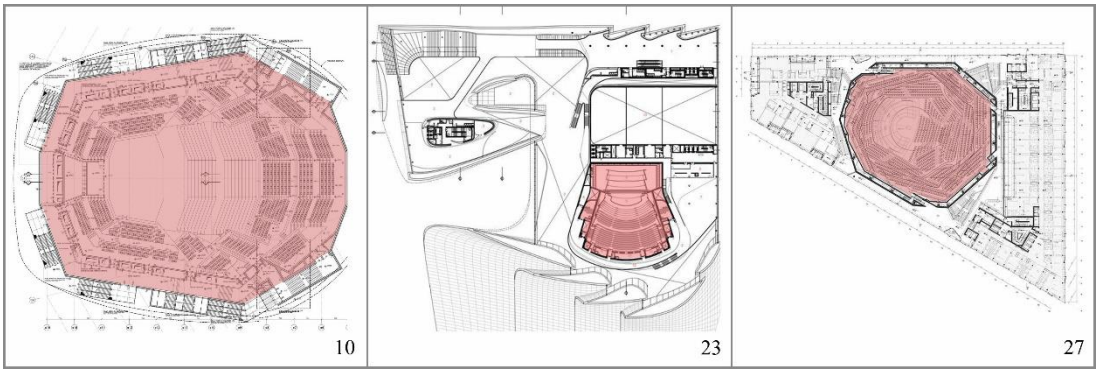

Figure 4.4. Cases exemplifying form defining spaces

Form defining spaces can be defined, with respect to the second category of spatial form introduced by Ching, as spaces that have specific functional and technical requirements and dictate specific spatial forms, such as concert halls, conference halls, theatres.[278] These spaces can directly affect the formal expression of the spaces around

[278] Ibid.

them, and in some cases they can affect the formal expression of the building skin itself.[279]

It is possible to reinterpret Ching's definition with respect to the visual examination of the cases. In general, form defining spaces are large scale spaces with specific functions. Cases 1, 2, 4, and 6 indicate that in the architectural works from 1950s and 1960s, form defining spaces constitute the most of the Free Form Architectural works. Case 1 is an auditorium by Eero Saarinen, case 2 is a basketball arena by Pier Luigi Nervi, case 4 is a hockey rink by Eero Saarinen, and case 6 is a gymnasium by Kenzo Tange. They were the spaces that determines the form of the entire structure. The visual examination of the cases 20, 21, and 24 from the 21st century shows that form defining spaces may not dominate the overall architectural form, since they usually constitute just a portion of the complex building program. Whereas, cases 10, 23, and 27 indicates the possibility of the dominance of from defining spaces over both the program of the building and the formal expression of the building skin. With regard to the cases 10, 23, and 27, it is possible to say that building skin might not be directly responsible for day-lighting, since the functional and technical requirements of the form-defining spaces do not necessitate natural light. In this case, the articulation of the building skin is directly influenced by the requirements of the form defining spaces. Their accessibility level depends on the pattern of usage and functional organization. With regard to the cases 10, 13, 21, 23, 24, and 27, they do not often apply visual or spatial continuity unless a functional or technical requirement dictates so.

The relationship between form defining spaces and the building skin varies in two ways. Firstly, they can define or have an impact on the formal expression of the building skin, although such impact may not be perceived from interior due to technical and functional adjustments of the spaces. Such relation can be seen in the cases 10 and 27 in *Figure 4.4*. Case number 10 is Auditorium Parco della Musica by

[279] Ibid.

Renzo Piano and the form of the auditorium has a significant effect on the formal expression of the building form. Case number 27, on the other hand, has a similar effect perceivable in section drawing rather than plan drawings of the Elbphilharmonie Hamburg by Herzog & de Meuron, which will be explained in detail in the following sections. Secondly, although they are form defining, the space can be separated from the building skin with a secondary skin and the building skin can be designed independently providing the space no connection or perception as in the case Heydar Aliyev Center by Zaha Hadid as indicated as case number 23 in *Figure 4.4.*

4.4.1.3. Flexible spaces

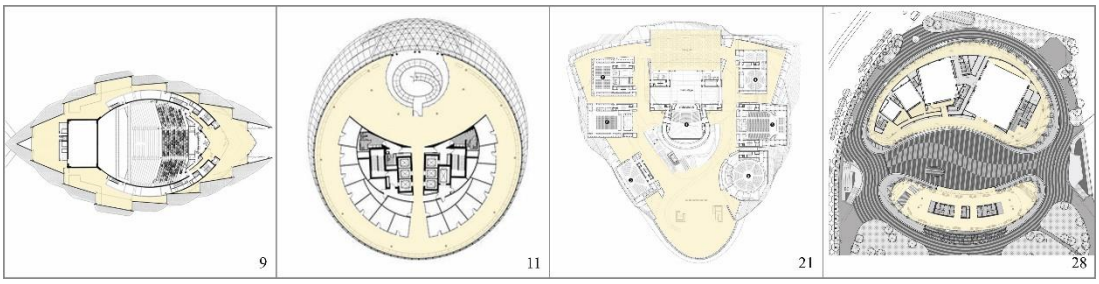

Figure 4.5. Cases exemplifying flexible spaces

Flexible spaces, according to Ching, are flexible in nature; therefore, they can be freely defined by the spaces or clusters of spaces around them.[280] It is possible to expand this definition with respect to the visual examination of the cases. Since flexible spaces do not have specific functional or technical requirements they can be defined by the building skin and interact freely with it. Therefore, such spaces are the most common type that the building skin interacts with in the cases selected in this study.

Flexible spaces can be of an arbitrary scale or form. They can take place as a large foyer as in case 21 (*Figure 4.5*), or a small exhibition hall as in case 14. Their proportions may also differ. They can be narrow corridor-like circulation spaces as in the case 15, or large and high foyers as in cases 9, 21, and 25. Such variations are an important determinant factor in the visual perception of the building skin, and also

[280] Ibid.

influential in the categorization which is done with respect to the vertical spatial organizational relations of the cases that will be explained in the following sections.

Flexible spaces are usually used as public spaces such as lobbies, foyers, exhibition halls; or circulation spaces as can be seen in the cases 9, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 23, 24, 25, 26, 27, and 28. They can provide a certain level of visual and spatial continuity with accordance to spatial organization of the buildings. They can act as a buffer zone between form defining spaces and the building skin as in the cases 9 and 28 in *Figure 4.5*. As in these cases, flexible spaces can be shaped by the form defining spaces and building skin and therefore they have the highest probability in providing users with visual perception of the building skin in the cases selected in this study. As it was mentioned in the previous chapter, these flexible spaces have a certain parallelism with Venturi's residual space[281]. In other words, they can act as a left-over space between the building skin and form defining spaces. Moreover, they can also offer a space within a space relationship as in the case 21 shown in *Figure 4.5*, which is Dalian International Conference Center by Coop Himmelb(l)au. In this case the flexible space that often functions as foyer, embraces and contains the opera hall entirely.

Overall, flexible spaces are usually large scale public spaces having the opportunity of providing spatial and or visual continuity and interact directly (without introducing a secondary skin as can be seen in all cases) with a large portion of the building skin. Therefore, it is possible to say that they have the highest possibility of a comprehensive visual perception of the building skin in the cases selected in this study.

4.4.2. Categories Obtained from Vertical Spatial Organization

Through the visual examination of section views of the cases, it is possible to focus on not only the relationship of the spaces with building skin but also the vertical relationships between spaces. In the categorization of spaces that interact with

[281] Venturi 1992, op. cit.

building skin, main objectives are scale, proportion, visual and spatial continuity between spaces since these are the determinant notions for the visual perception of the building skin. In a vertical manner, in some cases, spaces may maintain visual and spatial continuity that allows the visual perception. Moreover, in some cases spaces are separated completely allowing visual perception of only a very limited part of the building skin. In some other cases, building skin may define only one space which is directly and entirely bounded by the skin, whereas in some cases, the portion of the building that has a wider perspective in perception of the skin could act as an attic space. So, the careful visual examination of the cases with respect to the vertical spatial organization identifies four categories: set back spaces, conjoint spaces, solo spaces, and attic spaces, which cannot be strictly separated and can coexist in space configuration of the architectural work.

It is possible to see how the categories apply to the cases in *Figure 4.6*, and the images can be found separately in Appendix B.

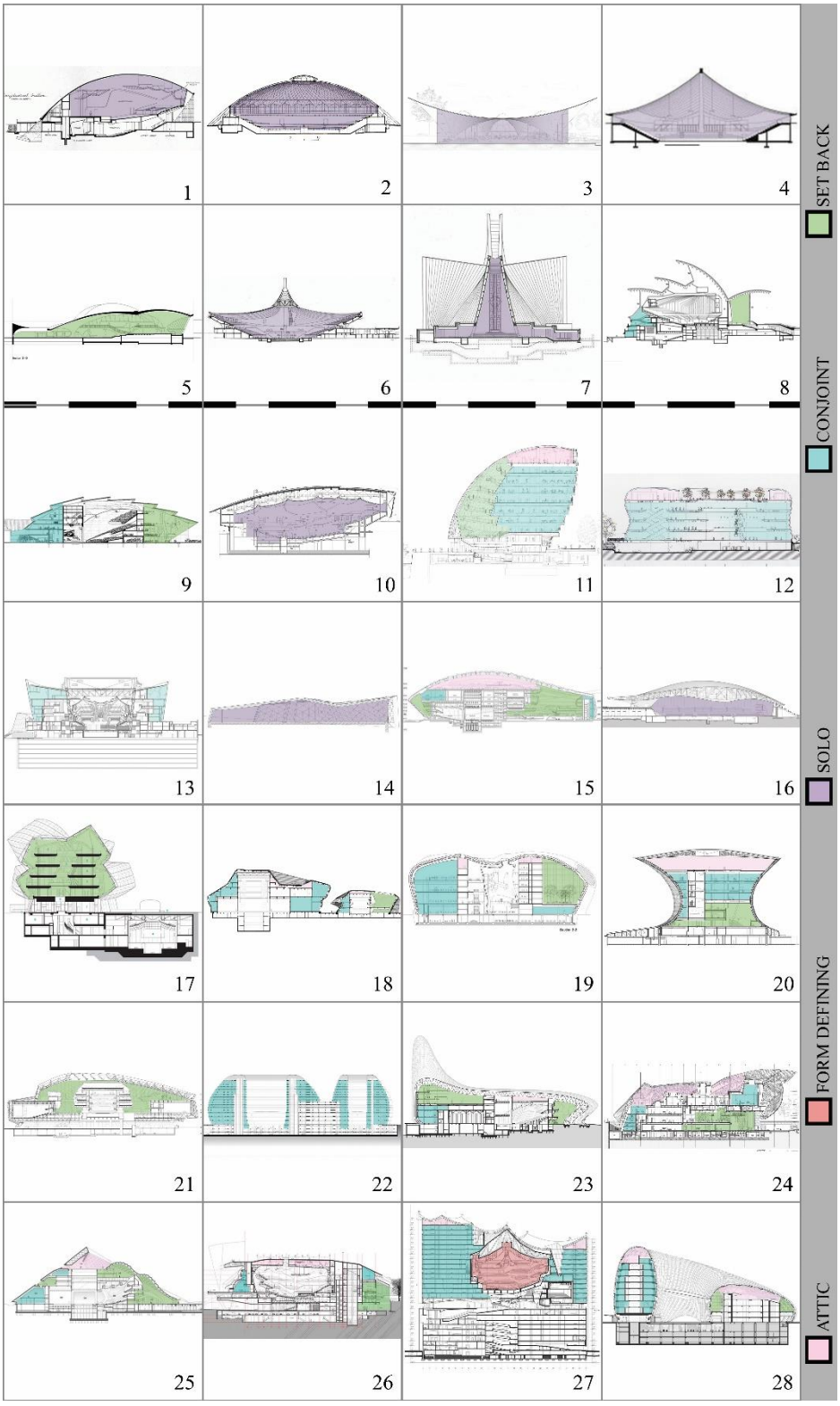

Figure 4.6. Categorization of spaces in section views

4.4.2.1. Set-Back Spaces

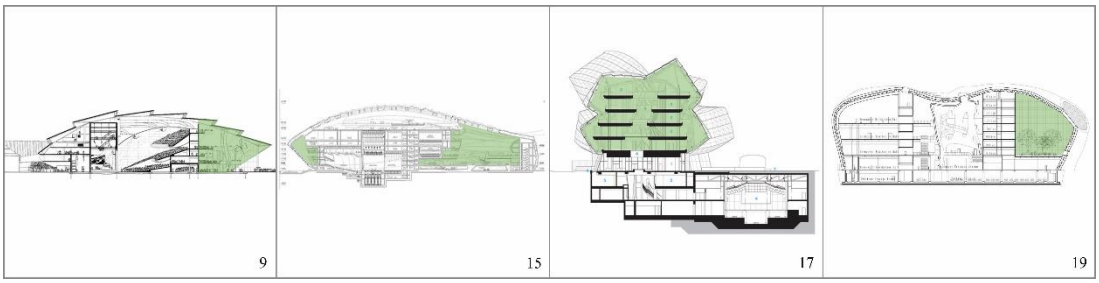

Figure 4.7. Cases exemplifying set back spaces

Set-back spaces can be defined as the spaces that maintain visual or spatial continuity by detaching away from the building skin and allowing a wider perspective for visual perception of the building skin. The form of the building skin determines the formal expression of the spaces.

As explained in the previous chapter, visual perception requires a certain distance from the target. Moreover, visual perception of the building skin of a large scale building requires either large scale spaces or small scale ones which are set-back in order to provide a certain distance for the visual perception of the building skin. The mentioned setting back could apply in two ways. It can be provided either with visual and spatial continuity as in the cases 5, 9, 11, 15, 17, 18, 20, 21, 23, 24, 25, and 26, or visual continuity only as in the cases 19 and 28. When spatial continuity is provided, it is possible to mention the spaces as united set back spaces which are usually large scaled. By courtesy of their height coming from the setting back, they are exposed more to the building skin and they often need big amounts of day light which is provided by the building skin. Since they provide visual and spatial continuity among spaces, it is possible to say that they are usually public spaces.

As can be seen in *Figure 4.7*, in cases 9 and 10, which are SEC Armadillo by Norman Foster and Auditorium Parco della Musica by Renzo Piano, visual and spatial continuity maintained by setback spaces which function as foyer. Whereas, in case 19 in *Figure 4.7*, which is Ordos Art & City Museum by MAD Architects, while visual continuity remains, spatial continuity does not occur. But in both ways a certain

perception of the building skin is achieved since a direct interaction with a large portion of the building skin is provided.

4.4.2.2. Conjoint Spaces

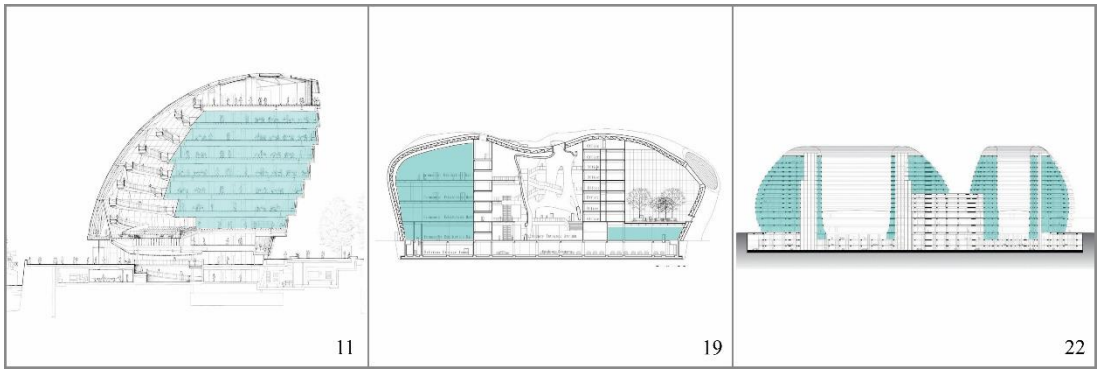

Figure 4.8. Cases exemplifying conjoint spaces

Conjoint spaces, shown in *Figure 4.8*, can be defined as spaces that are located on different levels, completely separated from each other, and directly adjacent to the building skin. The form of the building skin is determinate in formal expression of the very limited portion of the spaces. Since they interact with a very little portion of the building skin, the visual perception of the building skin is very limited.

Conjoint spaces are often small scale spaces as can be seen in cases 9, 15, 20, 22, 23, 24, 25, 26, and 28, and their formal proportions change in the horizontal level rather than vertical, and this proportional differences are not determinant in terms of visual perception of the formal expression of the building skin. In other words, with accordance to the cases, they often do not reach the height that is needed for a comprehensive visual perception of the building skin, but their width can change according to the functional needs. Their accessibility level differs according to the architectural organization and functional requirements of the spaces. No visual or spatial continuity occurs between the levels since they are all directly connected to the building skin without any set back.

There can be clustered spaces, form defining spaces or flexible spaces in different levels. Regarding the scale of the spaces, visual perception of the building skin may

vary. For example, in case 19, which is Ordos Art & City Museum by MAD Architects, due to the scale and proportions of the space, a considerable degree of visual perception is achieved in conjoint space. However, in case 22, which is Galaxy SOHO in Beijing by Zaha Hadid Architects, the spaces are small scale and they interact with a very limited portion of the building skin. In this sense case 22 can be defined as an extreme case which provides the user with the fewest perception among all cases. With regard to the visual examination of the cases, it is possible to say that conjoint spaces do not necessarily relate with one another physically, and their relationship with the building skin is mostly related to day-lighting rather than other reasons. Since they are usually small scaled and they do not interact with a large portion of the building skin, their interaction is limited and mostly natural illumination based.

4.4.2.3. Solo Spaces

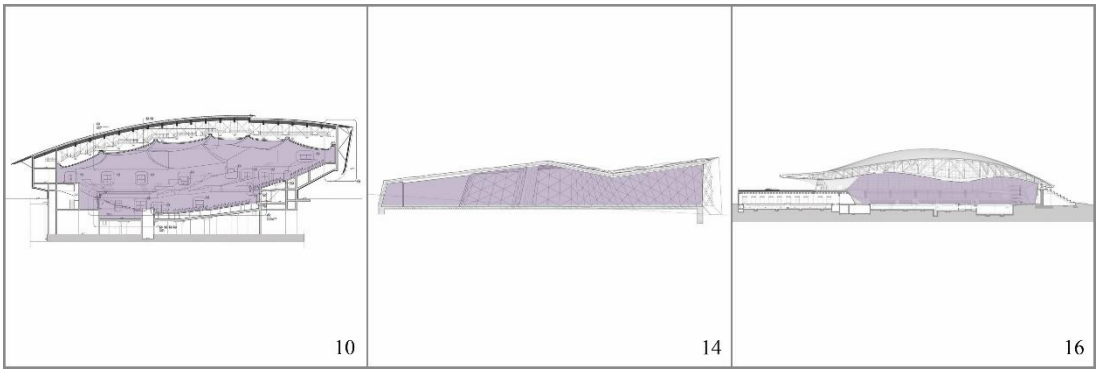

Figure 4.9. Cases exemplifying solo spaces

Solo spaces can be defined as the single spaces that interact with almost all parts of the building skin in a holistic manner. In this case it is both possible that the form of the building skin can be determined directly by the solo spaces, or the form of the building skin can define the form of the solo space.

It is possible to say that small-scale solo spaced buildings dominate the 20th century cases, especially the thin shell structures. The examination of the cases from 1950s and 1960s, especially cases 1, 2, 3, 4, 6, and 7, indicates that the early examples of

Free Form Architecture were mostly designed as small scale solo spaced buildings with a less complex program. The cases studied in this research include functions such as restaurants, auditoriums, sports halls. Since they are designed for merely one space (sometimes together with their subordinate services spaces) their function is the most determinant factor in the form of the building skin. Since the spaces are in direct interaction with the building skin (without a secondary skin) a comprehensive visual perception of the structure is achieved in indoor spaces as indicated in the same cases mentioned above.

Considering the cases from 21st century, it is possible to say that this category applies to two different building scales: small scaled buildings with a simple program containing one major space as case 14, and large scaled buildings with complex architectural programs containing one major dominant space in terms of function, scale, and proportion as case 10 and 16. In both scales minor service spaces can be ignored as long as the major spaces constitute the majority of the building program and almost all portions of the building skin.

In small scale buildings with a simple program it is possible to assert that there are two possible relationships provided between the solo space and building skin. The first possibility is that the spatial requirements of the solo space can be determinant in the form of the building skin. Cases 1, 2, 4, and 6 can be shown as examples. The second possibility is that when the solo space does not dictate a spatial form, the formal expression of the building skin is determinant in the form of the solo space. The case number 14, shown in the *Figure 4.9,* indicates a small scaled solo space which is also flexible: The Hinzert Museum and Document Center. In this case solo space derives its formal expression from the form of the buildings skin. Since it interacts directly with the building skin, without the presence of a second skin, it is possible to say that a comprehensive visual perception is achieved.

The same two possibilities apply to large scale solo spaced buildings too. Case 10 shown in *Figure 4.9,* Auditorium Parco della Musica is an example of form defining

solo space. It has a significant impact on the form of the building skin and it can be perceived from interior. Case 16, also shown in *Figure 4.9*, is London Aquatics Centre by Zaha Hadid Architects and it indicates a solo space that dominates other small scale service spaces. The functional requirements of the solo space have a certain impact on the form of the building skin but it is also possible to say that the formal expression of the building skin is not entirely derived from the solo space and is determinant in the form of the space. In both cases, since the spaces have specific functional and technical requirements, a secondary skin is needed. Since the spaces are not in direct interaction with the building skin, a comprehensive perception of the building skin is not possible.

Since this category focuses on single major spaces, the issues of accessibility, visual and spatial continuity are not applicable.

4.4.2.4. Attic Spaces

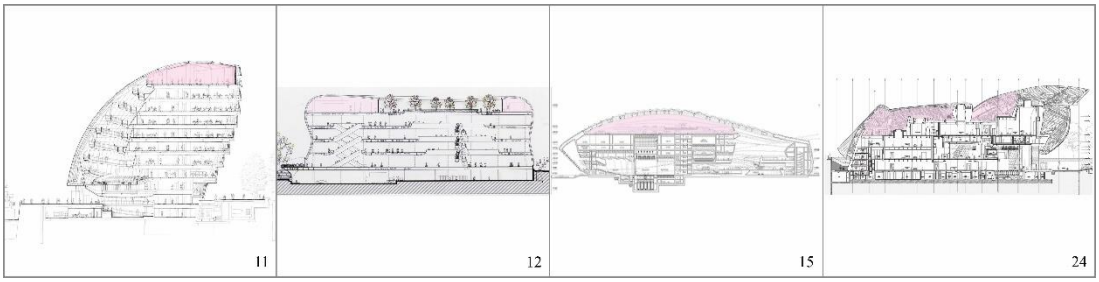

Figure 4.10. Cases exemplifying attic spaces

Attic spaces (*Figure 4.10*) can be defined as spaces located on the highest levels of the buildings interacting with a very large portion of the upper building skin. Their form is almost completely defined by the formal expression of the building skin.

Attic spaces are often large scale public spaces but it is possible for them to take place as both single spaces serving as flexible public spaces as in case 12, 11, 15, 24, 25, and 26 or more private and small scaled spaces such as offices, as in cases 19, 27, and 28, depending on the functional and spatial organization of the building. In terms of proportion, it is possible to say that the former ones are wide to comprehend a very large portion of the skin but the visual perception depends on the height of the spaces

since it requires a certain distance for perception. Visual and spatial continuity can be maintained in a horizontal level but they are not in terms of vertical connections.

There is one special case indicating a different situation. In case 27, which is Elbphilharmonie Hamburg by Herzog & de Meuron, as shown in *Figure 4.11*, the complexity of the building skin establishes itself through attic spaces. The building skin derives its form from the concert acting as a form defining space and creates some small scaled attic spaces. They are the only spaces that witnesses the complexity of the building skin.

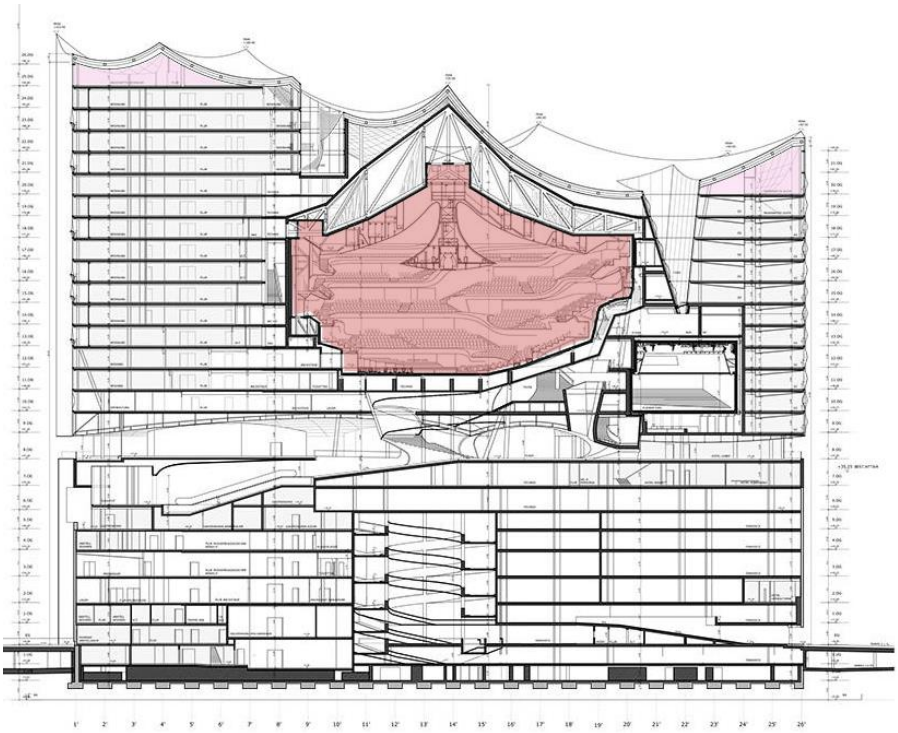

Figure 4.11. Section of the Elbphilharmonie Hamburg

4.5. Representative Cases

In the previous sections the principles and considerations of the analysis of the cases have been introduced and the basis of categorization of the cases and categories have been explained. Although the investigation of the plan and section drawings of the cases suggested a categorical separation of the spaces with regard to horizontal and

vertical spatial organization, it is important to understand holistacally how they act together. For this purpose, four representative cases are selected with respect to the dominancy of the categorized spaces.

Galaxy SOHO Beijing by Zaha Hadid Architects will be examined for the clustered and conjoint spaces. Auditorium Parco della Musica by Renzo Piano will be examined for form defining and solo spaces and City Hall by Norman Foster will be examined for flexible and set back spaces. Fondation Louis Vuitton by Frank Gehry will be examined for attic spaces.

4.5.1. Galaxy SOHO Beijing, Zaha Hadid

Galaxy Soho (*Figure 4.12*) is designed by Zaha Hadid Architects as a complex that houses retail, entertainment and work spaces in the capital city of China. It is a 332,857 m^2 work whose construction completed in 2012. It is a grand scale example of Free Form Architecture with a complex program.

Figure 4.12. Galaxy Soho Beijing

Source: https://www.archute.com/galaxy-soho-stunning-urban-landscape-zaha-hadid-architects/

According to the architects of the project, who are Zaha Hadid and Patrik Schumacher, the main objective of the design was to achieve fluid movement and continuous open spaces, and to bring a new and contemporary interpretation to the traditional Chinese courtyards which can be seen in *Figure 4.13*.[282] Three lower levels contain retail and entertainment spaces, whereas upper ones consist of work spaces and innovative business offices. Top levels are reserved for bars and restaurants due to the advantage of having a extensive city view.

Figure 4.13. Courtyard of Soho Beijing

Source: http://www.zaha-hadid.com/architecture/galaxy-soho/

In this study plan and section drawings of this building complex is examined to explore the relationship between the interior spaces and the building skin. It is possible to see the categorization of spaces that interact with the building skin in plan drawings, as shown in *Figure 4.14* and section drawings, as shown in *Figure 4.15*. Appendix A contains further visual material and other plan and section drawings to provide further information.

Galaxy SOHO is a mixed use building complex with a complex architectural program. It constitutes heterogeneous spaces that are different from one and other in terms of

[282] This information is retrieved from the official website of Zaha Hadid Architects, http://www.zaha-hadid.com/architecture/galaxy-soho/

scale and functions. The program of the building includes shops as retail spaces, entertainment spaces, and offices as work spaces. They are all small scale spaces with specific but similar functions. The building form is designed as clusters that surround large atriums and are in direct connection with the building skin. They are organized as adjacent spaces connected to each other with circulation spaces that take place along the atriums and are the only flexible spaces in the project. The building form is determinant in the way that the spaces are clustered. In other words, the form and organization of the cluster is defined by the form of the building.

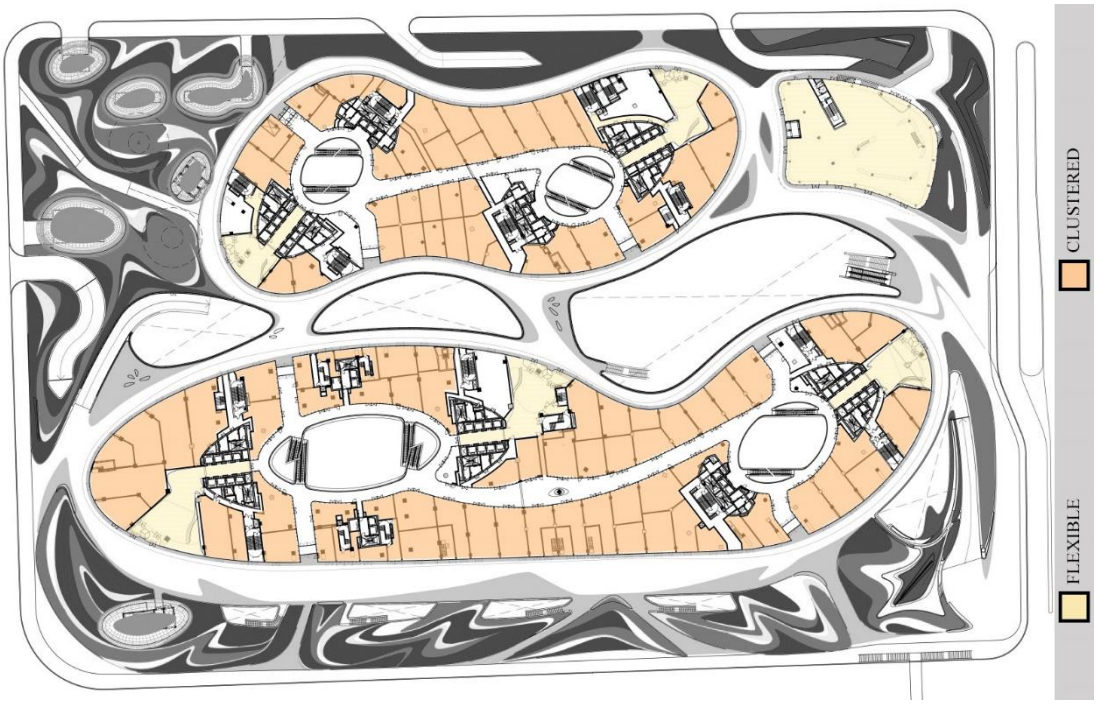

Figure 4.14. Ground Floor plan of Galaxy Soho

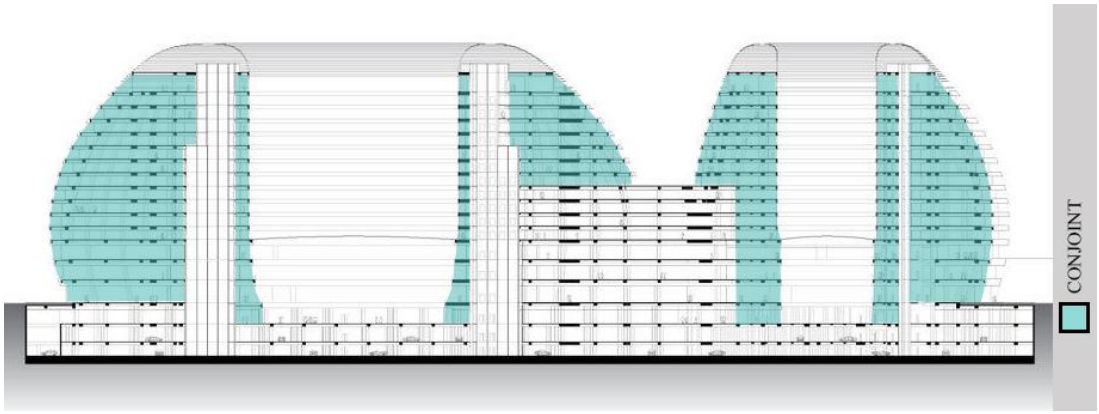

Figure 4.15. Section drawing of Galaxy Soho

As it can be seen in *Figure 4.15*, the clustered spaces are in direct contact with the building skin having no vertical visual or spatial continuity. Since the spaces interact with only a very limited portion of the building skin, visual perception of the formal expression of the building skin is not possible. In this case, building skin serves as a means of natural illumination rather than imposing a formal expression to the spaces it interacts. *Figure 4.16* is one of the very rare interior renders of Galaxy Soho. It is possible to say that the fluid form of the building skin has certain impact on the interior spaces, but this influence is provided by the ornamental elements and a little portion of the building skin. Since the spaces are conjoint to the building skin, a comprehensive perception is not possible and the fluid expression of the interior space is not directly created by the formal expression of the building.

An intention to reflect the formal expression of the building skin to interior space has not been publicly declared as a design objective by the architectural design team of the building. The impact of the building skin on interior space may not always be the main objective of the design process but it is possible to say for Galaxy Soho that there is no intention or effort to reflect the formal expression of the building to interior space except the fluid ornaments implanted inside of the building. The fluid character of the design is only perceivable from the exterior spaces such as the courtyard and open circulation spaces which can be seen in *Figure 4.13*.

Figure 4.16. Interior render of Galaxy Soho

Source: https://arcspace.com/feature/galaxy-soho/

4.5.2. Auditorium Parco della Musica, Renzo Piano

Parco della Musica (*Figure 4.17*) is a large public music complex which is designed on the site of the 1960 Olympics in Rome, by Renzo Piano for competition in 1994 and constructed in 2002. It includes three buildings which are often referred as 'music boxes': Sala Santa Cecilia, Sala Sinopoli, and Sala Petressi. They are positioned around an open air amphitheater.

Figure 4.17. Parco della Musica

Source: http://arch-mess-of-me.blogspot.com/2012/07/auditorium-parco-della-musica_22.html

The 750-seat Sala Petrassi is a very versatile space. By using a movable floor and ceiling and altering the characteristics of the walls, it is possible to obtain the best possible acoustics. The Sala Sinopoli, with a 1,200 seat capacity, also has flexible elements, with a mobile stage and adjustable ceiling make it particularly suited to chamber music and dance performances. The main hall, Sala Santa Cecilia, seats 2,800 people and is reserved for symphonic concerts. Each concert hall differs from the other in terms of dimension and functions, but they are all characterized by an extreme flexibility and versatility of the space. By these means, space can be regulated and adjusted to the nature of performance, where floor and ceiling can be moved to adjust the acoustic properties of the wall.

The plan and section drawings of the largest auditorium, which is Sala Santa Cecilia, is examined in the previous sections. The spaces that have specific functions and technical requirements such as auditoriums require specific forms and they have been previously categorized as form defining spaces in this study. In this case, auditoriums have a significant impact on the overall formal expression of the building skins. As it can be seen in the plan drawing in *Figure 4.18*, and section drawing in *Figure 4.19*, the auditorium is the dominant space that defines the form of the skin and it is the one and only space that has an interaction with almost all parts of the building skin. So it is possible to define it as form defining solo space.

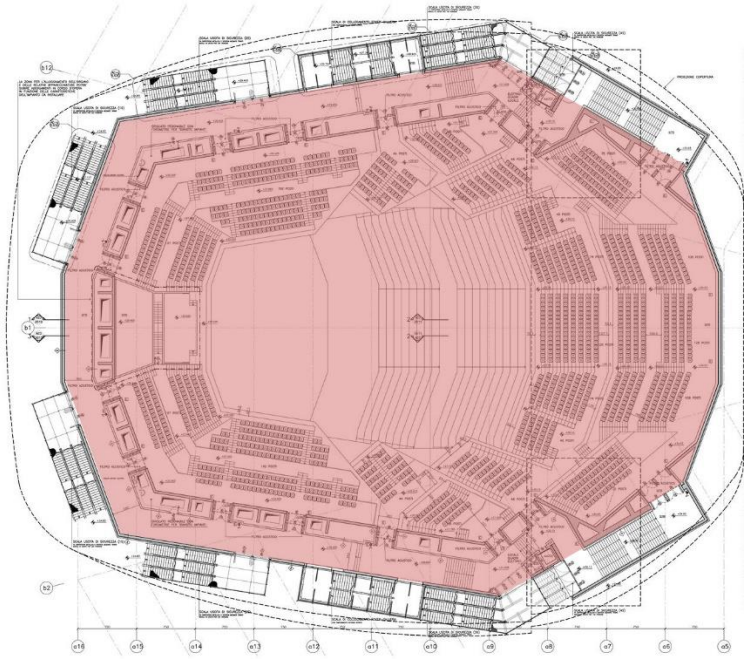

Figure 4.18. Plan drawing of the Auditorium Parco della Musica

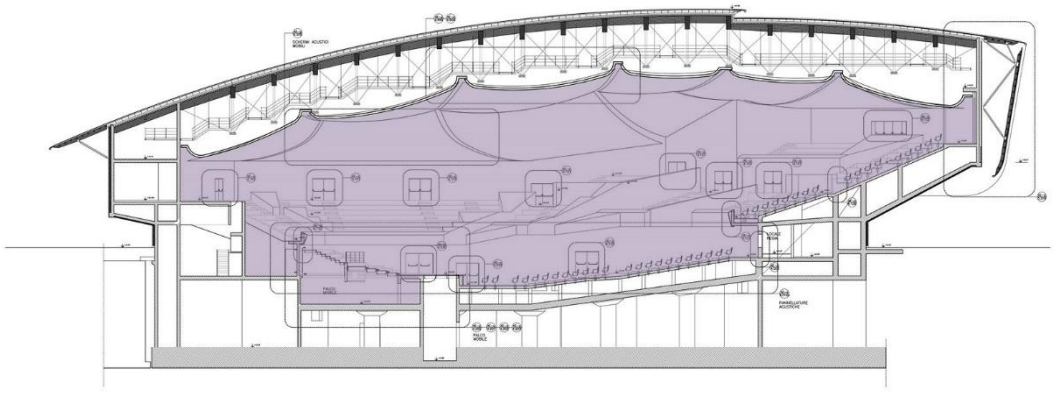

Figure 4.19. Section drawing of the Auditorium Parco della Musica

Although the space has an impact on the formal expression of the building skin, such impact may not be perceived from the interior due to technical and functional adjustments of the spaces. The architectural elements and layers used for mostly acoustical features of the spaces makes it impossible to have a direct visual contact with the building skin (*Figure 4.20*). So, the relationship is constructed on the form of the building skin rather than the surface articulation of it.

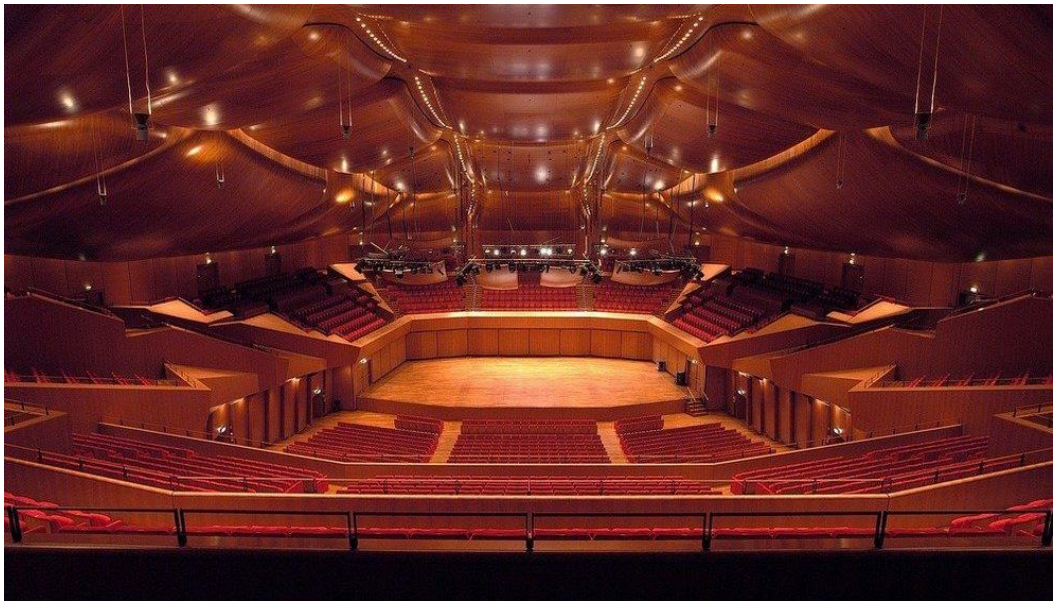

Figure 4.20. Interior of Auditorium Parco della Musica

Source:https://www.10best.com/destinations/italy/rome/airport-fco/nightlife/auditorium-parco-della-musica/

4.5.3. City Hall, Norman Foster

The City hall of London was designed by Norman Foster and completed in 2002. It can be described as one of the most symbolically important project of the capital city of England as it aims to express the transparency of the democratic process.[283] Besides its symbolic references, one of the main objective of the design process of the building is reaching optimum energy performance by minimizing the surface area exposed to direct sunlight.[284] This was possible by the analysis of sunlight patterns throughout the year and employment of a range of active and passive shading devices.

[283] This information is retrieved from the official website of Foster + Partners, https://www.fosterandpartners.com/projects/city-hall/
[284] Ibid.

Figure 4.21. Enter the Figure Caption here

Source: https://www.expedia.mx/fotos/gran-londres/londres/ayuntamiento-de-londres.d6079025/arquitectura-moderna/

The City Hall houses an Assembly chamber, committee rooms and public facilities, together with offices for the Mayor, Assembly members, the Mayor's cabinet and support staff, providing 12,000 m^2 of accommodation on ten levels. The Assembly chamber faces the north and the transparency of the building skin allows Londoners to watch the Assembly at work. The offices are located at the southern part of the building in clusters surrounded by flexible circulation area. At the top floor a flexible space called 'London's Living Room' is also open to public use and it can be used for exhibitions as well.

In the examination of the plan and section drawings of the architectural work, it is revealed that many different categories coexist in the spatial organization of the building. In *Figure 4.22* and *Figure 4.23* the coexisting categories are shown. It is possible to reach other technical drawings of the case in Appendix A for further information.

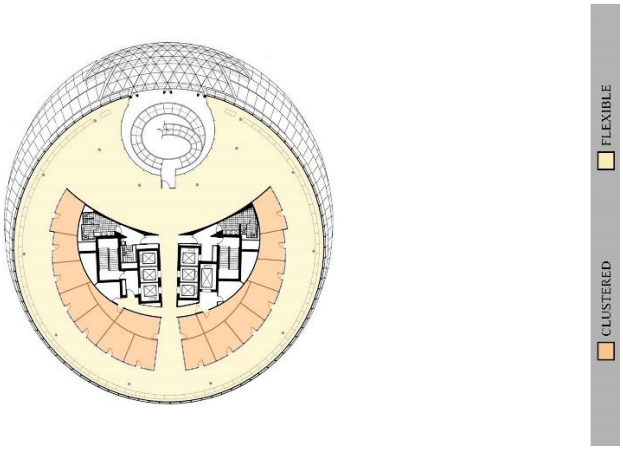

Figure 4.22. Plan drawing of City Hall

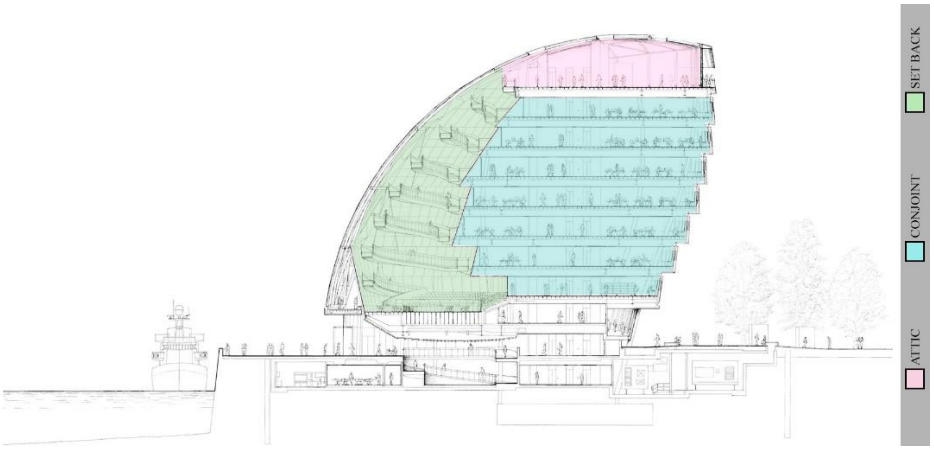

Figure 4.23. Section drawing of City Hall

With accordance to the plan views of the case, it is possible to claim that the flexible spaces have direct contact with the building skin, which is almost entirely transparent. This transparency provides a high level of day lighting for the interior spaces. The visual continuity between the clustered spaces, which are often offices, with the flexible space that surrounds it, which is circulation space, makes it possible to transfer the day light even to the clustered spaces that are not in direct contact with the building skin. As can be seen in the section drawing (*Figure 4.23*), the above mentioned flexible spaces are conjoint to the building skin. However, they become set back spaces as they function as vertical circulation space which reaches to an exhibition area, as on the left hand side of the section drawing. In the conjoint part the visual

perception of the building skin is limited due to the absence of visual or spatial continuity of spaces in a vertical manner. Whereas, in the set back spaces, both visual and spatial continuity is maintained and therefore, a comprehensive perception of the building skin was possible. On the top level, 'London's Living Room' interacts with the whole upper part of the building skin by providing a wide range of visual perception, therefore can be categorized as attic space.

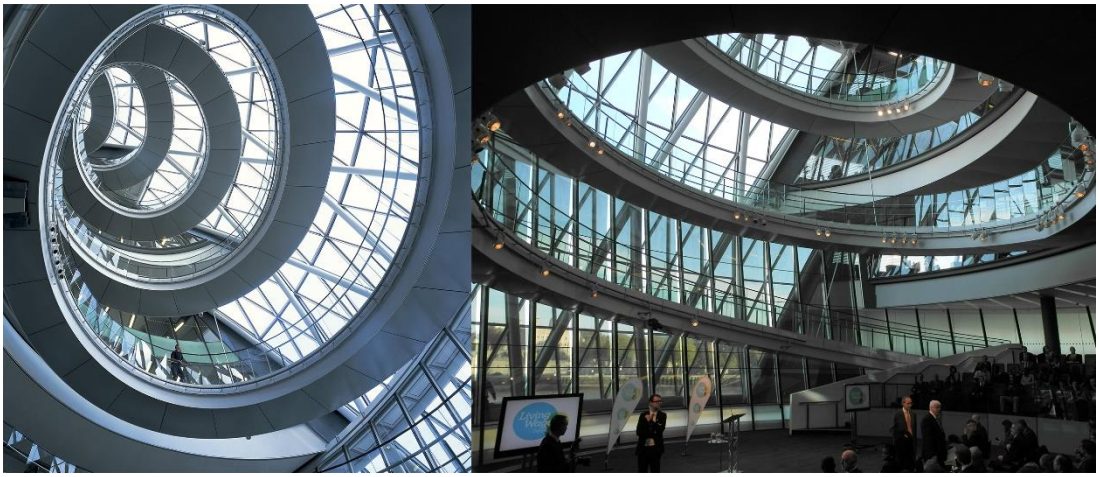

Figure 4.24. Interior of City Hall

Source: https://www.fosterandpartners.com/projects/city-hall/#gallery and https://tiggerrenewing.wordpress.com/2012/11/09/views-of-london-the-changing-landscape/

Although the conception of the building roots itself from symbolic references and performative purposes, it is possible to say that the interaction of the building skin with interior spaces is an important consideration during the design phase. The form of the building and formal expression of the building skin is determinant in spatial configuration and organization. It is possible to say that it is a building which concerns the characteristics of interior space and successful in providing perceivable relationships between building skin and interior spaces especially in the set back spaces as can be seen in *Figure 4.24.*

4.5.4. Fondation Louis Vuitton, Frank Gehry

Foundation Louis Vuitton (*Figure 4.25*) is designed as a large scale cultural center with a complex program. It is 11700,0 m^2 which is completed in 2014. It is located in the Jardin d'Acclimatation in Paris. Since it is located in a garden, the architect approaches it as a pavilion and aims to evoke the tradition of the 19^{th} century glass garden buildings.

Figure 4.25. Fondation Louis Vuitton

Source:https://www.architonic.com/en/project/frank-o-gehry-fondation-louis-vuitton/5103341

The building skin has two layers of elements which can be described as the main body and attached surfaces as shown in *Figure 4.26*. Fondation Louis Vuitton is constructed with an assemblage of white blocks, which are also known as 'the icebergs', clad in panels of fiber-reinforced concrete. Twelve immense glass 'sails' supported by wooden beams are attached to the main body aiming to give Fondation Louis Vuitton its transparency and sense of movement reflecting the water, woods and garden and continually change with the light.

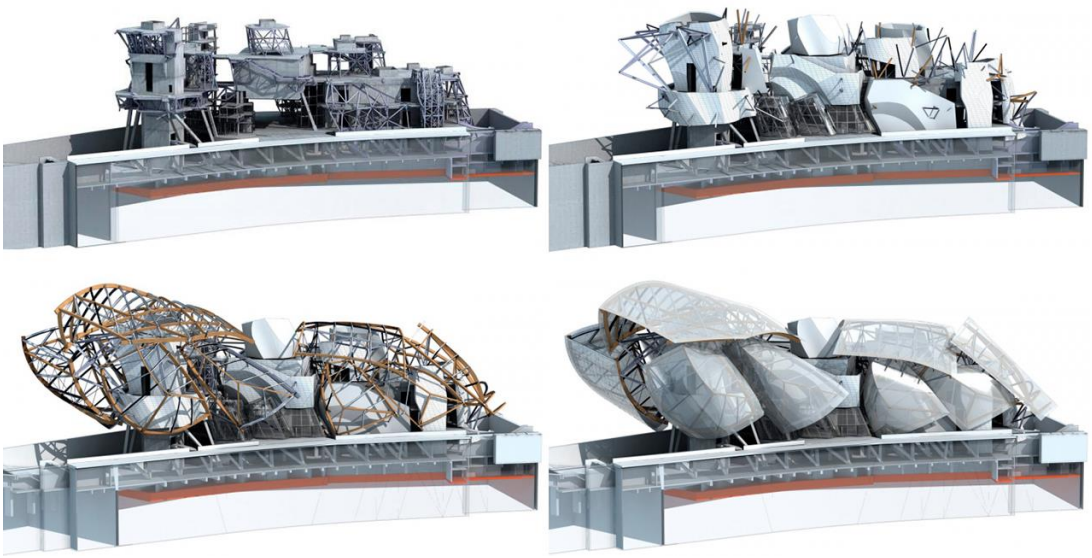

Figure 4.26. Layering of the building skin of Fondation Louis Vuitton

Source: https://www.urbanloka.com/mengintip-megahnya-museum-louis-vuitton-karya-frank-gehry/

The building program contains exhibition areas, offices, a multipurpose hall, open terrace, restaurants, bookstore, library, and art studios. The ground level serves as an active social space hosting a large entrance, exhibition areas, restaurant and bookstore. The relationships of these spaces with the building skin is examined through plan (*Figure 4.27*) and section drawings (*Figure 4.28*). Referring to these drawings it is possible to say that flexible spaces are the ones that interact with the building skin. In the circulation areas visual continuity is provided by the building skin and therefore the glass panels that area attached to the main body could be at least seen rather than applying a formal impact on the interior spaces. As can be seen in the section drawing (*Figure 4.28*), the spaces other than circulation are defined by a secondary skin provided inside and have no direct or indirect relationship with the building skin or the glass panels attached to it.

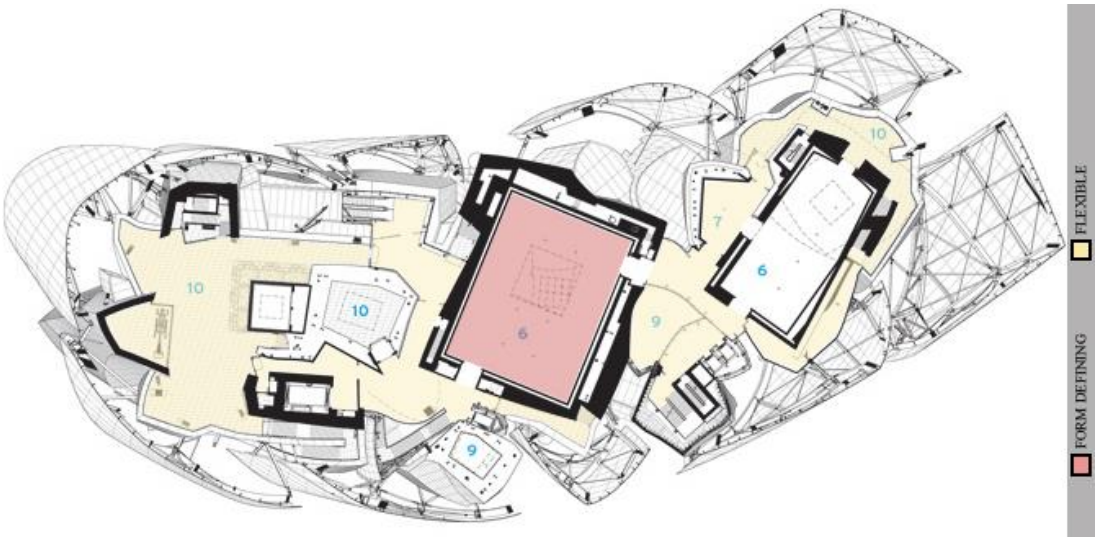

Figure 4.27. Plan drawing of Fondation Louis Vuitton

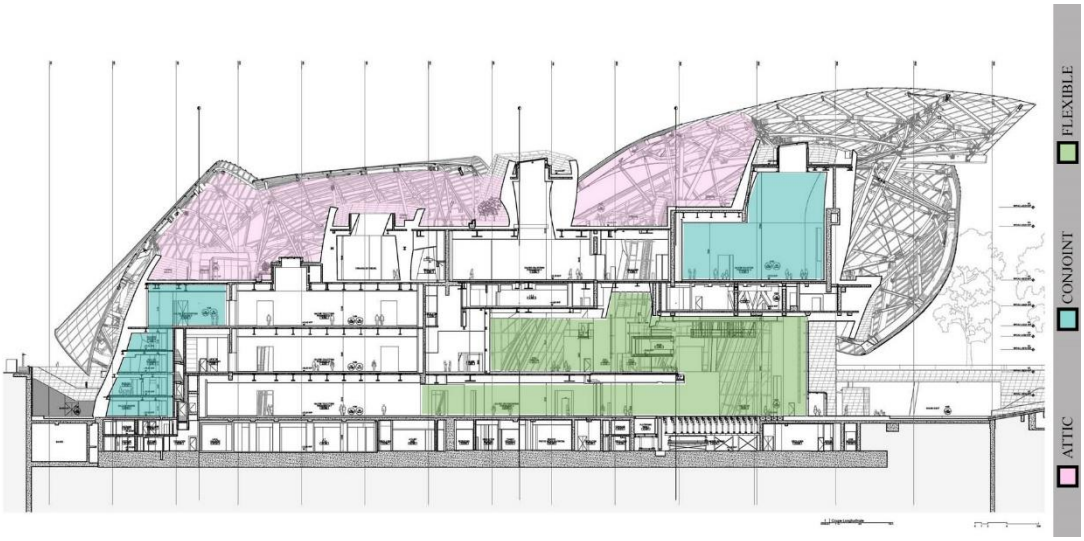

Figure 4.28. Section drawing of Fondation Louis Vuitton

The only space from which it is possible to perceive the attached panels and the building skin in a comprehensive way is the attic space serving as an open terrace (*Figure 4.29*). From the open vertical circulation spaces located in between the main body and the attached skin a limited perception of the panels and the building skin is also possible as can be seen in *Figure 4.29*.

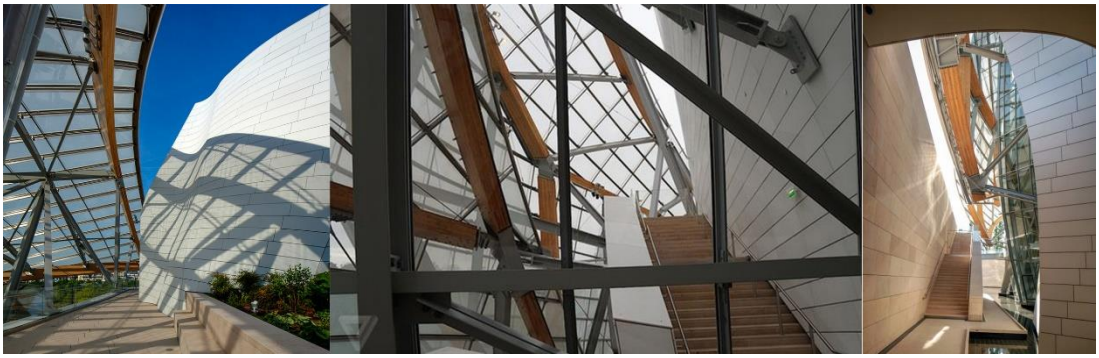

Figure 4.29. Open terrace and vertical circulations of Fondation Louis Vuitton

Source: https://www.archdaily.com/555694/fondation-louis-vuitton-gehry-partners

4.6. Discussion

As this thesis focuses on the relationship between the formal expression of Free Form Architecture and the characteristics of interior spaces, the exploration of these relationships required the examination of the built works of the mentioned domain. The cases of Free Form Architecture ranging from 1950s to 2010s are explored to understand the characteristics of interior spaces in relation to the formal impact of building skin. This case based critical analysis revealed that scale and programmatic complexity of the Free Form Architectural works may have changed through time. The cases from 1950s were small scale buildings with simple architectural programs. They were mostly solo spaced buildings and by courtesy of having one major space, the building skin could have a determinant impact on the formal expression of the space providing a comprehensive perception of the skin. In contrast, the cases from 21st century reveals that as the scale and programmatic complexity of the building increases, the relationship between the building skin and interior spaces may vary according to the spatial solutions provided by the architect.

Since architecture is an act of defining spaces both interior and exterior, independent from the design objectives, and form reasoning of the architectural works the characteristics of the interior spaces is an important issue to be discussed. The

categorization provides a ground to examine and discuss the characteristics of the interior spaces designed in Free Form Architecture.

With accordance to the findings of the comparative analysis of the Free Form Architectural works, it is possible to say that the maximum interaction and perception of building skin may be provided with buildings of solo spaces in 21stcentury as it was in 1950s. However, in case of buildings with complex programs, it is seen that the interaction with the building skin might be limited to the spaces that are organized around the boundary of the skin. The relationship between the building skin and interior spaces depend on the functional and spatial requirements of the spaces, scale and proportion of the spaces, accessibility levels of spaces, and the visual and spatial continuity between spaces. The visual perception of the building skin can only be possible if the building skin interacts directly with the interior spaces. In other words, the presence of a secondary skin created to define a formal expression for the spaces independent from the building skin, detaches the skin from the interior space by providing residual spaces. A comprehensive visual perception of the building skin requires large scale interior spaces, which can be both solo spaces or attic spaces, or setting back of the spaces allowing visual and spatial continuity.

Based on the findings of this research, it is possible to claim that there is a certain intention in reflecting the formal expression of the building skin to interior space in most of the studied cases; however, because of the scale and complexity of the program it may not be not possible for spaces especially following the from the outside in approach. According to the examination of the cases, such reflection is made possible for large scale public spaces and it may be renounced in small scale private spaces in most of the cases. By considering the positive and negative findings about the interrelations between the building skin and interior spaces, it is possible to summarize the ways to provide relatively better relationships between the building skin and interior spaces based on the categories and the findings of the research. It is possible to address four main results:

1. Direct physical interaction of spaces with building skin is essential. The cases 10, 13, and 27, which contain form defining solo spaces such as conference halls, indicates that although the spaces have a direct influence on the building form and the formal expression of the building skin, it is not perceivable from the interior. The reason for this situation is the second skin that is created inside to satisfy the technical requirements of the space. In this case it is possible to say that in order to be able to discuss the desired interrelations, the building skin might be preferred to be in direct physical contact with the interior space.
2. As it was explained further in chapter III, the visual perception of the building skin from interior spaces may require a certain distance. The scale and proportions of the spaces have a great impact in providing the necessary distance from the building skin. Large scale spaces that are in direct physical contact with building skin might lead to a more comprehensive visual perception of the building skin.

The combination of the first and second results can be seen in the 1950s thin shell structures. They consist of one major space and the presence of a second skin is not applicable. In the first seven cases it is possible to see that the spaces are in direct physical contact with the building skin and a comprehensive visual perception is provided since almost the entire skin is perceivable from the interior. However, it is rather more difficult to provide similar interior space characteristics when it comes to large scale 21stcentury Free Form Buildings with a complex building program. Similar relationships might be possible with large scale interior spaces which might also be attic spaces.

3. Under the same concerns, small scale spaces can also provide the desired distance when they are organized vertically as set back spaces. When the visual and spatial continuity are provided, the observer might visually perceive the building skin in a more comprehensive way, and

the spaces (that are organized by setting back) might generate a integrated relationship with the building skin.

4. Flexible spaces can be better in generating a direct physical interaction with the building skin. Since flexible spaces would not have specific technical requirements or proportional restrictions, it might be easier to organize them interacting directly with the building skin.

CHAPTER 5

CONCLUSION

Within the scope of this research, first and foremost it is aimed to explore the reflection of the formal expression of the building skin on the characteristics of interior spaces in the domain of Free Form Architecture. The roots and principles of Free Form Architecture have been discussed and its current state is explored. The first phase of the literature review revealed that the main concerns about the design and form reasoning process of the free form architectural works are digital production tools, representation tools, rationalization process including structural and material aspects, and performative features according to the common study fields. Another aspect of Free Form Architecture which the literature review indicates, is that there are not many studies about the interior space definition or visual perception of the building skin from the interior. This is an indication of the design intentions of the mentioned architecture and rises questions that guides this thesis.

In order to be able to answer the questions about the building skin and interior space, it is important to study the space-boundary relationship. The second phase of the literature review served this purpose. Architectural space definition can be explored through spatial relationships and the categorization of spatial forms. Building skin is examined through its technical and performative purposes and its relationship to interior space definition is explored. This exploration revealed an important aspect in the interrelation of the building skin and interior spaces, which is the visual perception. The visual perception principles defined to be able to examine the existing examples of Free Form Architecture.

Considering all the information gathered in the literature review section of the thesis, research considerations are detected for the case study research. Since this thesis aims

to explore the existing relations in an architectural domain without a pre-established theory, case study research can be considered as a consistent method. The examination of a number of cases selected both from 20th and 21stcentury Free Form Architecture, revealed certain types of relationships existing between the building skin and interior space. A categorization could be possible to provide a framework for discussion. The categories have been explained individually but they exist together in the architectural works. Therefore, in order to comprehend the discovered relationships, they have been examined together on the representative cases. The case study research revealed that the reflection of the formal expression of building skin on interior spaces can be made possible for large scale public spaces and it can be renounced in small scale private spaces in general.

With accordance to the information gathered in this case based critical analytical research it is possible to claim about Free Form Architecture that in 21stcentury building scale and the complexity of architectural program has increased. So, spatial organization and a perceivable relationship between the interior spaces and the building skin has become a challenge. In most of the cases, since Free Form Architecture adopts from the outside in approach, its primary design considerations may not contain the relationship between the interior space and the skin. As mentioned in the first chapter, construction systems, materials and rationalization process may have become the primary concerns, as well as, performative issues.

Regarding the information derived from the case study research, it is possible to say that even though the primary design considerations may not include the interaction of the building skin to interior space, it is not totally ignored too. It is possible to detect a certain effort to reflect the formal expression of the building skin to interior space in the cases. The complexity of building program and the ambition comes from the possibilities of the digital tools weakens the possible relations. Therefore, the comprehensive and perceivable relationships may be limited to a small portion of the interior spaces which are usually flexible large scale public spaces. The rest, such as

small scale private spaces, may be renounced for the sake of providing a provoking appearance to the city.

The formal expression of building skin can be very limitedly perceived from the inside. Therefore, the spatial concerns may have been regarded as secondary design consideration in Free Form Architecture. Therefore, the fact that architecture is the act of defining spaces is not completely ignored but it is clearly not a primary design criterion in the increasingly complex free form architectural works. As it is detected that Free Form Architecture may serve the technical requirements and the iconic statement to the city more than it serves to interior space.

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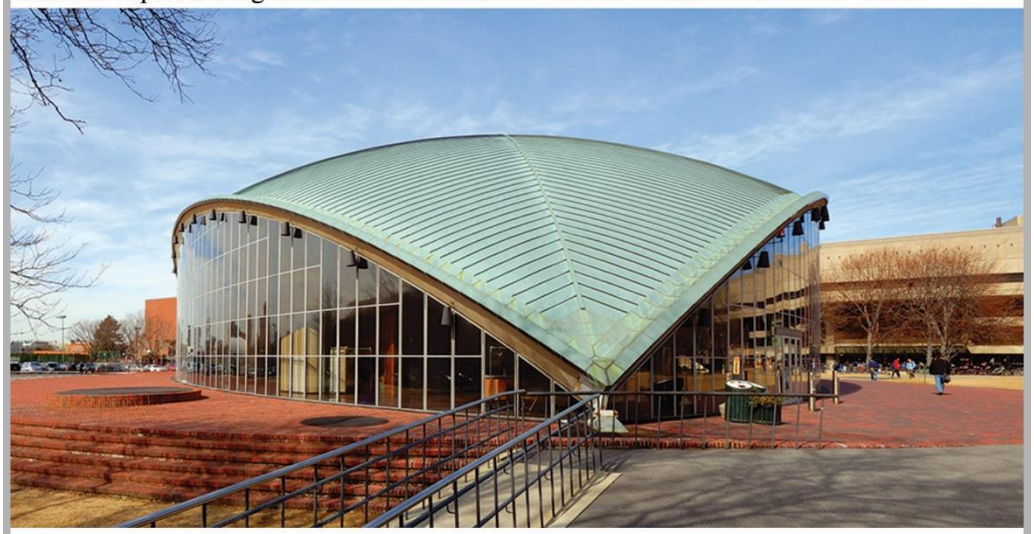
APPENDICES

A. CASES

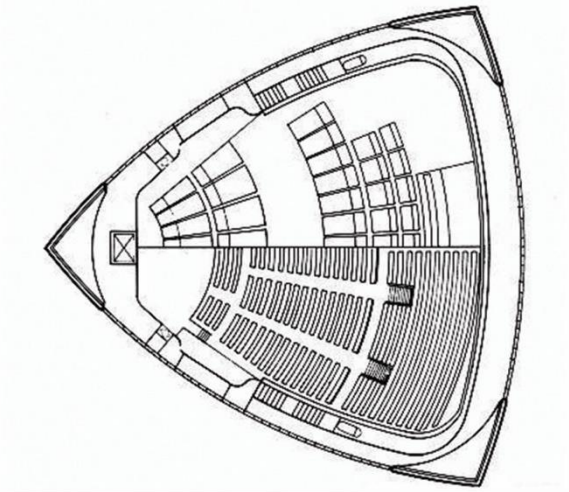
1. Kresge Auditorium, 1955, Eero Saarinen, Massachusetts, US

Source: https://www.glassdoor.com/Photos/MIT-Office-Photos-IMG1832214.htm



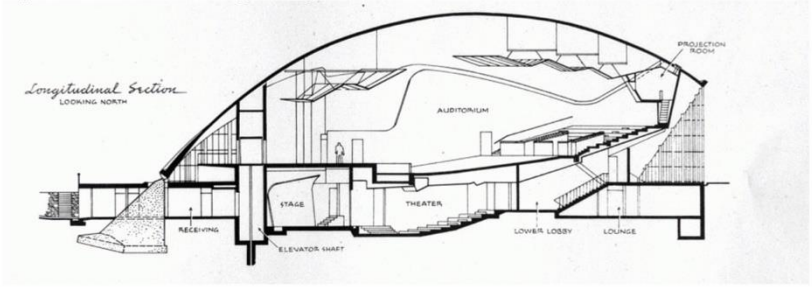
Source: https://www.archdaily.com/492176/ad-classics-kresge-auditorium-eero-saarinen-and-associates/533aca0fc07a80be520000a0-ad-classics-kresge-auditorium-eero-saarinen-and-associates-image

Source: https://davidfixler.com/mit-kresge-auditorium



PLAN

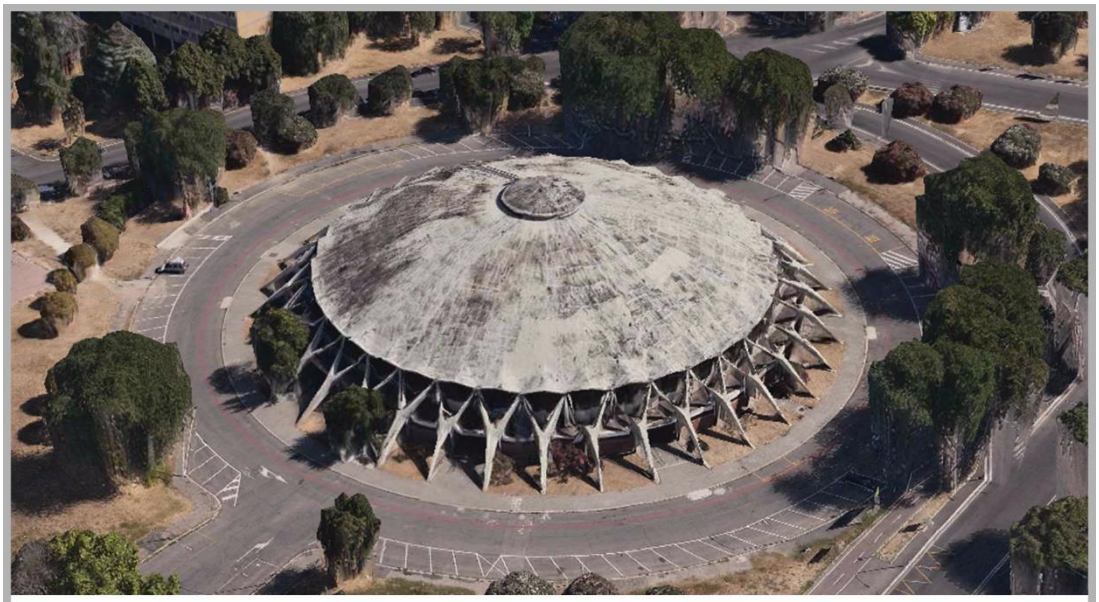
Source: https://tr.redsearch.org/images/866555



SECTION

Source: https://en.wikiarquitectura.com/building/kresge-auditorium/

2. Palazzetto dello Sport, 1956, Annibale Vitellozzi, Pier Luigi Nervi, Rome, Italy



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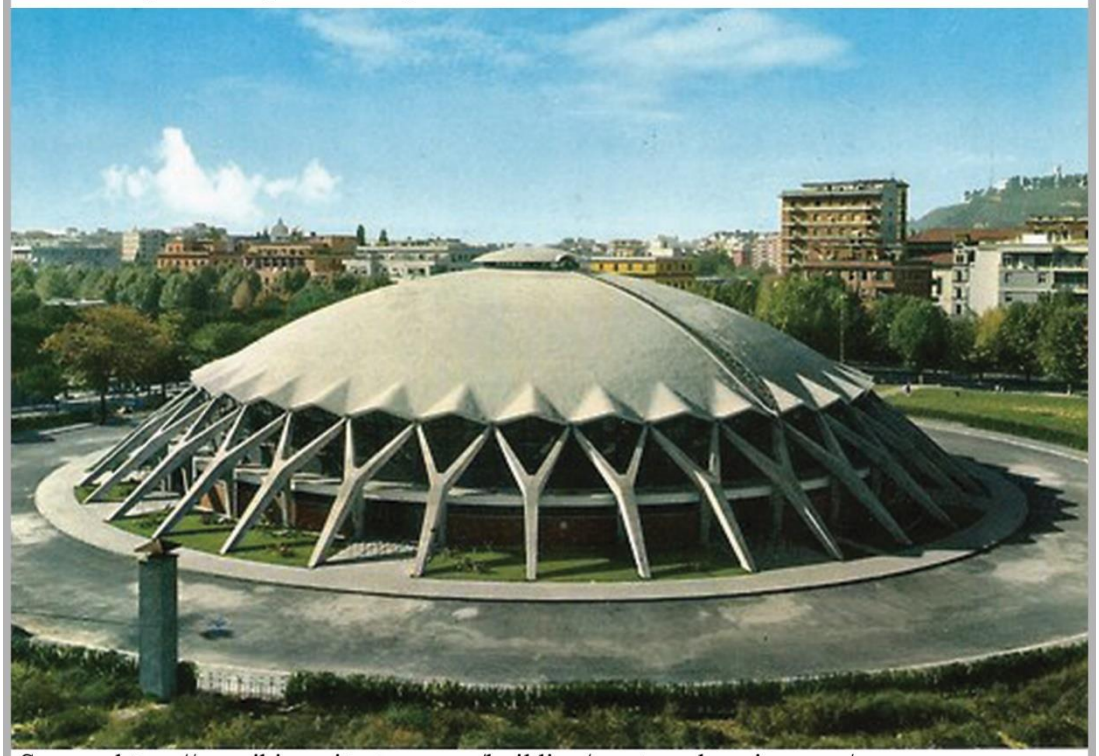

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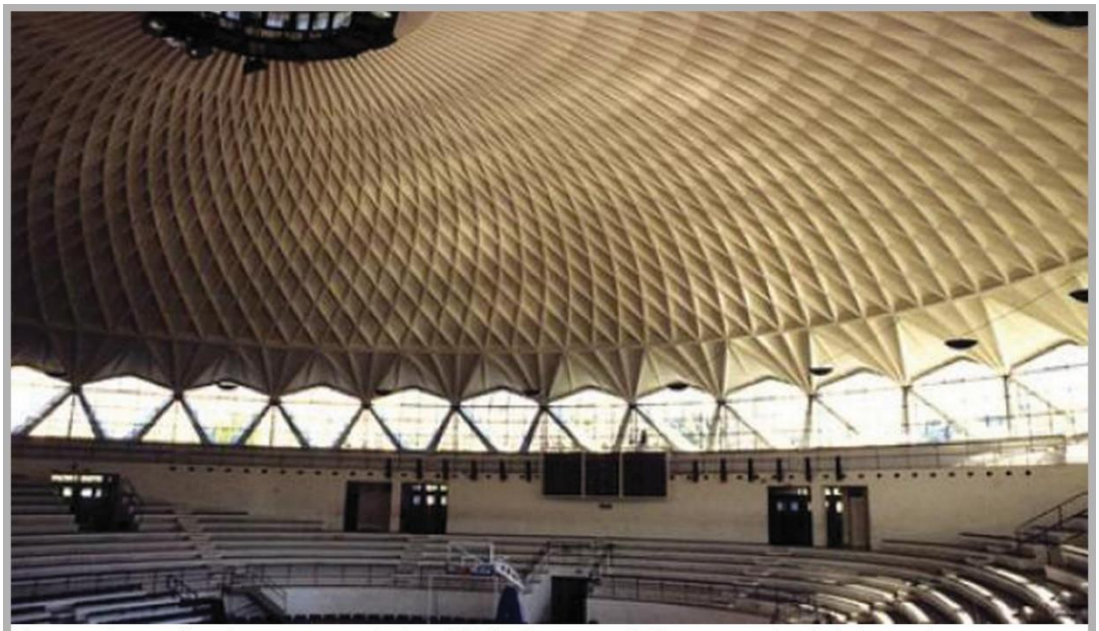

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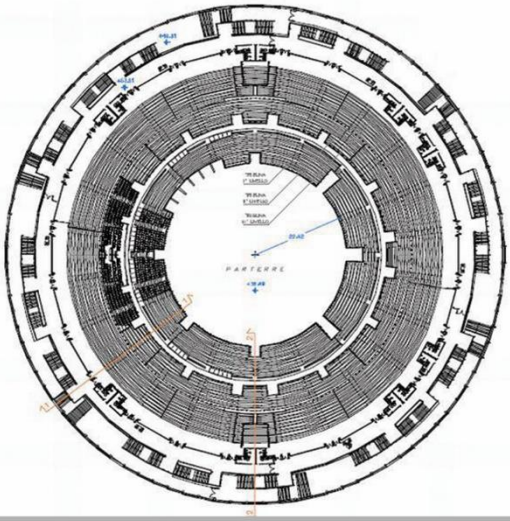
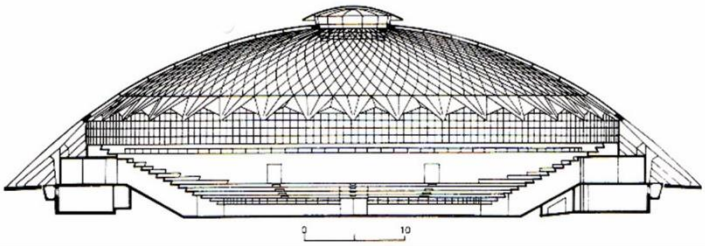


PLAN

Source: https://en.wikiarquitectura.com/building/palalottomatica/



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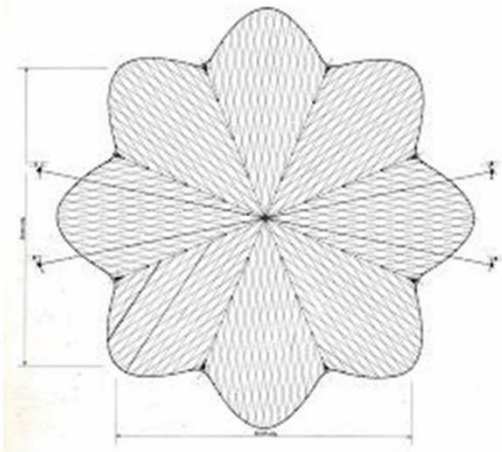
Source: https://picswe.net/pics/palazzetto-dello-sport-structure-analysis-a0.html

3. Los Manantiales, 1958, Felix Candela, Mexico

Source: https://www.archdaily.com/496202/ad-classics-los-manantia-les-felix-candela/5346206cc07a80f94d0000a0-ad-classics-los-manantiales-felix-candela-image

Source: https://tr.pinterest.com/pin/333759022367010299/?lp=true

Source: https://www.archdaily.com/496202/ad-classics-los-manantia-les-felix-candela/53462042c07a80a76e0000a6-ad-classics-los-manantiales-felix-candela-image



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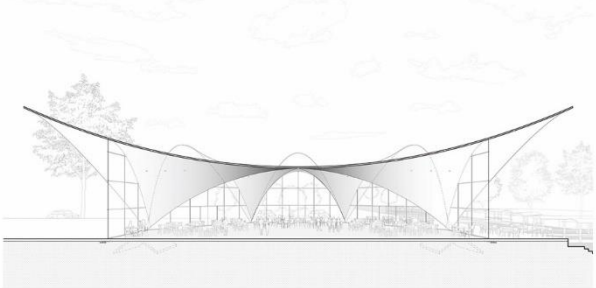

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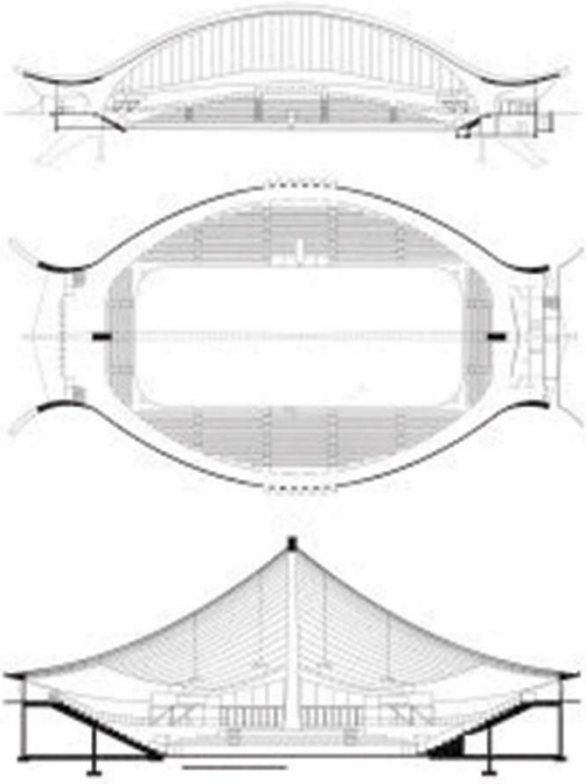
https://tr.pinterest.com/pin/282249101627851230/?lp=true

4. Ingalls Rink, 1958, Eero Saarinen, Connecticut, USA

Source: https://architizer.com/projects/yale-university-david-s-ingalls-rink/

Source: https://101independencecenter.com/yale-school-of-architecture/

Source: https://stadiumsandarenas.files.wordpress.com/2014/12/3613.jpg



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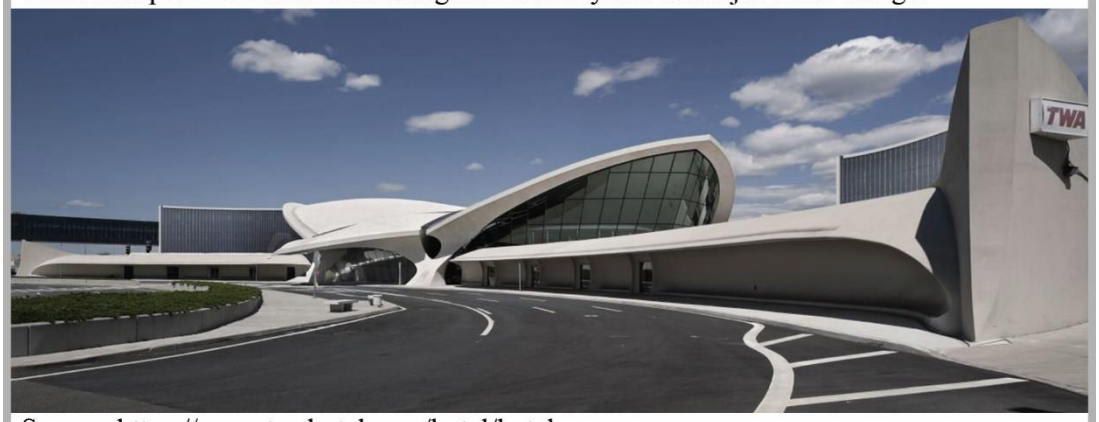
Source: https://tr.pinterest.com/pin/721983383988313956/?lp=true

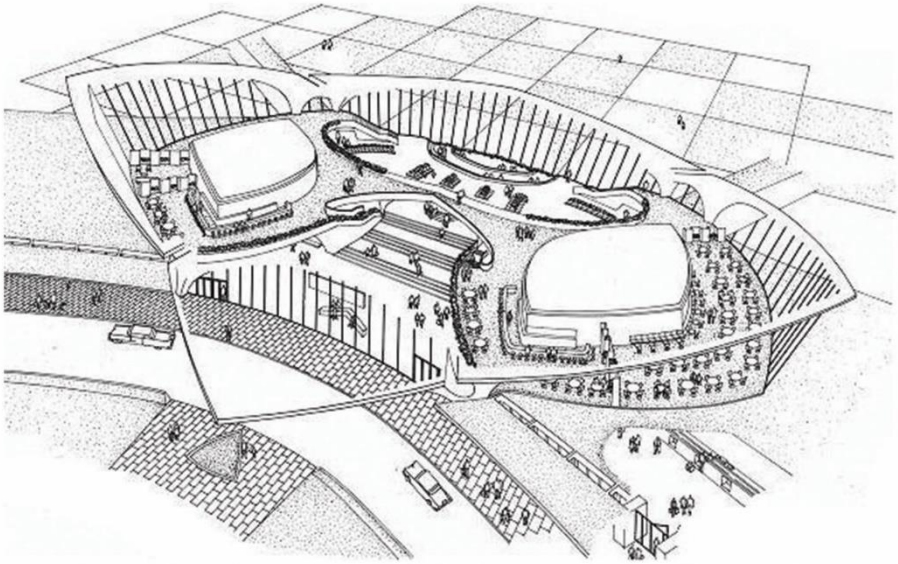
5. TWA Flight Center, 1962, Eero Saarinen, NYC

Source: https://www.architecturaldigest.com/story/twa-hotel-jfk-room-design

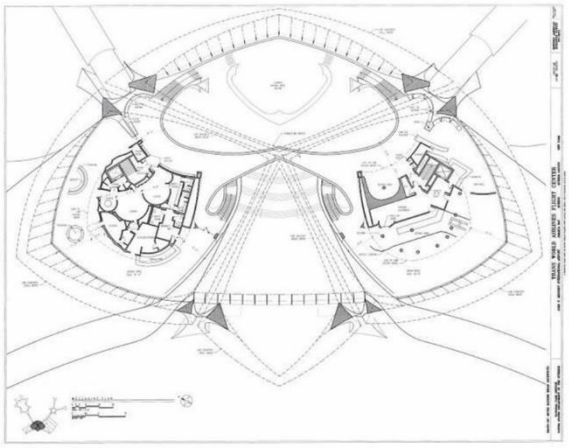


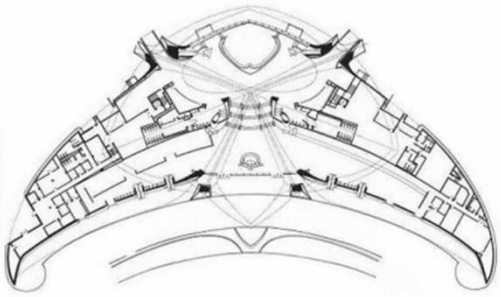
Source: https://www.twahotel.com/hotel/hotel

Source: https://tr.pinterest.com/pin/360780620134743189/?lp=true



Source: https://en.wikiarquitectura.com/building/twa-terminal-at-jfk-airport/





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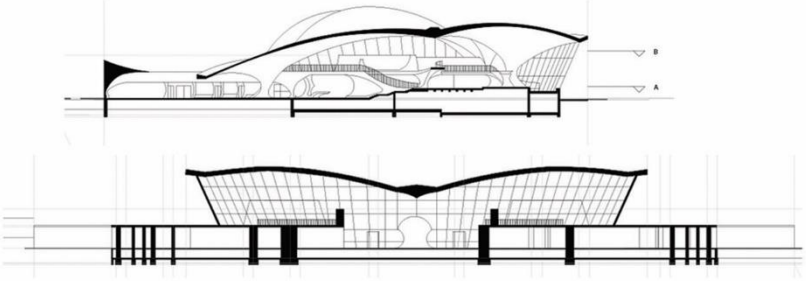
Source: https://en.wikiarquitectura.com/building/twa-terminal-at-jfk-airport/



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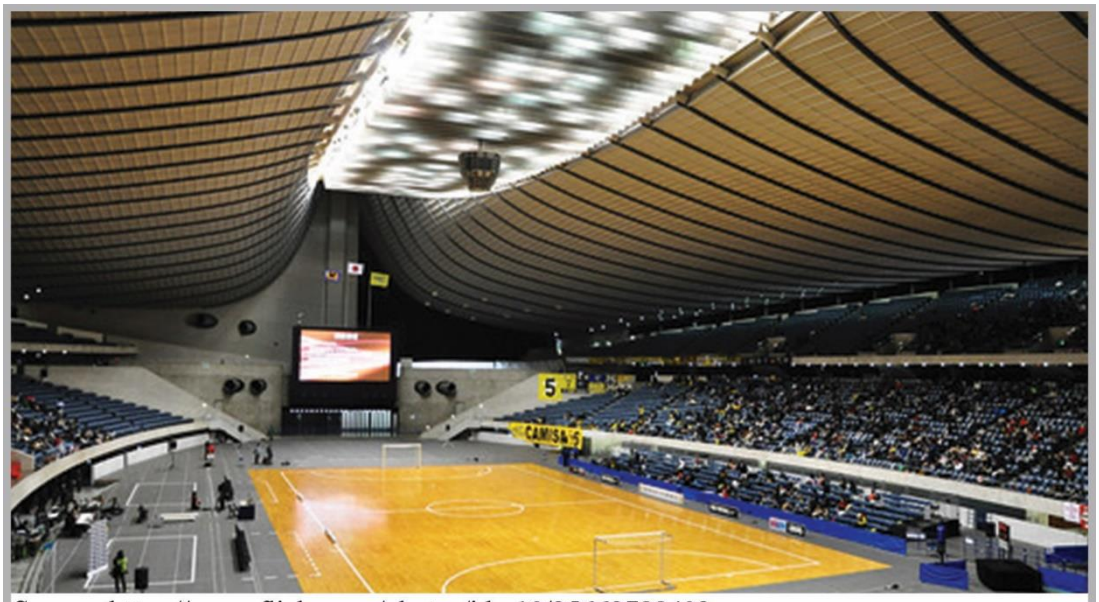
Source: https://en.wikiarquitectura.com/building/twa-terminal-at-jfk-airport/

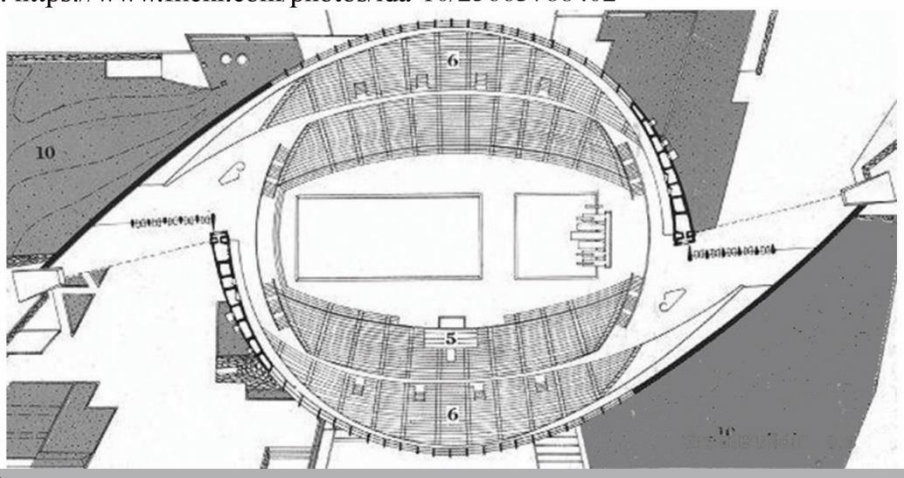
6. Yoyogi National Gymnasium, 1964, Kenzo Tange, Tokyo, Japan

Source: https://tr.pinterest.com/pin/342555115379963692/?lp=true

Source: http://www.ggany.com/publications/the-five-best-and-five-worst-olympic-stadiums-an-unofficial-ranking.html



Source: https://www.flickr.com/photos/ida-10/25663788402



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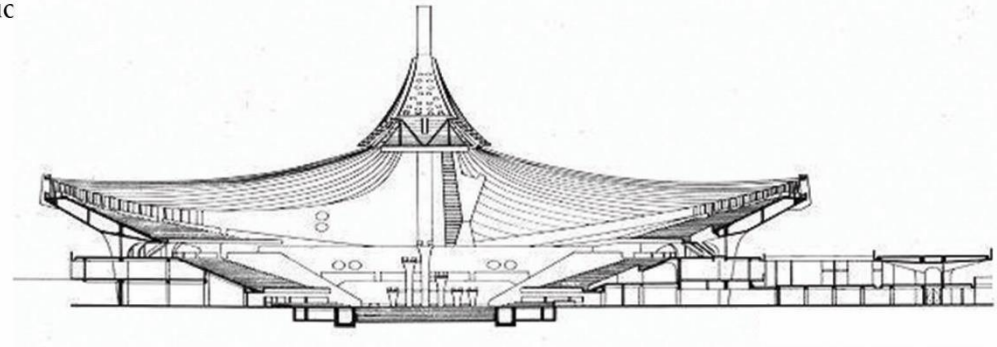
Source: https://faculty.arch.tamu.edu/media/cms_page_media/4433/Yoyo-giNatic



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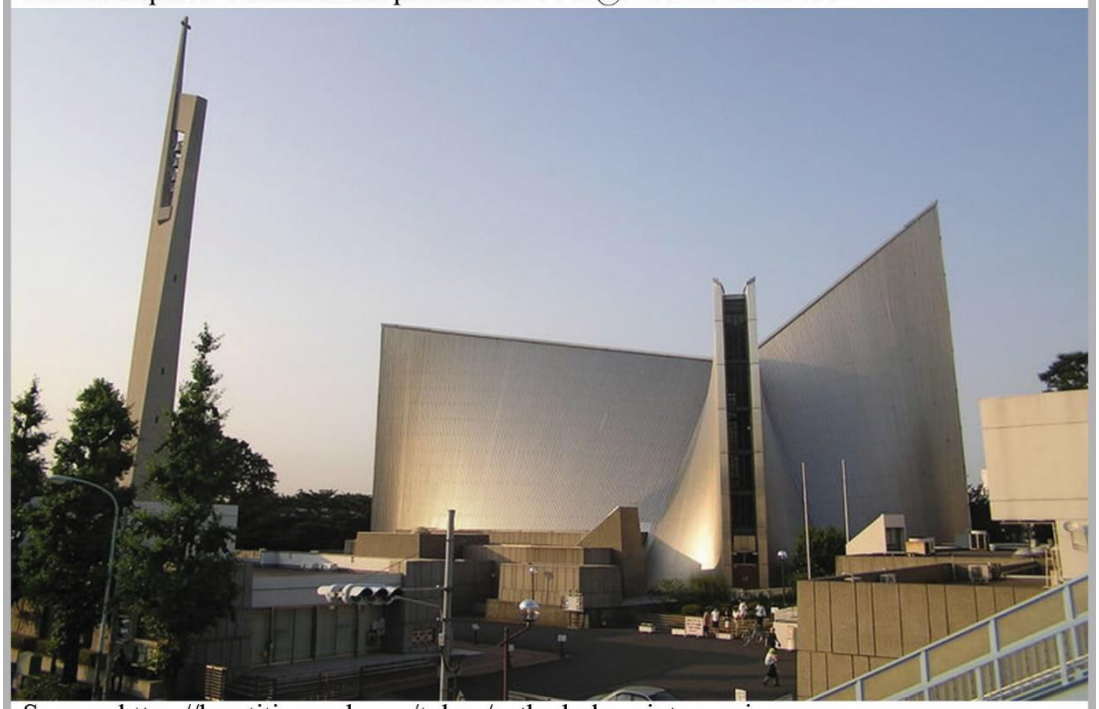
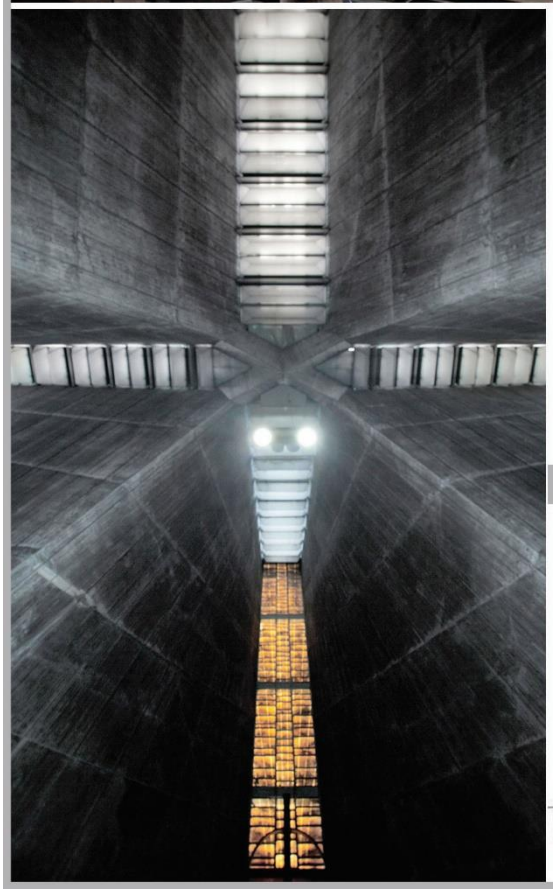
Source: https://www.pinterest.com/pin/172614598189477596/

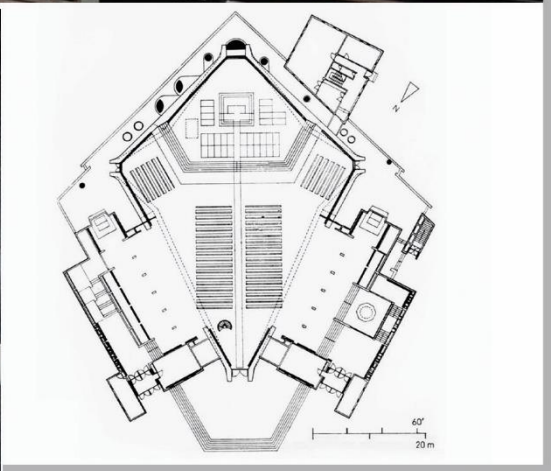
7. St. Mary Cathedral, 1964, Kenzo Tange, Tokyo, Japan

Source: https://www.flickr.com/photos/77597060@N02/28729979416



Source: https://lepetitjournal.com/tokyo/cathedrale-sainte-marie





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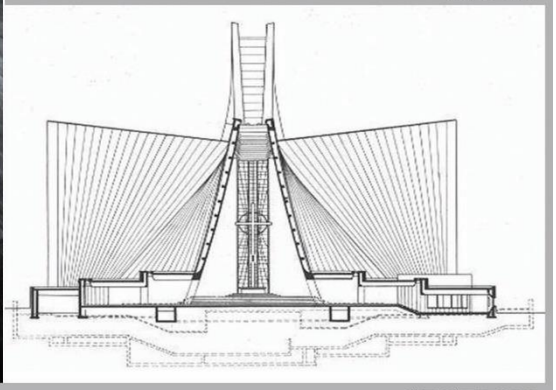

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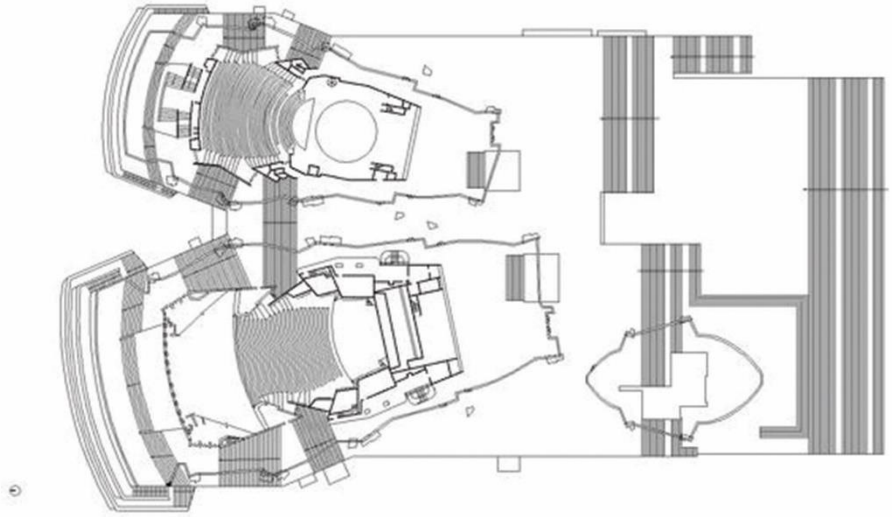
Sources: https://tr.redsearch.org/images/4223767

8. Sydney Opera House, 1973, Jørn Utzon, Sydney, Australia

Source: https://blogs.getty.edu/iris/preserving-the-future-of-the-sydney-opera-house/

Source: https://www.flickr.com/photos/132084522@N05/16524153093

Source: https://www.aurecongroup.com/projects/property/sydney-opera-house-renewal



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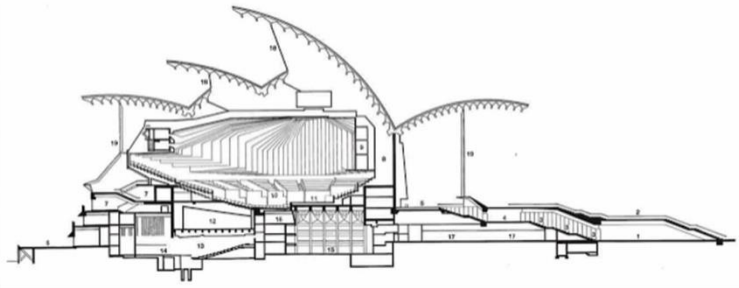
Source: http://www.boss888.net/cad-blocks-drawings-download/product/sydney-opera-house/



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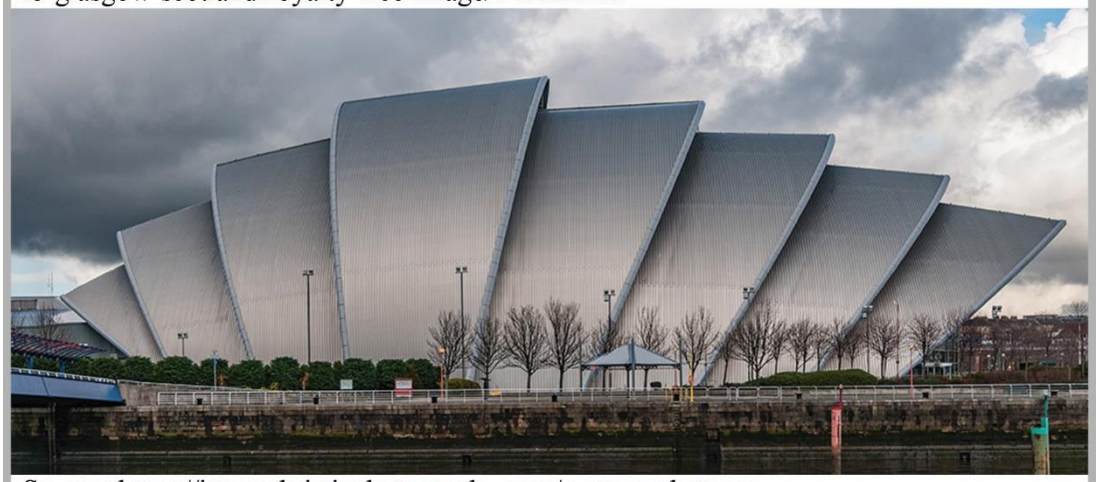
Source: https://en.wikiarquitectura.com/building/sydney-opera-house/

9. SEC Armadillo, 2000, Norman Foster, Glasgow, Scotland

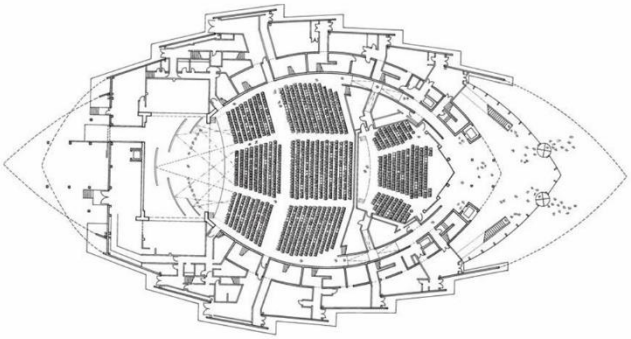
Source: https://www.dailyrecord.co.uk/news/scot-tish-news/sec-glasgow-submits-200million-expansion-13595843

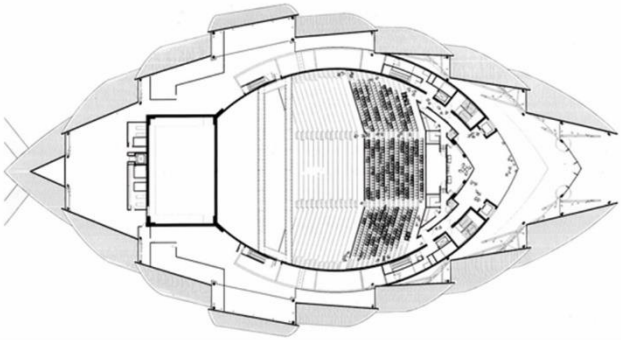
Source: https://www.gettyimages.com/detail/photo/armadil-lo-glasgow-scotland-royalty-free-image/848612538



Source: https://jameschristiephotography.com/custom-photogra-phy-tours-of-scotland/armadillo-glasgow/

Source: https://www.sec.co.uk/organise-an-event/event-spaces/sec-armadillo





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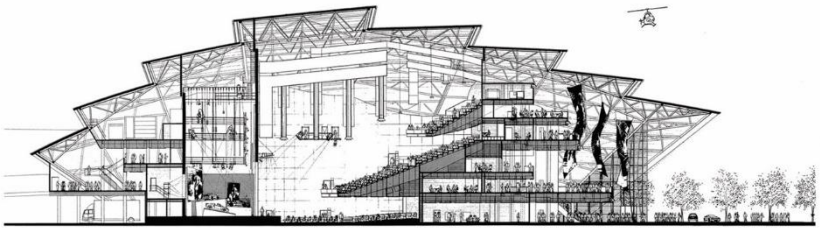
Source: http://sagekuningabangijo.subir.pw/clyde-auditorium-floor-plan



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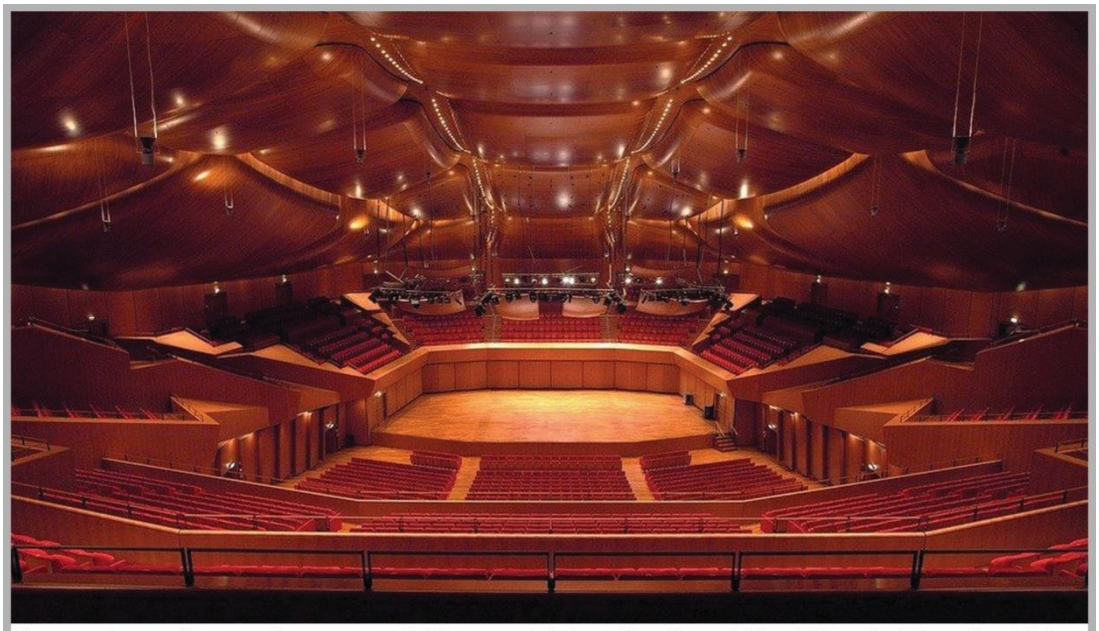
Source: https://www.pinterest.ie/pin/742601426032429519/

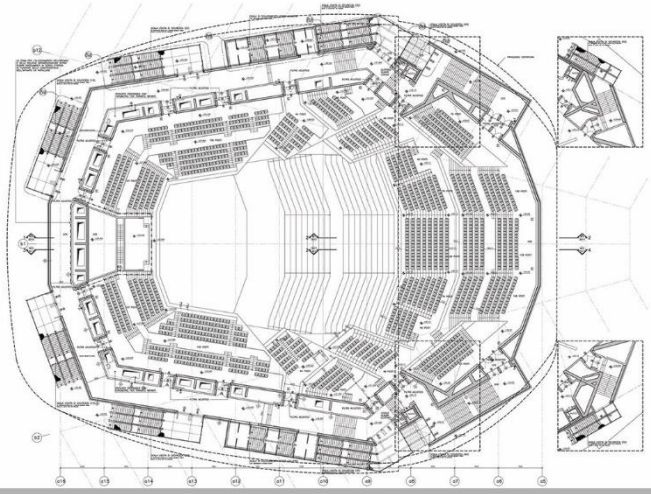
10. Auditorium Parco della Musica, 2002, Renzo Piano, Rome, Italy

Source: https://tr.pinterest.com/pin/120119515036691651/?lp=true

Source: https://www.flickr.com/photos/arkimastru/34100883126



Source: https://www.viagogo.co.uk/Concert-Tickets/Rock-and-Pop/Giorgio-Moroder-Tickets



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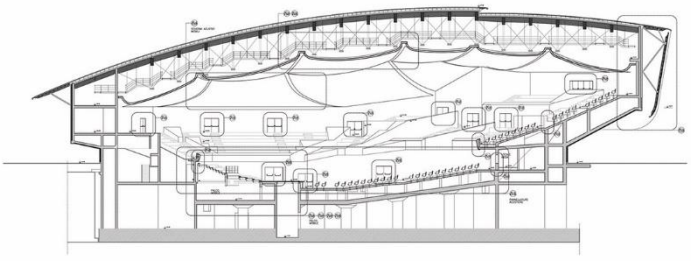
Source: https://tr.redsearch.org/images/8047729



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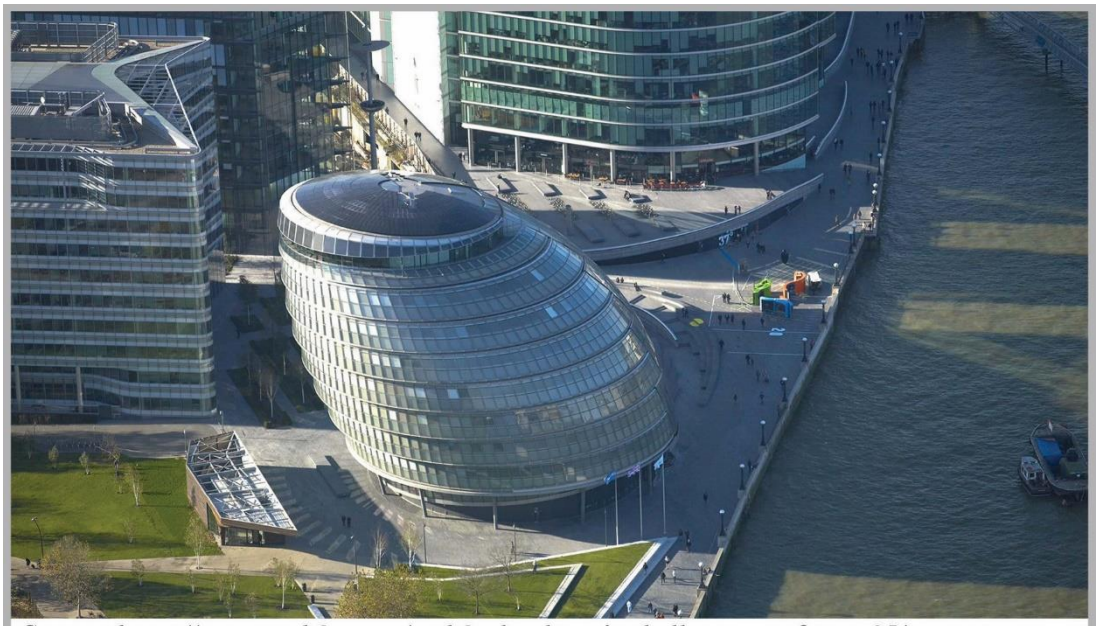
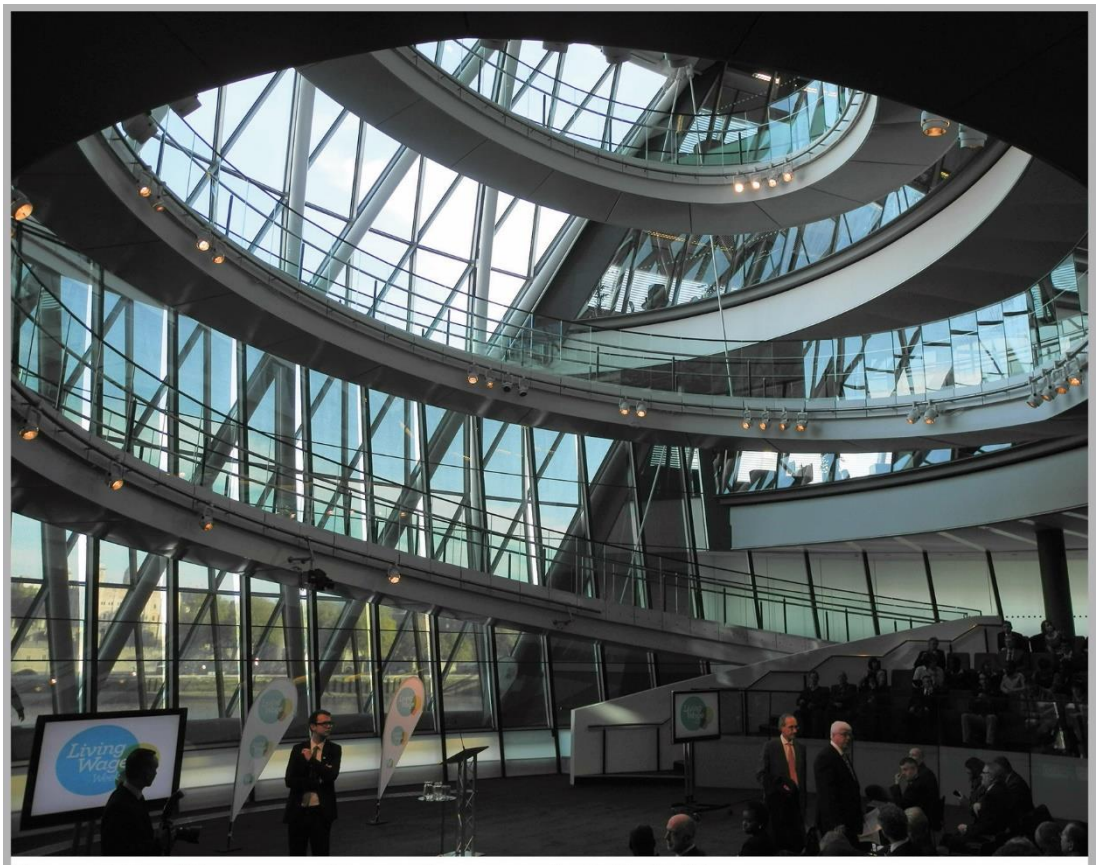
Source: https://www.pinterest.fr/pin/557953841324133251/

11. City Hall, 2002, Foster & Partners, London, UK



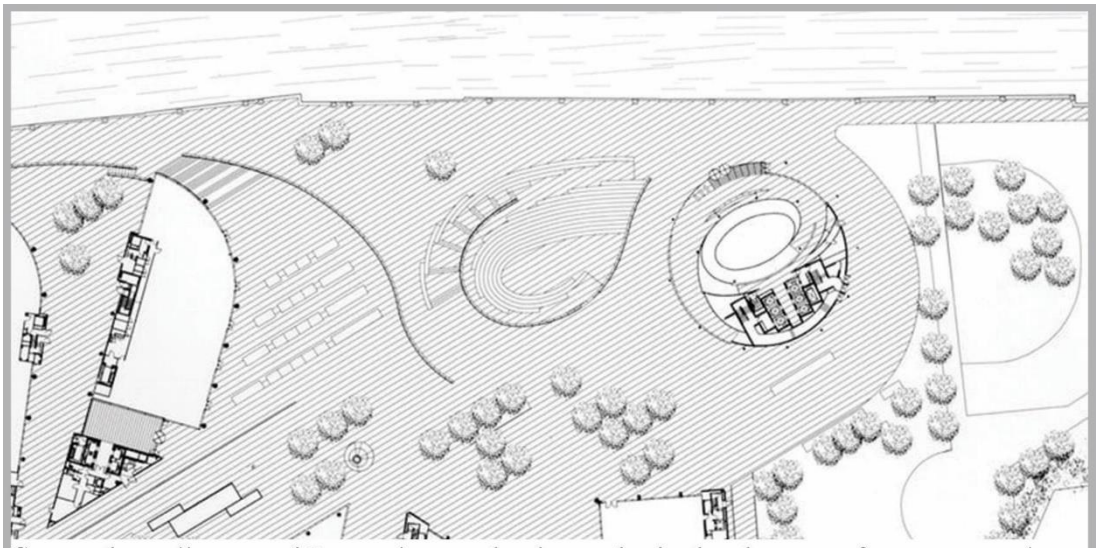
Source: https://www.arch2o.com/arch2o-london-city-hall-norman-foster-05/

Source: https://en.wikipedia.org/wiki/City_Hall,_London

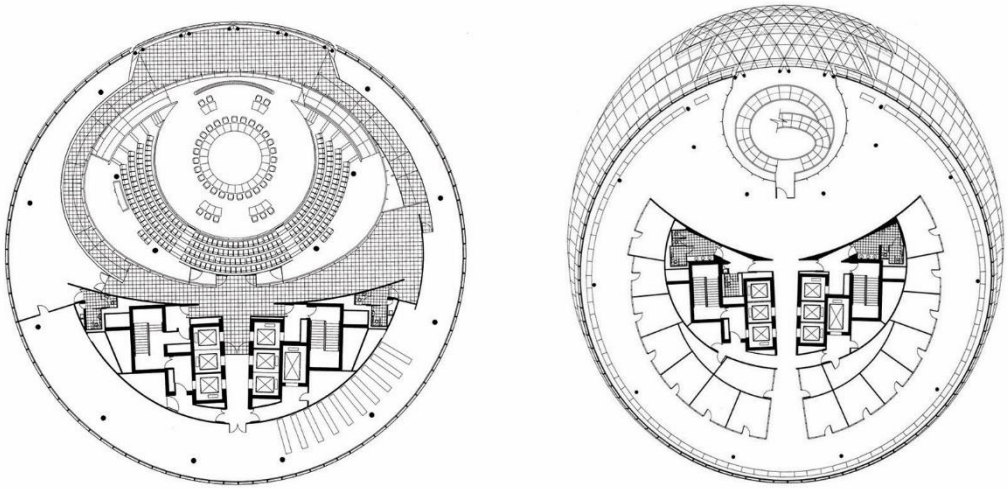


Source: https://tiggerrenewing.wordpress.com/tag/city-hall/

Source: https://www.arch2o.com/arch2o-london-city-hall-norman-foster-22/



Source: https://www.arch2o.com/greater-london-authority-headquarters-foster-partners/



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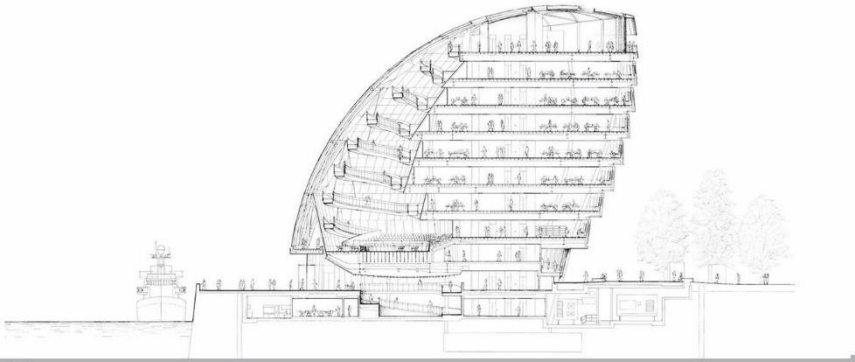
Source: https://www.fosterandpartners.com/projects/city-hall/#drawings



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Source: https://www.fosterandpartners.com/projects/city-hall/#drawings

12. Selfridges Department Store, 2003, Future Systems, Birmingham, UK

Source: https://www.pinterest.com/pin/126523070752800295/

Source: https://designdautore.blogspot.com/2014/02/selfridges-building-birmingham-future.html#.XOW0NMgzZPY

Source: https://en.wikipedia.org/wiki/Selfridges_Building,_Birmingham

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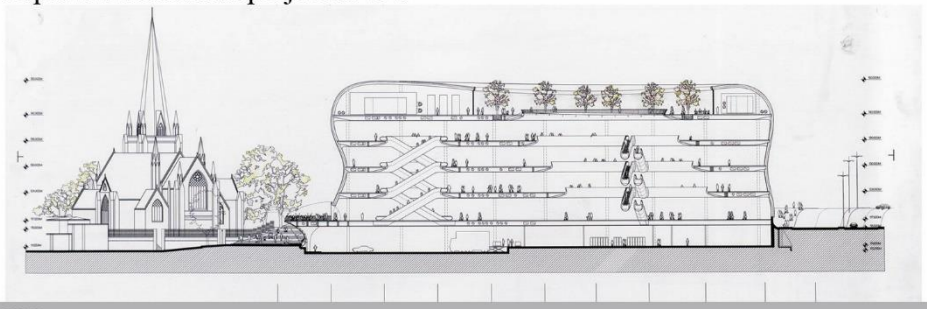
Source: http://www.bfcaa.uk/projects/9494/



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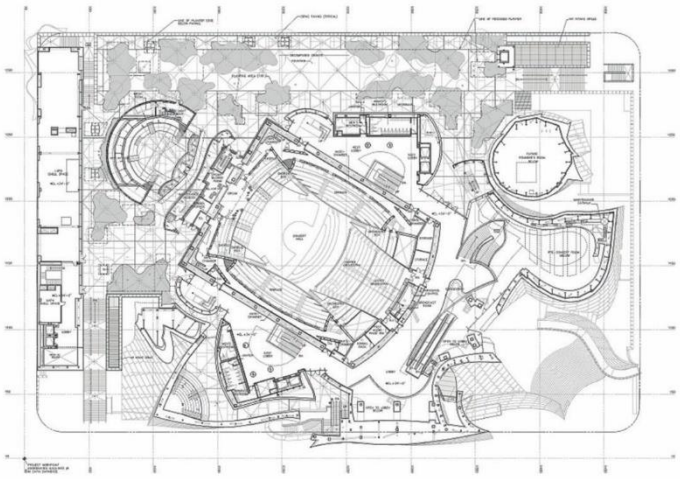
Source: http://www.bfcaa.uk/projects/9494/

13. Walt Disney Concert Hall, 2003, Frank Gehry, California, USA

Source: https://www.archdaily.com/441358/ad-classics-walt-disney-concert-hall-frank-gehry

Source: https://www.flickr.com/photos/giuseppemilo/25822037213

Source: https://www.reddit.com/r/RoomPorn/comments/2f3xiz/walt_disne-



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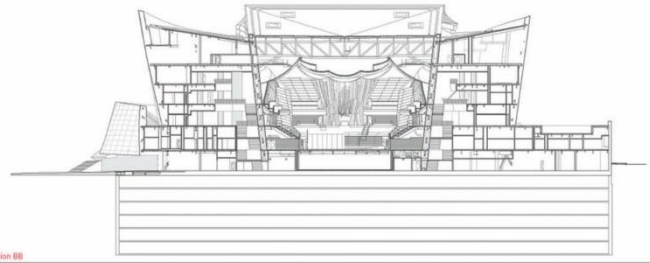
Source: https://en.wikiarquitectura.com/building/walt-disney-concert-hall/



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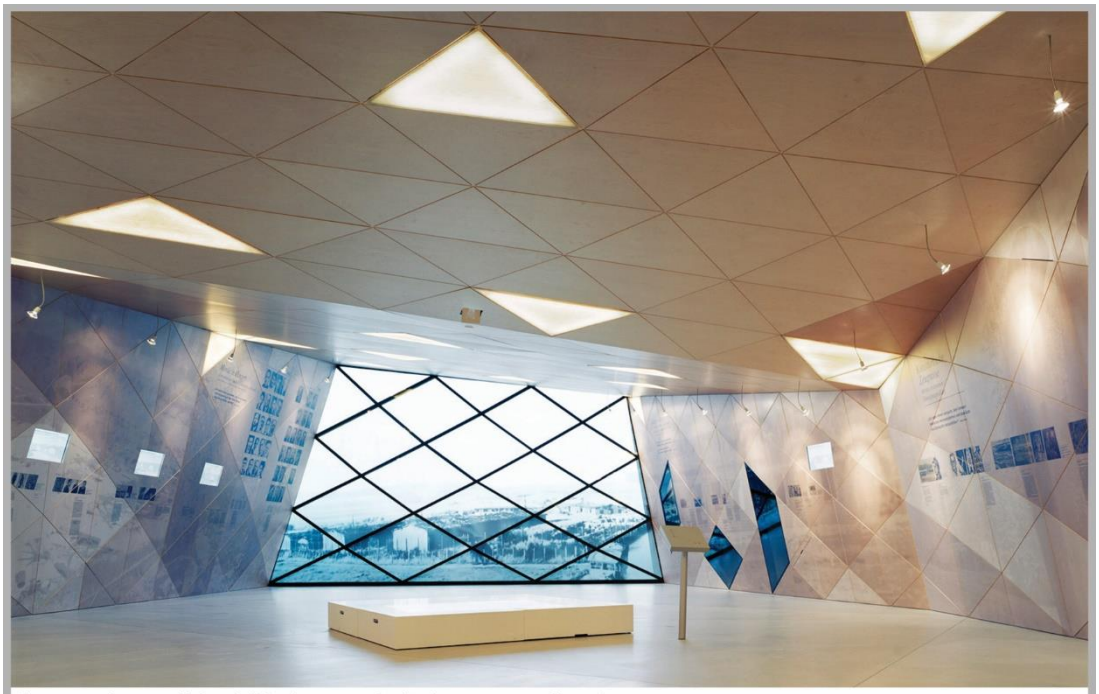
Source: https://tr.redsearch.org/images/8049054

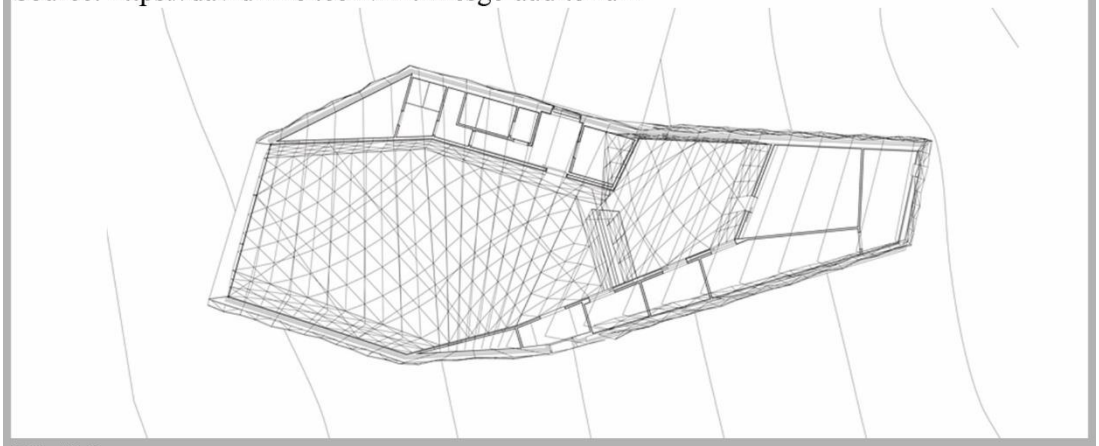
14. The Hinzert Museum and Document Center, 2005, Wandel Hoefer Lorch + Hirsch, Halle, Germany

Source: https://www.archdaily.com/317207/the-hinzert-museum-and-document-center-wandel-hoefer-lorch-hirsch

Source: https://www.arch2o.com/the-hinzert-museum-and-document-center-wandel-hoefer-lorch-hirsch/



Source: https://davidfixler.com/mit-kresge-auditorium



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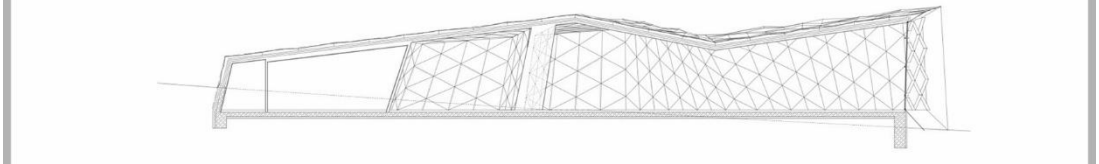
Source: https://tr.redsearch.org/images/866555



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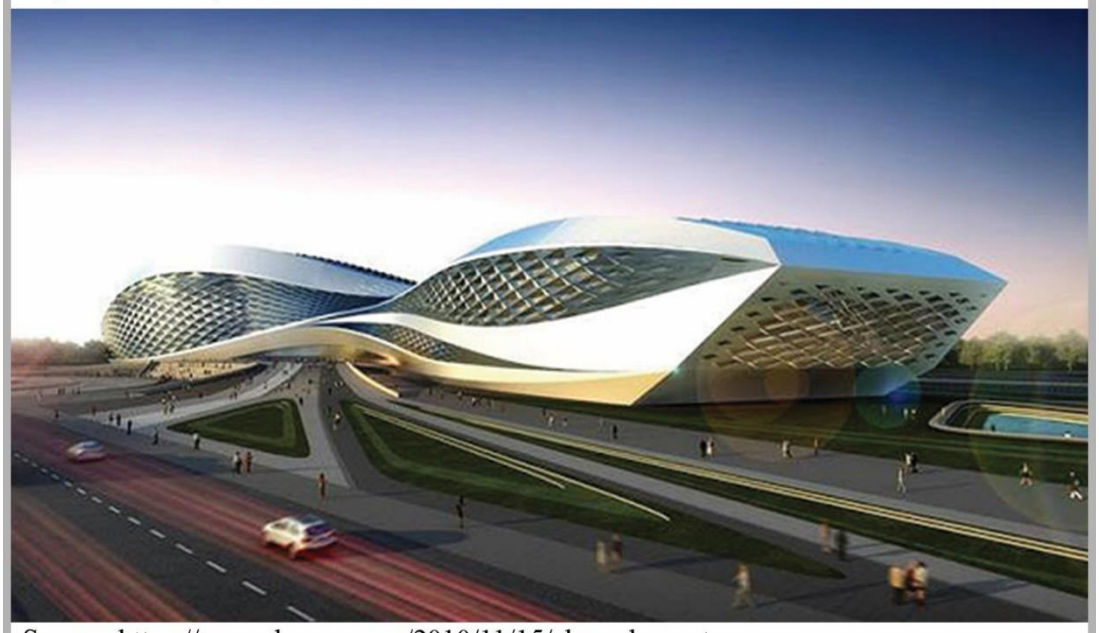
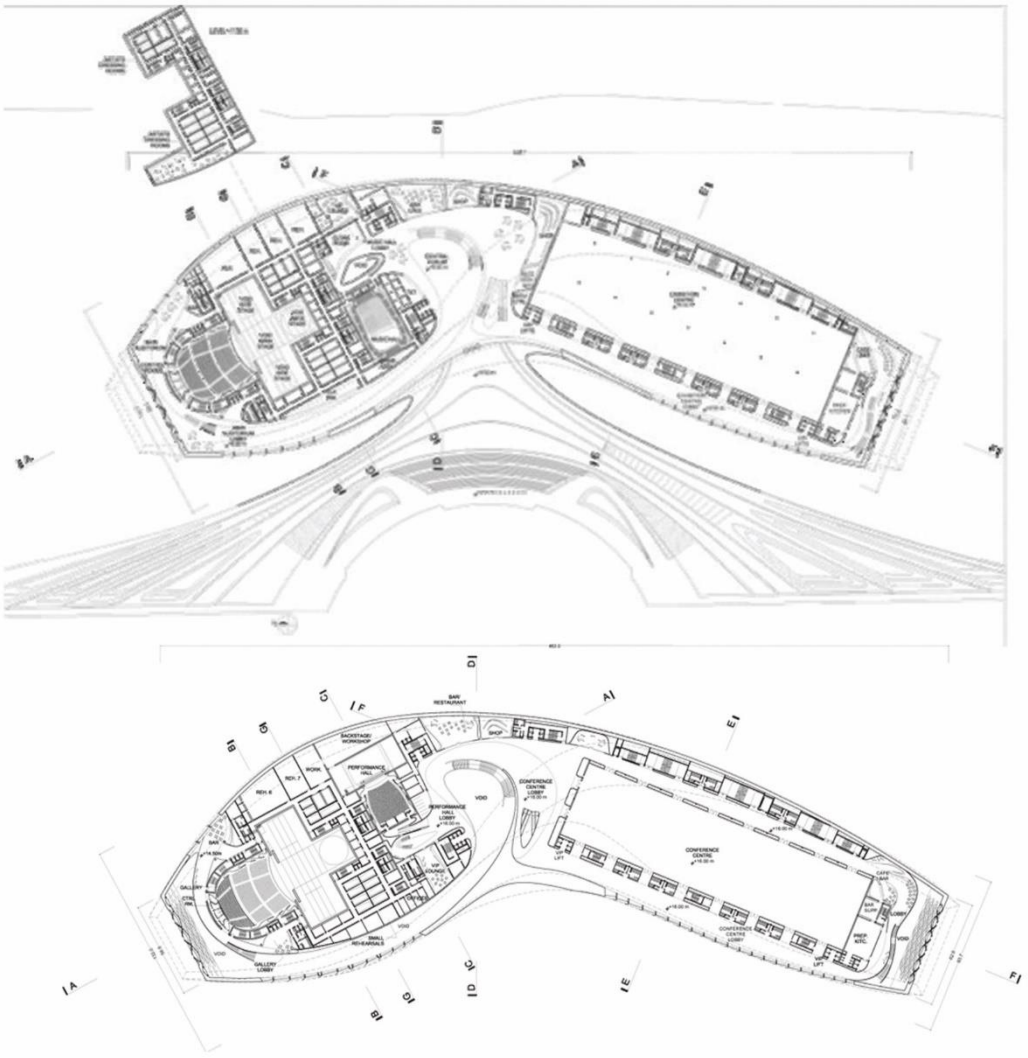
Source: https://en.wikiarquitectura.com/building/kresge-auditorium/

15. Chengdu Contemporary Art Centre, 2007, Zaha Hadid, Chengdu, China

Source: https://www.dezeen.com/2010/11/15/chengdu-contemporary-art-centre-by-zaha-hadid-architects/



Source: https://www.dezeen.com/2010/11/15/chengdu-contemporary-art-centre-by-zaha-hadid-architects/



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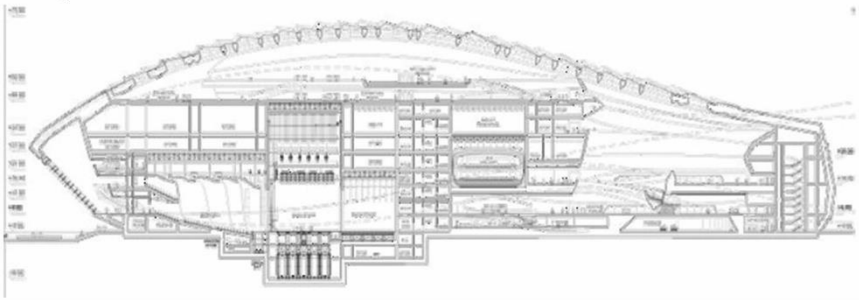
Source: https://www.dezeen.com/2010/11/15/chengdu-contemporary-art-centre-by-zaha-hadid-architects/



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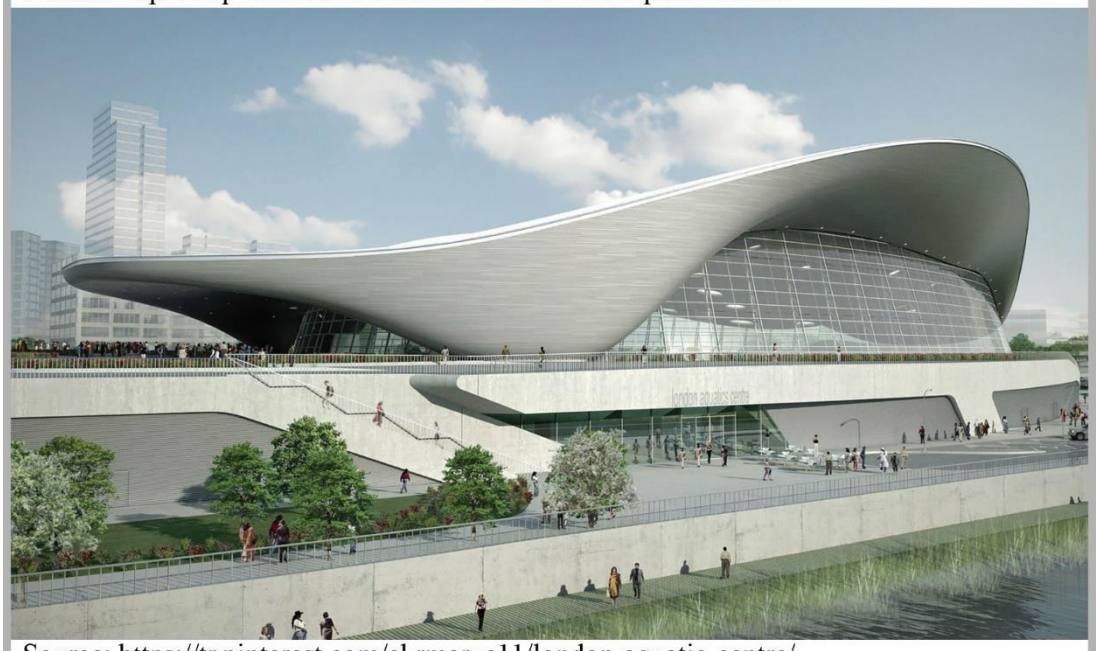
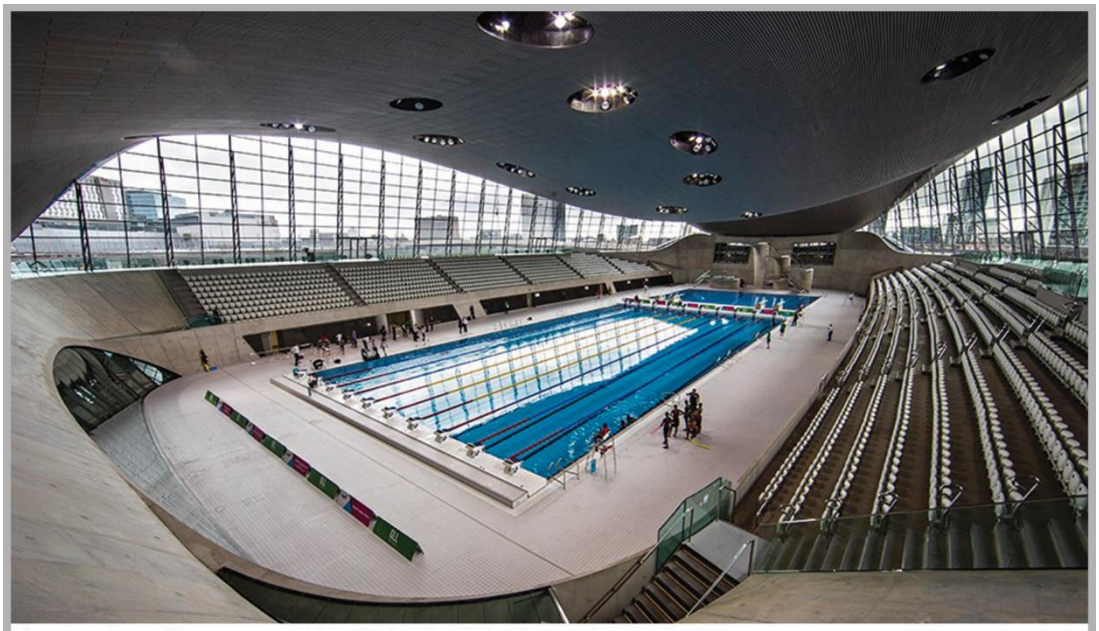
Source: https://www.dezeen.com/2010/11/15/chengdu-contemporary-art-centre-by-zaha-hadid-architects/

16. London Aquatics Centre, 2008, Zaha Hadid, London, UK

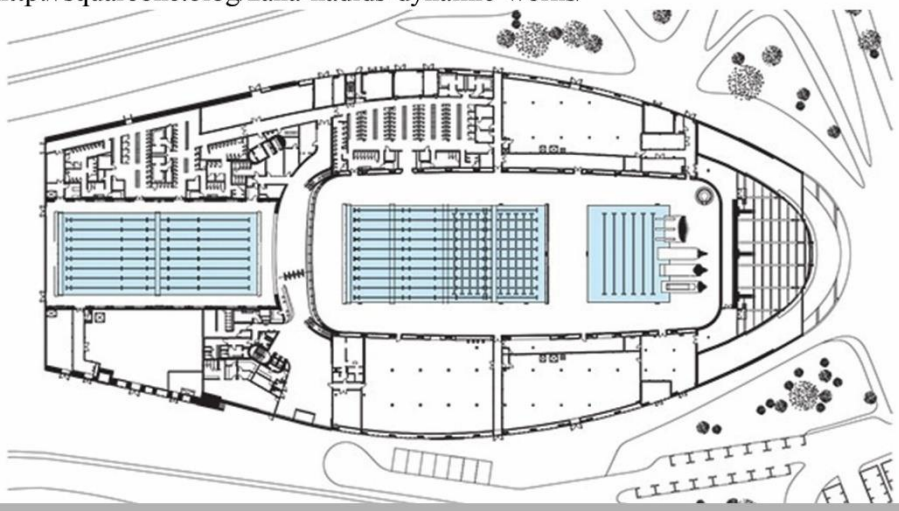
Source: https://tr.pinterest.com/ckrmerve11/london-aquatic-centre/



Source: https://tr.pinterest.com/ckrmerve11/london-aquatic-centre/



Source: http://squareone.blog/zaha-hadids-dynamic-works/



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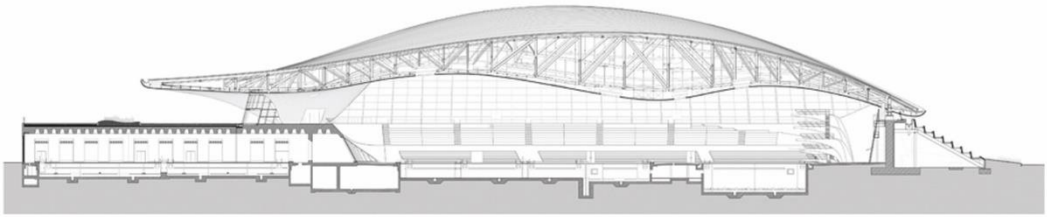
Source: https://www.architectural-review.com/buildings/london-aquat-ics-centre-by-zaha-hadid-architects/8686871.article



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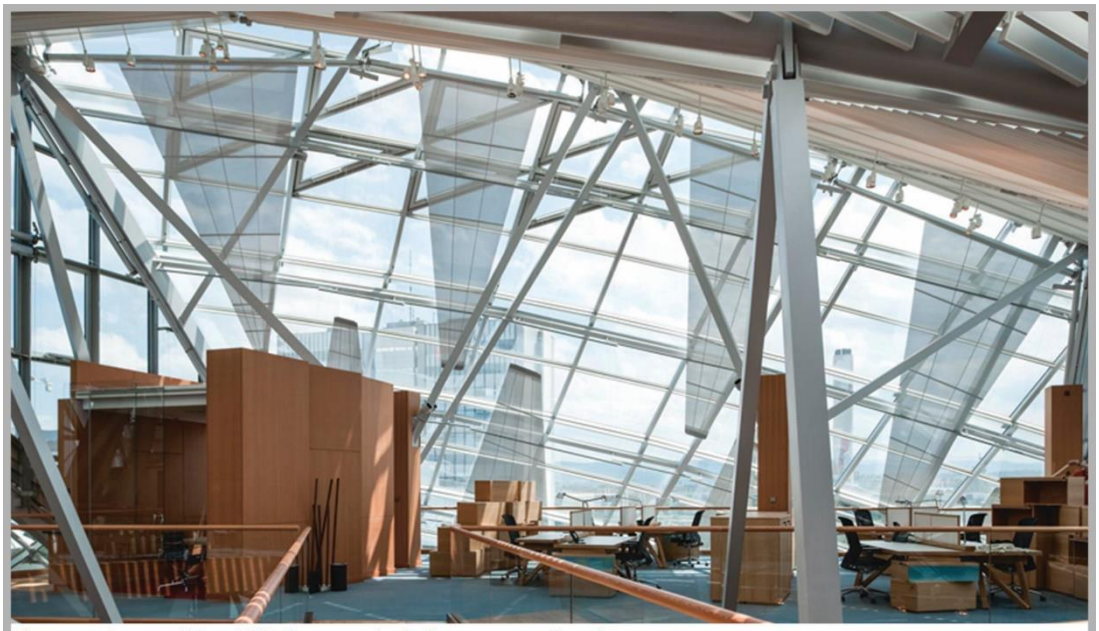
Source: https://www.detail-online.com/article/london-2012-aquatics-centre-16400/

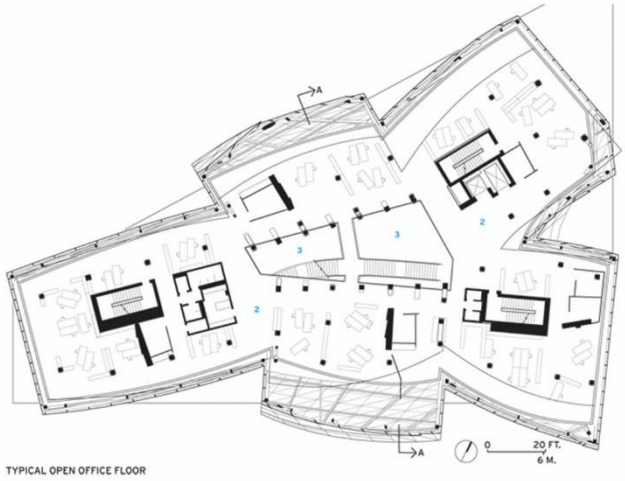
17. Novartis Pharma A.G. Campus, 2009, Frank Gehry, Basel, Switzerland

Source: https://www.architecturalrecord.com/articles/7661-fabrikstrasse-15?v=preview

Source: https://arcspace.com/feature/novartis-building/



Source: https://davidfixler.com/mit-kresge-auditorium



PLAN

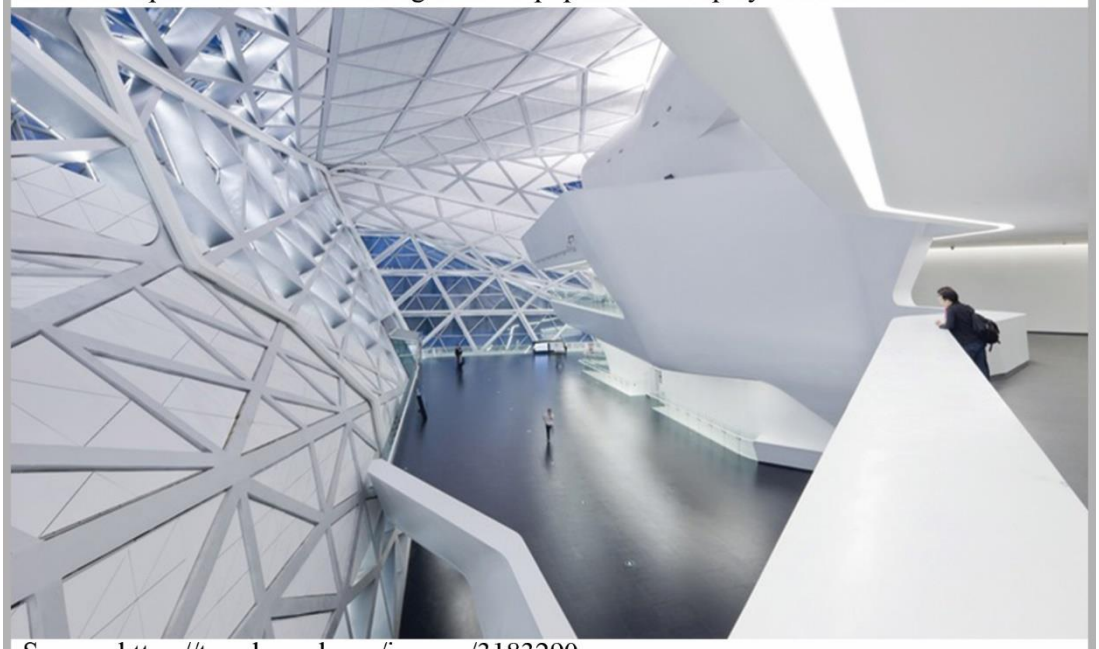
Source: http://frankgehryproject.blog-spot com/2012/10/gehrys-work.html

SECTION

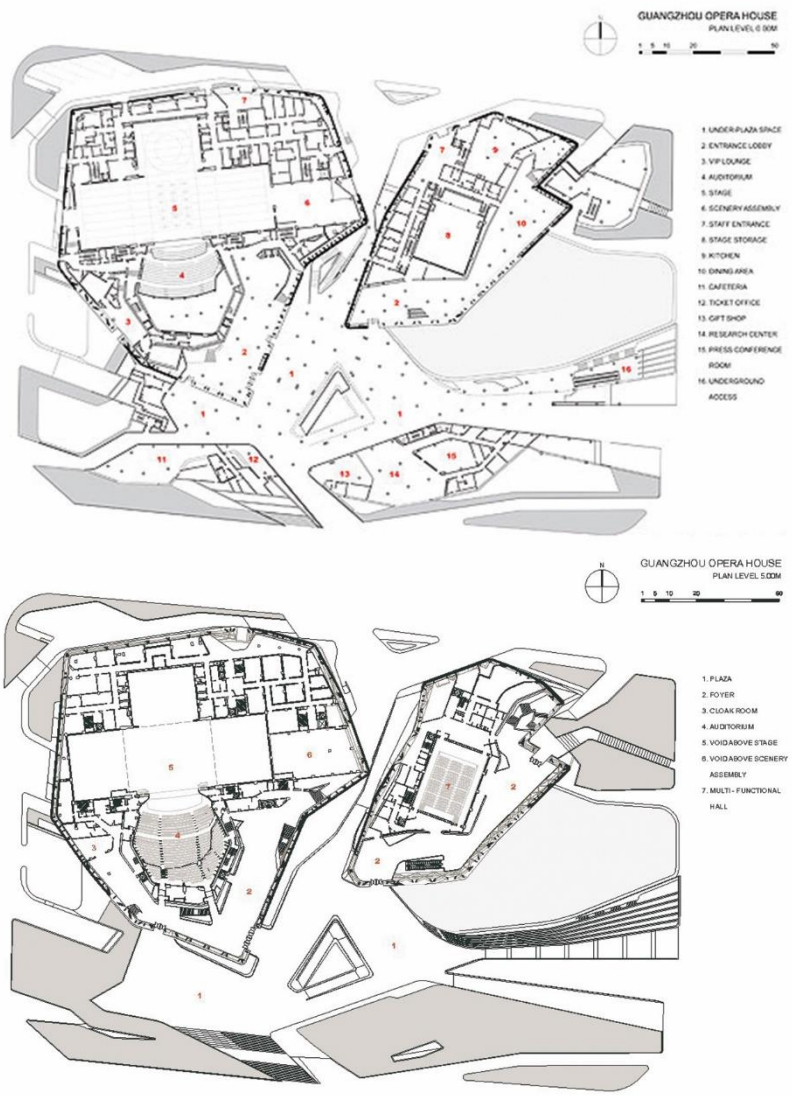
Source: http://frankgehryproject.blogspot.com/2012/

18. Guangzhou Opera House, 2010, Zaha Hadid, Guangdong, China

Source: http://v3.arkitera.com/arsgratiaartis.php?action=displayNewsItem&ID=61211



Source: https://tr.redsearch.org/images/3183290



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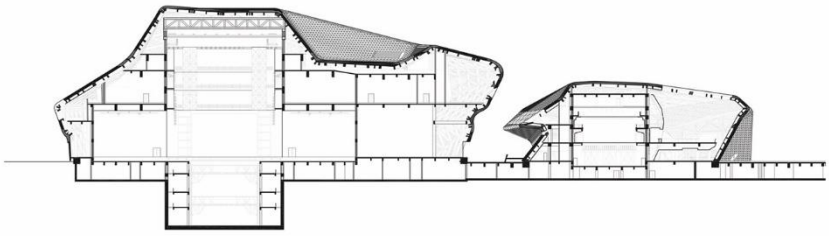
Source: https://aasarchitecture.com/2012/09/guangzhou-opera-house-by-zaha-hadid.html

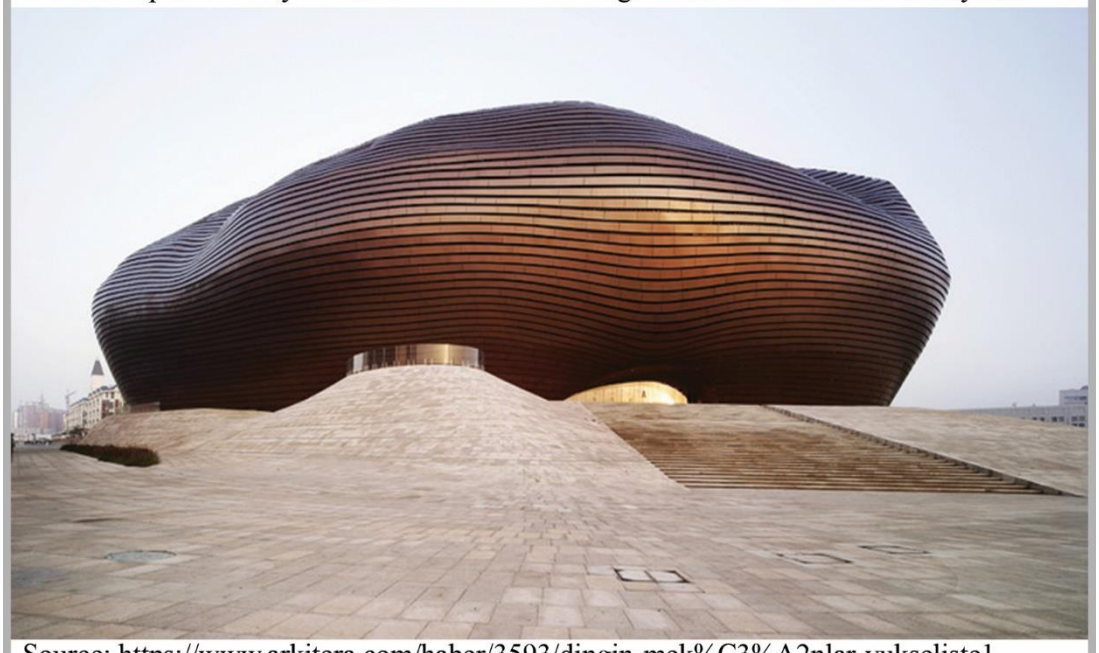


SECTION

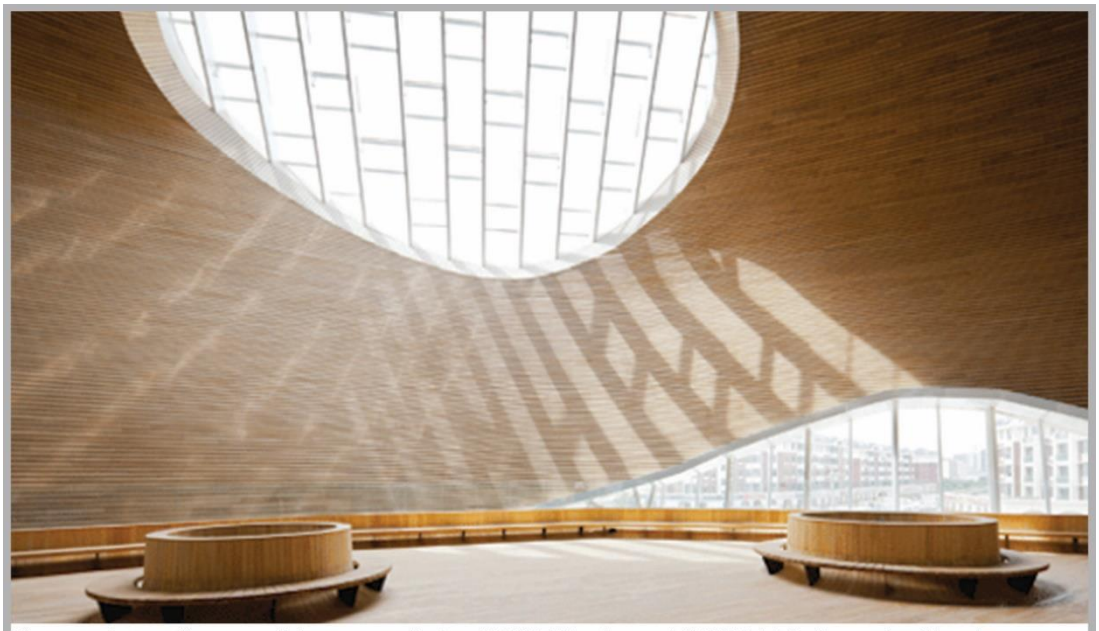
Source: https://en.wikiarquitectura.com/building/guangzhou-opera-house/

19. Ordos Art & City Museum, 2011, MAD Architects, China

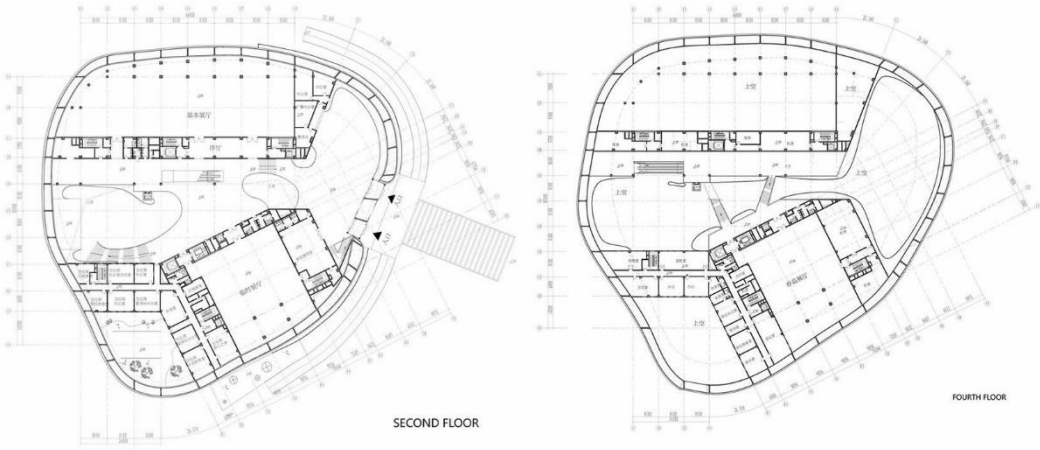
Source: https://www.nytimes.com/2015/03/06/t-magazine/ordos-china-tourist-city.html



Source: https://www.arkitera.com/haber/3593/dingin-mek%C3%A2nlar-yukseliste1



Source: https://www.arkitera.com/haber/3593/dingin-mek%C3%A2nlar-yukseliste1



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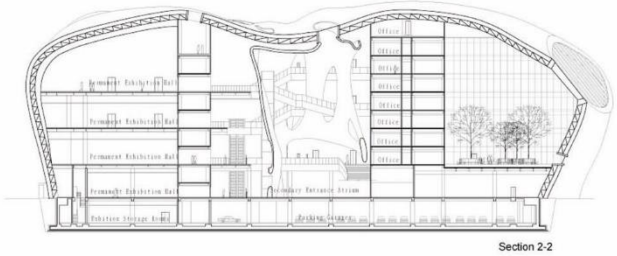
Source: http://museumsofarchistars.altervista.org/ordos-museum-mad-architects/



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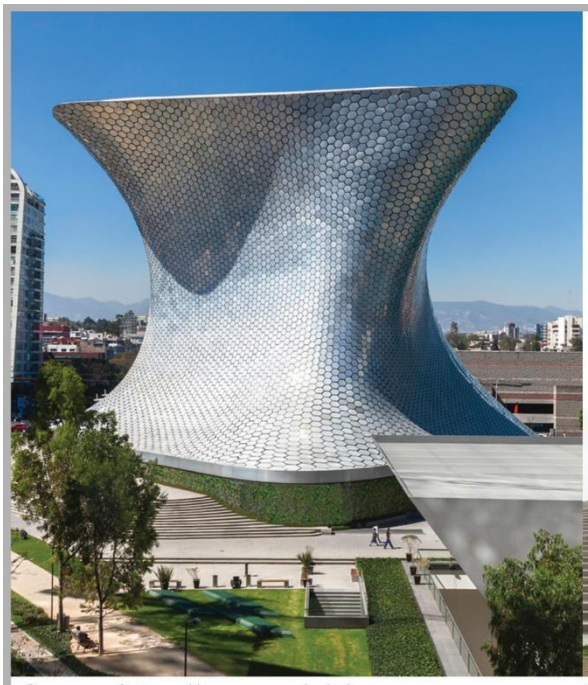
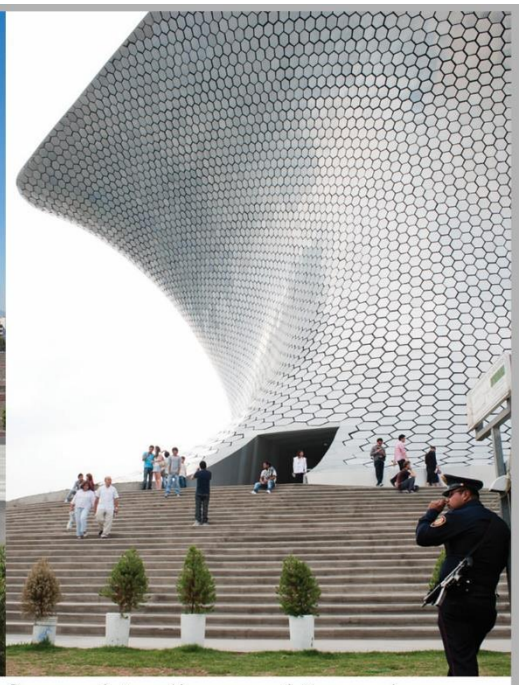
Source: https://www.arch2o.com/ordos-museum-mad-architects/

20. Soumaya Museum, 2011, FR-EE/ Fernando Romero Enterprise, Mexico City, Mexico



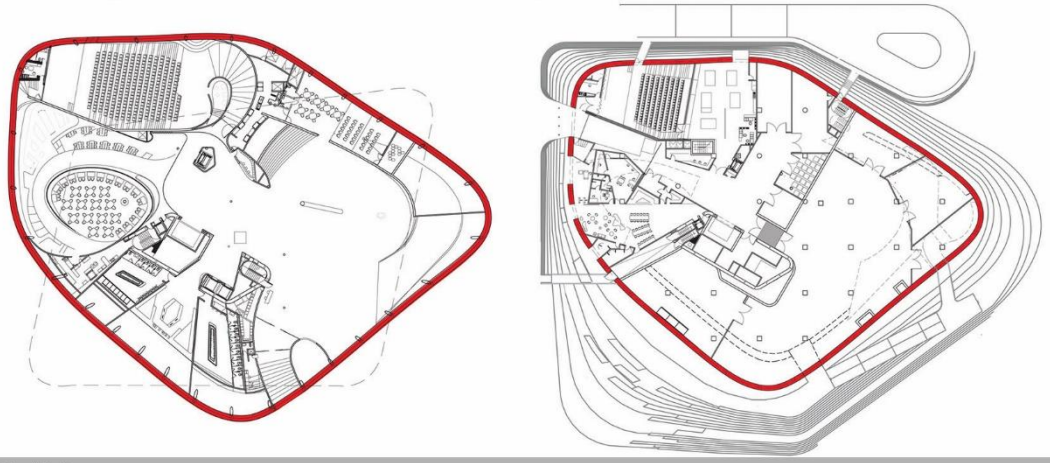
Source: https://www.archdaily.com/452226/museo-soumaya-fr-ee-fernando-romero-enterprise/52954315e8e44e809a00



Source: https://www.arch2o.com/museo-soumaya-fr-ee-fernando-romero-enterprise/

Source: https://tr.redsearch.org/images/1677844

Source: https://www.arch2o.com/museo-soumaya-fr-ee-fernando-romero-enterprise/



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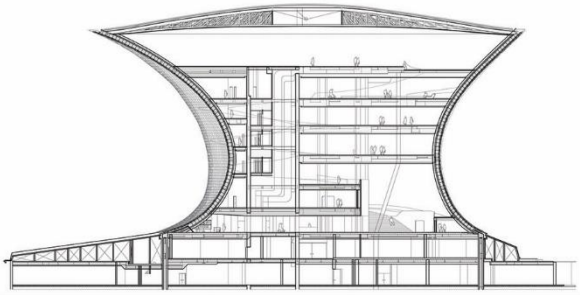
Source: https://www.arch2o.com/museo-soumaya-fr-ee-fernando-romero-enterprise/



SECTION

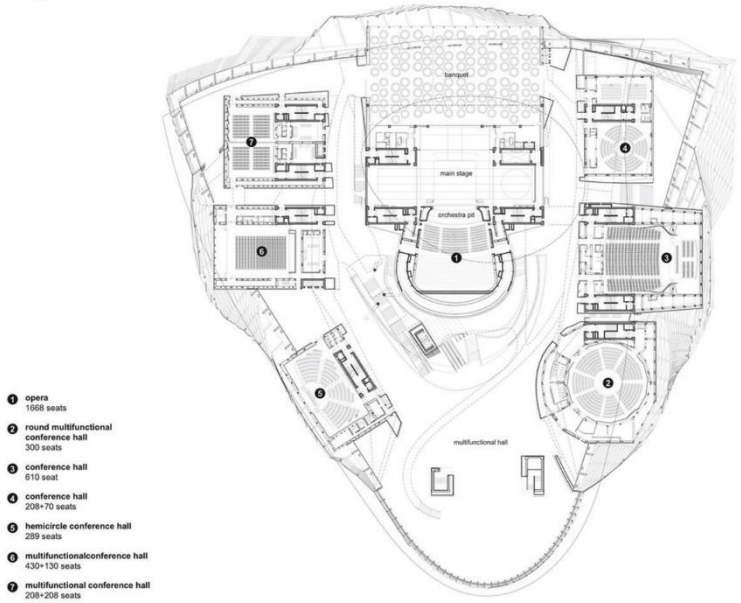
Source: http://www.mimdap.org/?p=138192

21. Dalian International Conference Center, 2012, Coop Himmelb(l)au, Dalian, China

Source: https://www.archdaily.com/405787/dalian-international-conference-center-coop-himmelb-l-au

Source: https://parametric-architecture.com/dalian-international-conference-center-by-coop-himmelblau/

Source: https://www.dezeen.com/2013/03/20/dalian-conference-center-by-coop-himmelblau/



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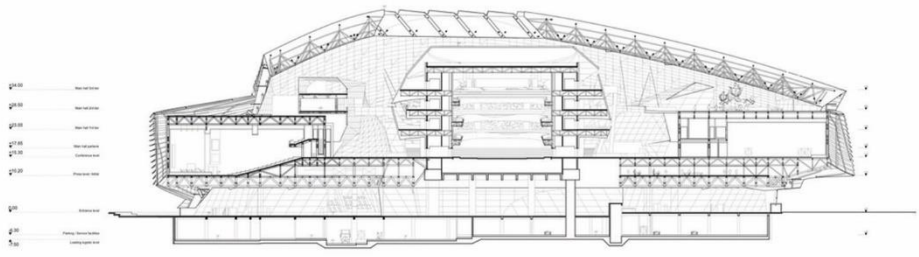
Source: https://en.wikiarquitectura.com/building/dalian-international-conference-center/



SECTION

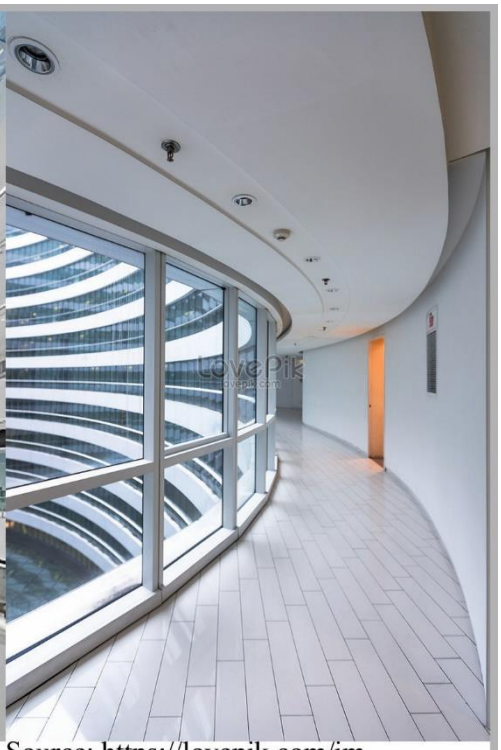
Source: http://www.antc.co.kr/amina/print.php?bo_table=achi&wr_id=66

22. Galaxy SOHO in Beijing, 2012, Zaha Hadid, Beijing, China

Source: https://www.archdaily.com/294549/galaxy-soho-zaha-hadid-architects-by-hufton-crow/50a642c3b3fc4b46eb000054-galaxy-soho-zaha-hadid-architects-by-hufton-crow-photo

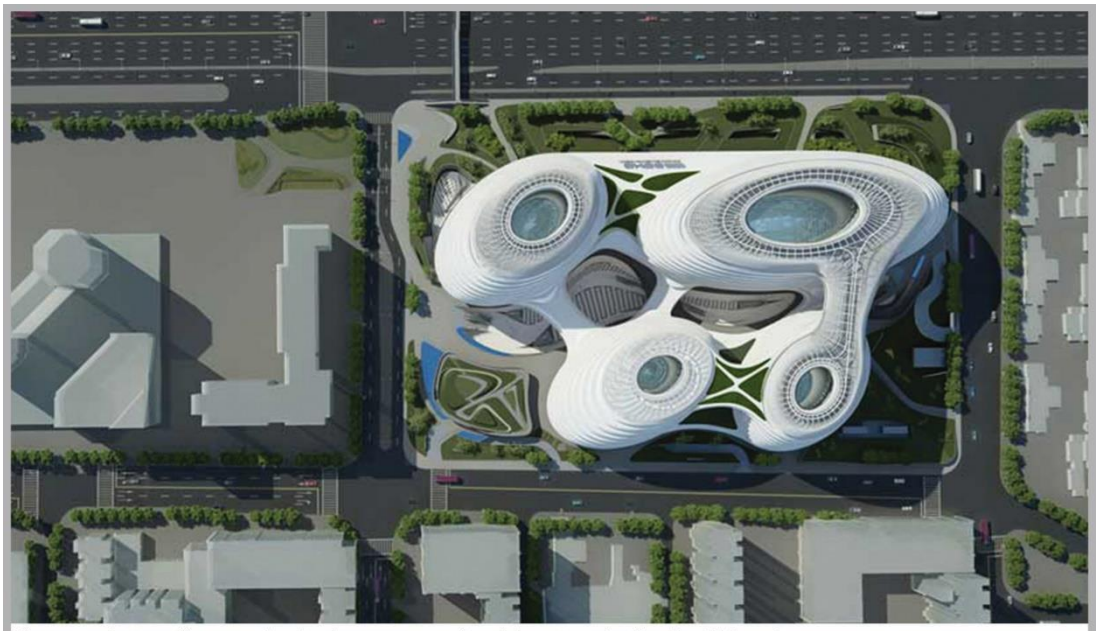
Source: http://www.artmanik.com/en-populer-eserleriyle-unlu-mimar-zaha-hadid/

Source: https://www.archute.com/galaxy-soho-stunning-urban-landscape-zaha-hadid-architects/

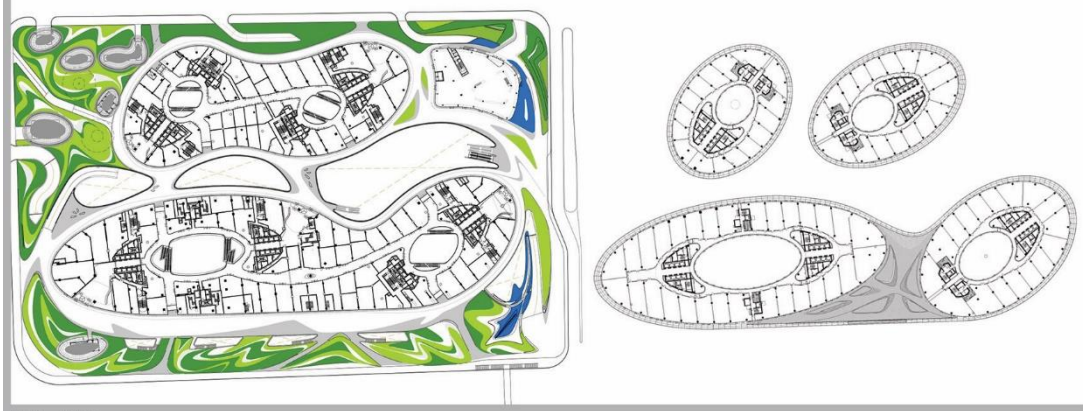


Source: https://lovepik.com/image-500981211/galaxy-soho-interior.html

Source: https://www.arch2o.com/galaxy-soho-zaha-hadid-architects/



Source: https://www.designboom.com/architecture/zaha-hadid-galaxy-so-ho-chaoyangmen-soho-now-under-construction/



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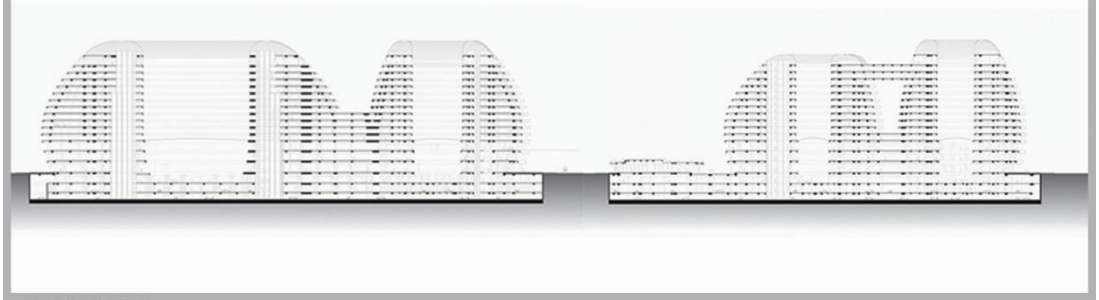
Source: https://en.wikiarquitectura.com/galaxy-soho-03-2/



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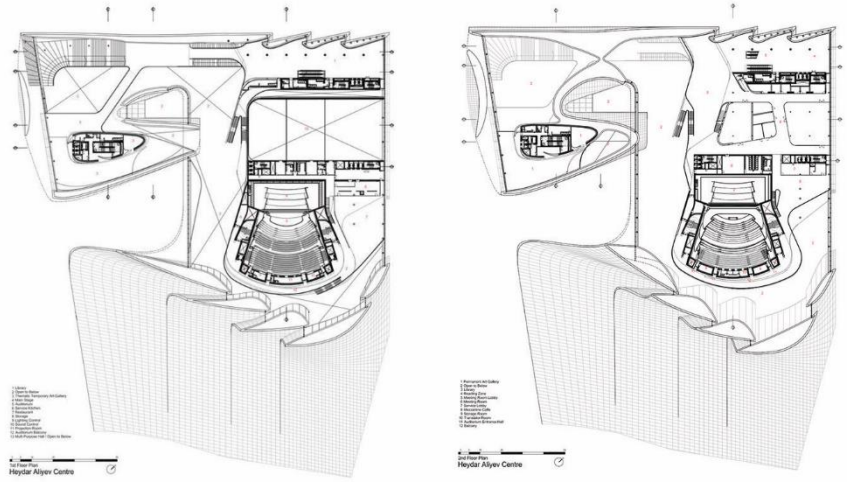
Source: https://arqa.com/english-es/architecture-es/galaxy-soho-in-beijing-china.html

23. Heydar Aliyev Center, 2013, Zaha Hadid, Baku, Azerbaijan

Source: https://www.dezeen.com/2013/11/14/zaha-hadid-heydar-aliyev-centre-baku/

Source: https://www.archdaily.com/448774/heydar-aliyev-center-za-ha-hadid-architects/52852180e8e44e222500014a-heydar-aliyev-center-zaha-hadid-architects-photo

Source: http://biksimg.pw/Heydar-Aliyev-Cultural-Center-Zaha-Hadid-Architecture.html



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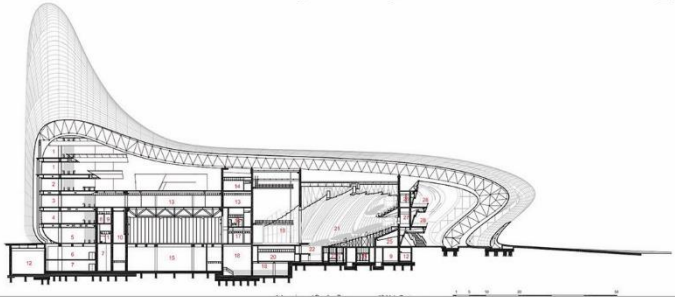
Source: https://www.arkitektuel.com/haydar-aliyev-kultur-merkezi/3rd_floor_plan/



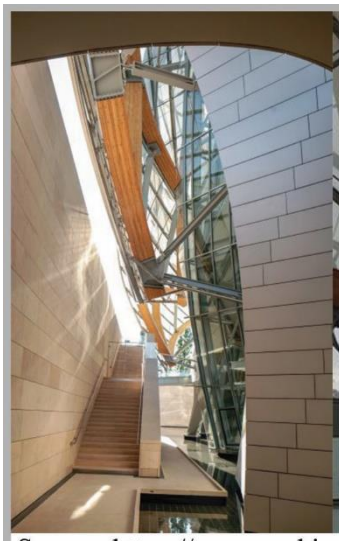
SECTION

Source: https://www.arkitektuel.com/haydar-aliyev-kultur-merkezi/01_section_aa/

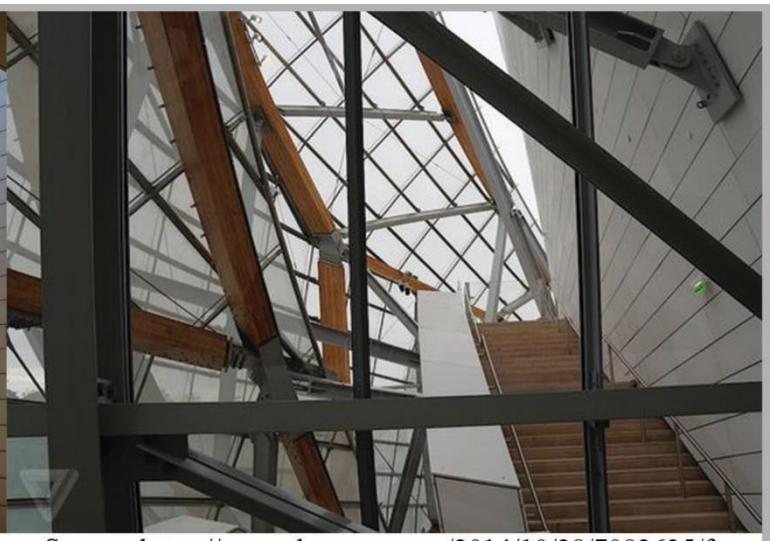
24. Fondation Louis Vuitton, 2014, Frank Gehry, Paris, France

Source: https://www.arkitektuel.com/louis-vuitton-vakfi/

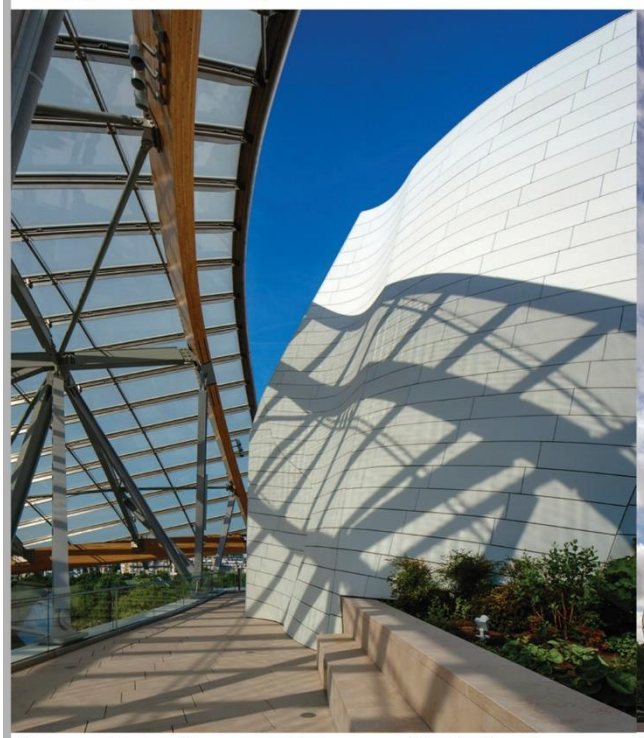
Source: https://www.mimarsiv.com/article/bund-finance-centre



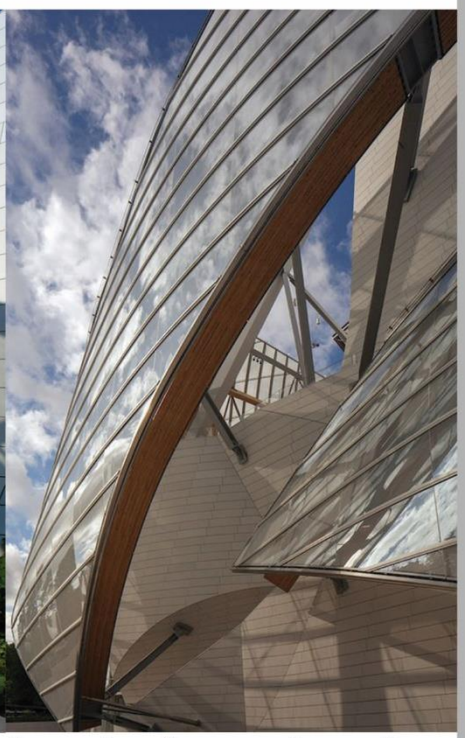
Source: https://www.architectmagazine.com/design/buildings/fondation-louis-vuitton-designed-by-gehry-partners_o



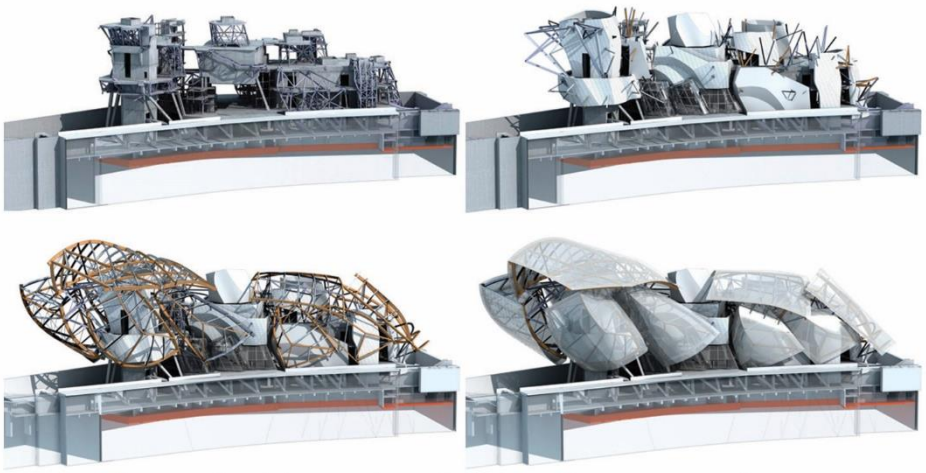
Source: https://www.theverge.com/2014/10/28/7082635/fondation-louis-vuitton-frank-gehry-photos



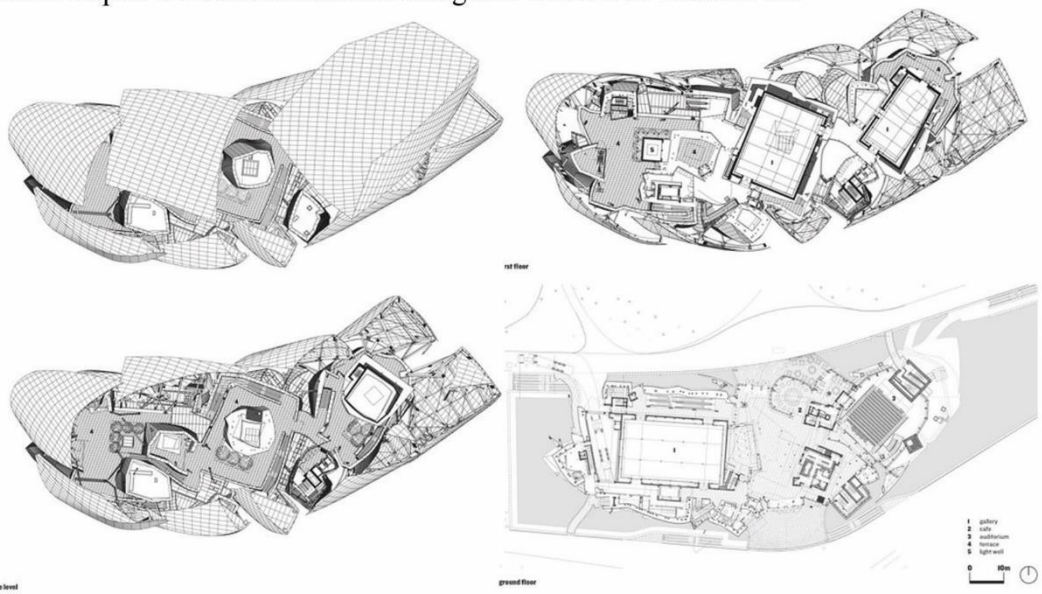
Source: https://www.archute.com/fondation-louis-vuitton-frank-gehrys-audacious-act-yet/



Source: http://www.gentlemansdiary.com/the-blog/tag/LOUIS+VUITTON



Source: https://www.urbanloka.com/mengintip-megahnya-museum-lou-



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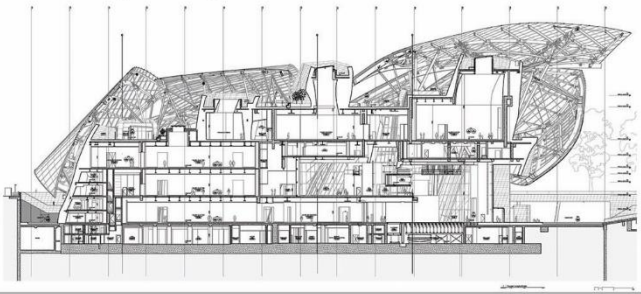
Source: https://carminevolpe.wordpress.com/2016/03/13/fondation-louis-vuitton-building/

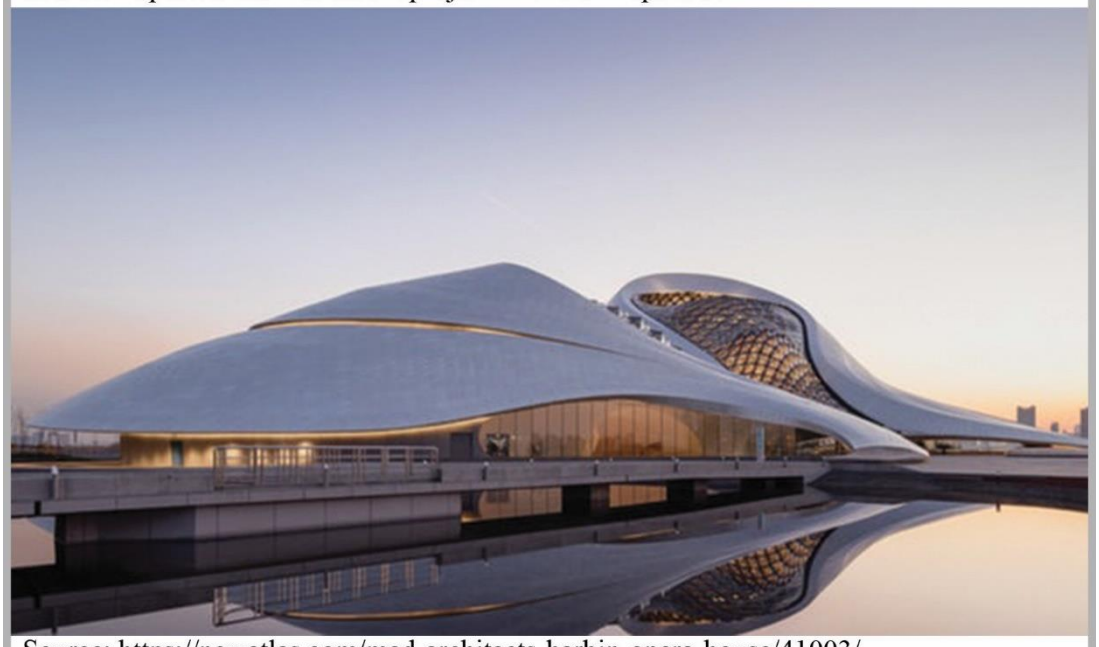


SECTION

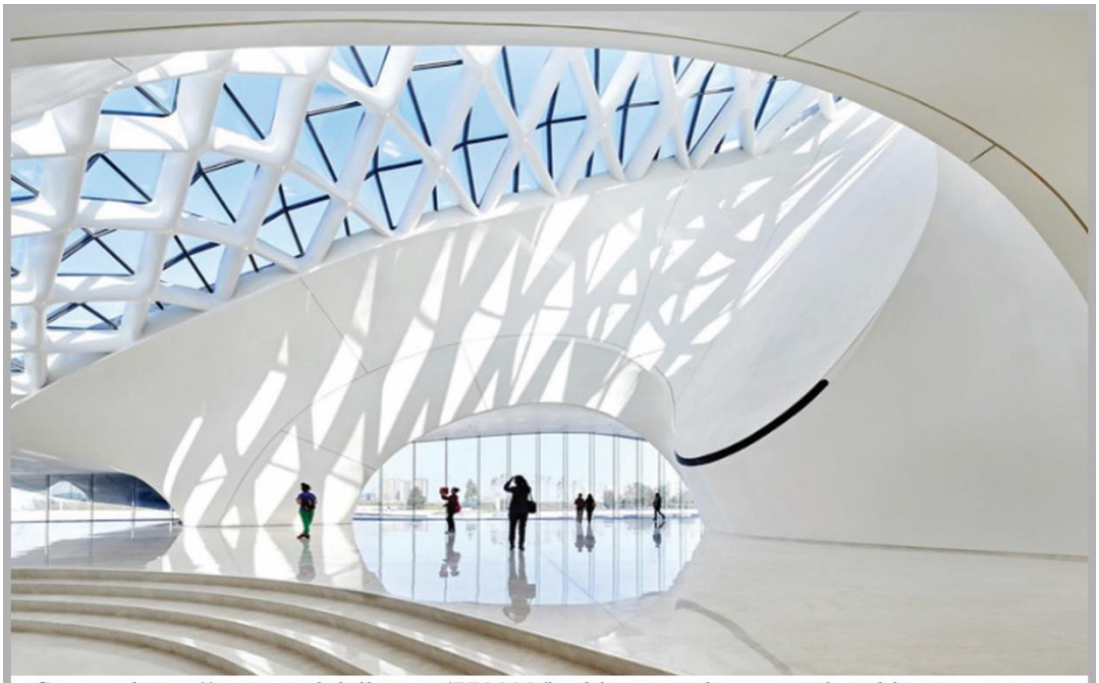
Source: https://www.pinterest.com/pin/544583779940552804/

25. Harbin Opera House, 2015, MAD Architects, Heilongjiang, China

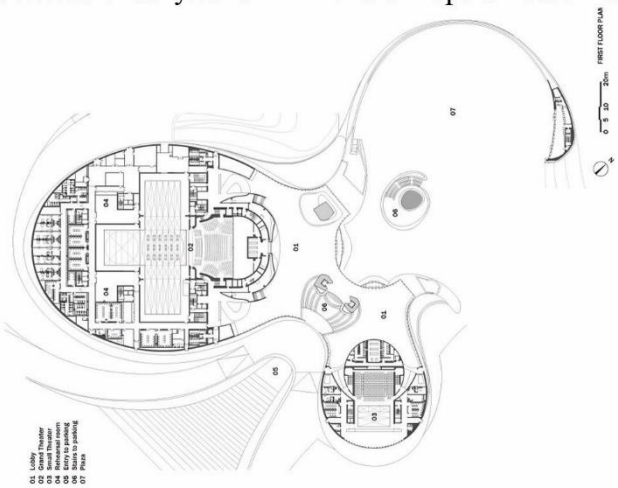
Source: http://www.arkitera.com/proje/7177/harbin-opera-evi



Source: https://newatlas.com/mad-architects-harbin-opera-house/41003/



Source: https://www.archdaily.com/778933/harbin-opera-house-mad-architects



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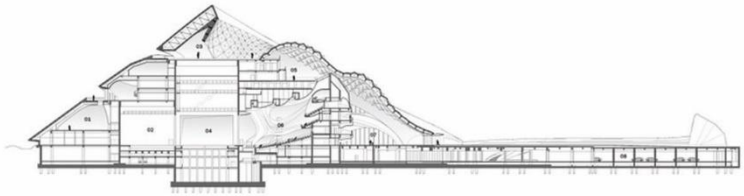
Source: https://www.archdaily.com/778933/harbin-opera-house-mad-architects



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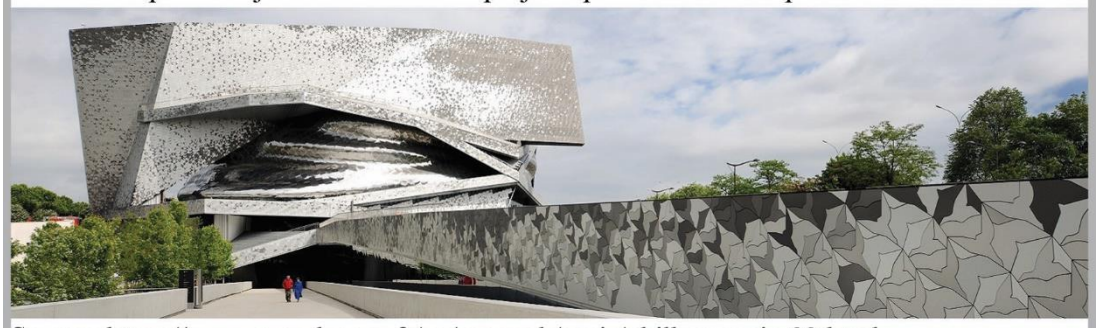
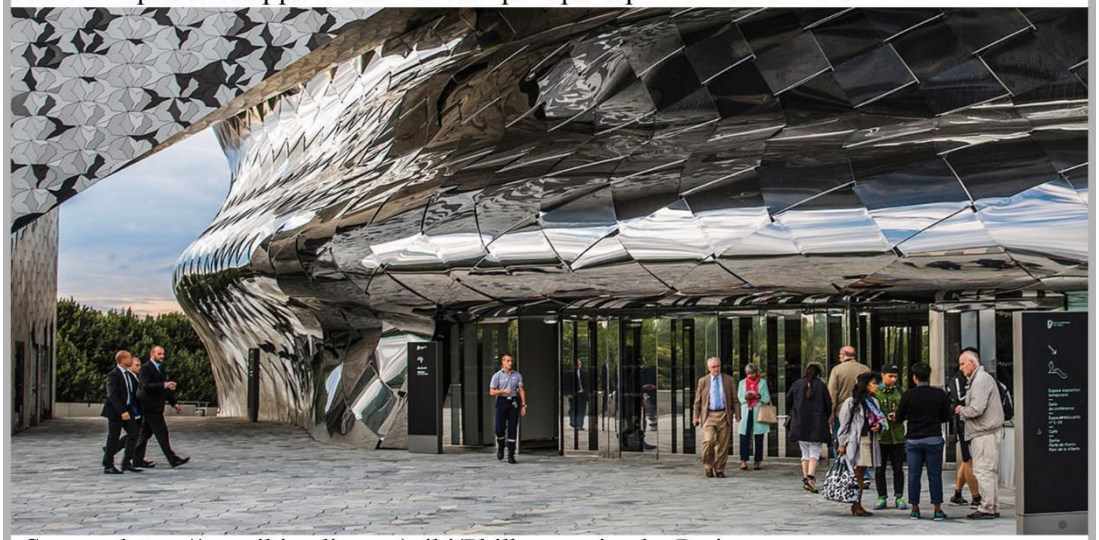
Source: https://www.archdaily.com/778933/harbin-opera-house-mad-architects

26. Paris Phillarmonie, 2015, Jean Nouvel, Paris, France

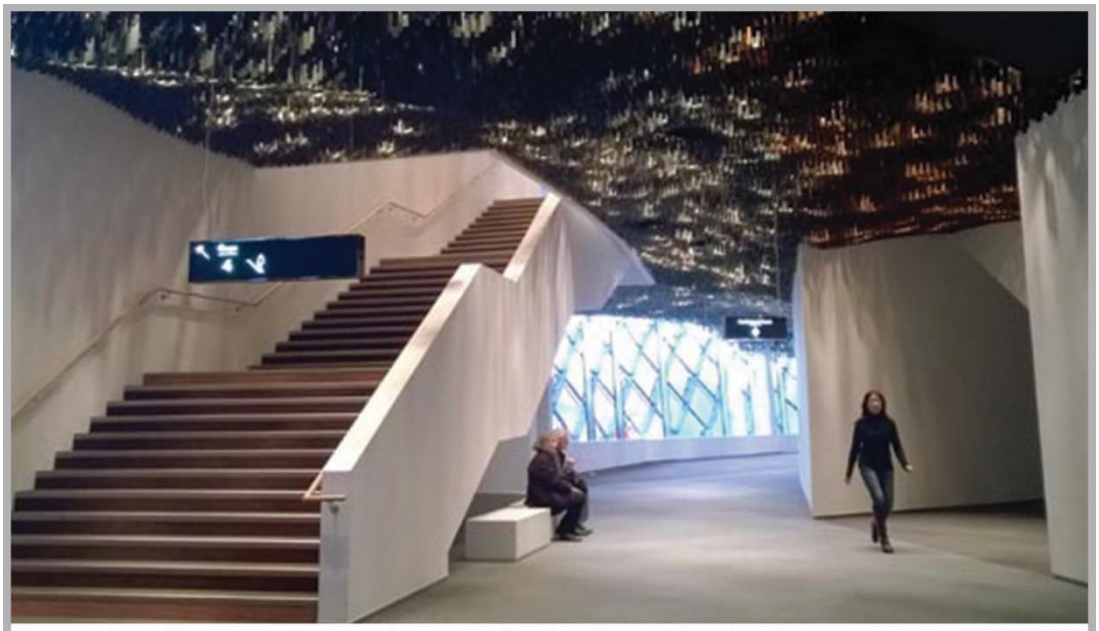
Source: http://www.jeannouvel.com/en/projects/philharmonie-de-paris/



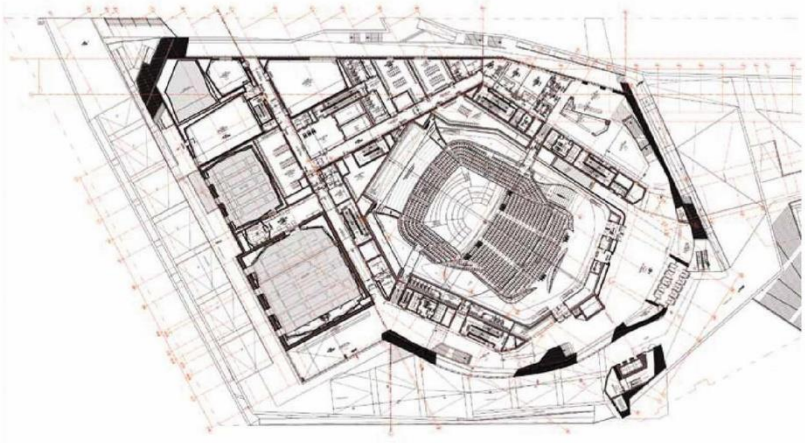
Source: https://www.q-park-resa.fr/en/car-park/paris/philharmonie-22.html



Source: https://en.wikipedia.org/wiki/Philharmonie_de_Paris



Source: http://www.yanous.com/news/topflop/topflop150123.html



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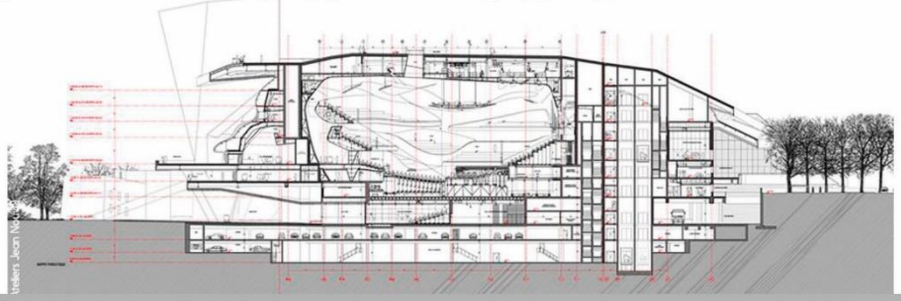
Source: https://redsearch.org/images/p/philharmonie_de_paris_plan



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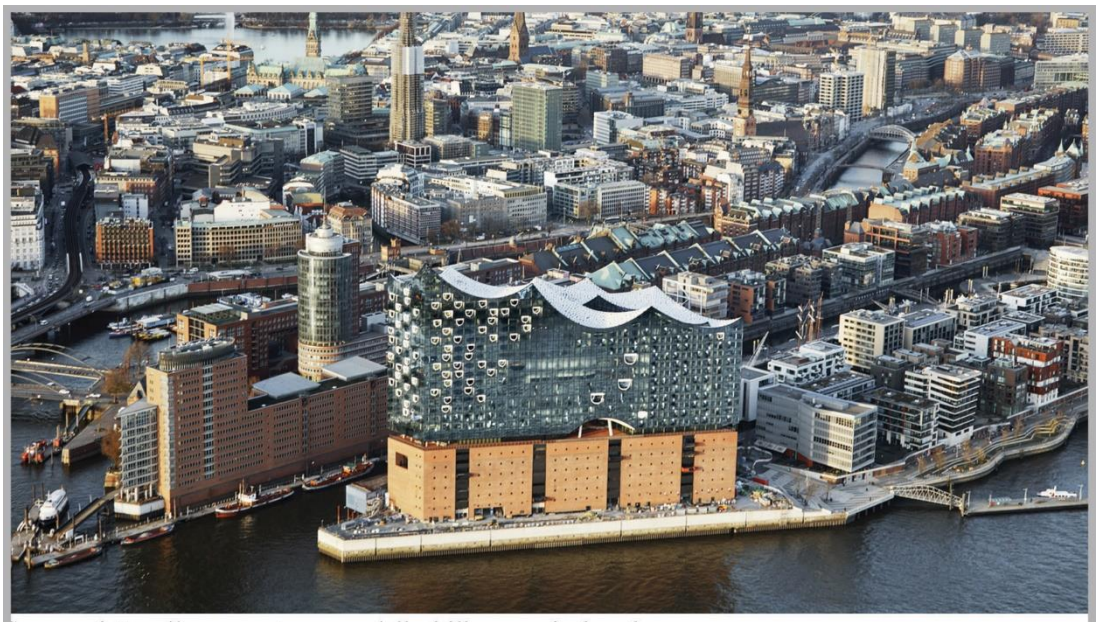
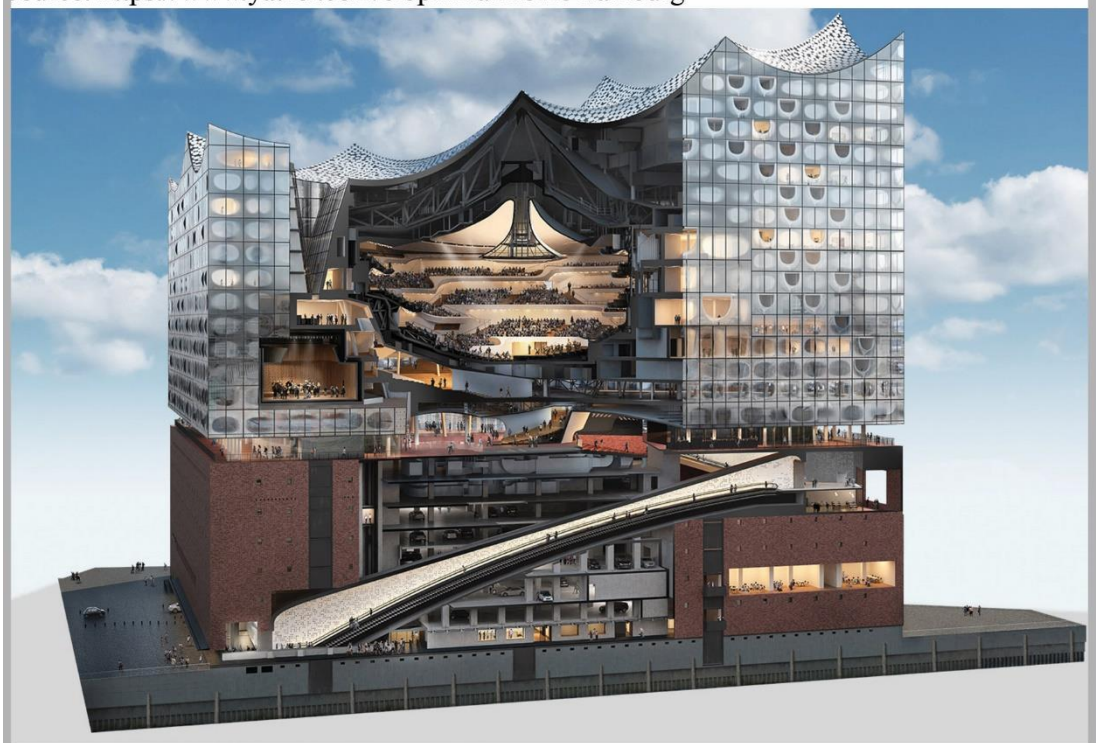
Source: http://e-wiki.org/tr/images/Jean_Nouvel_buildings

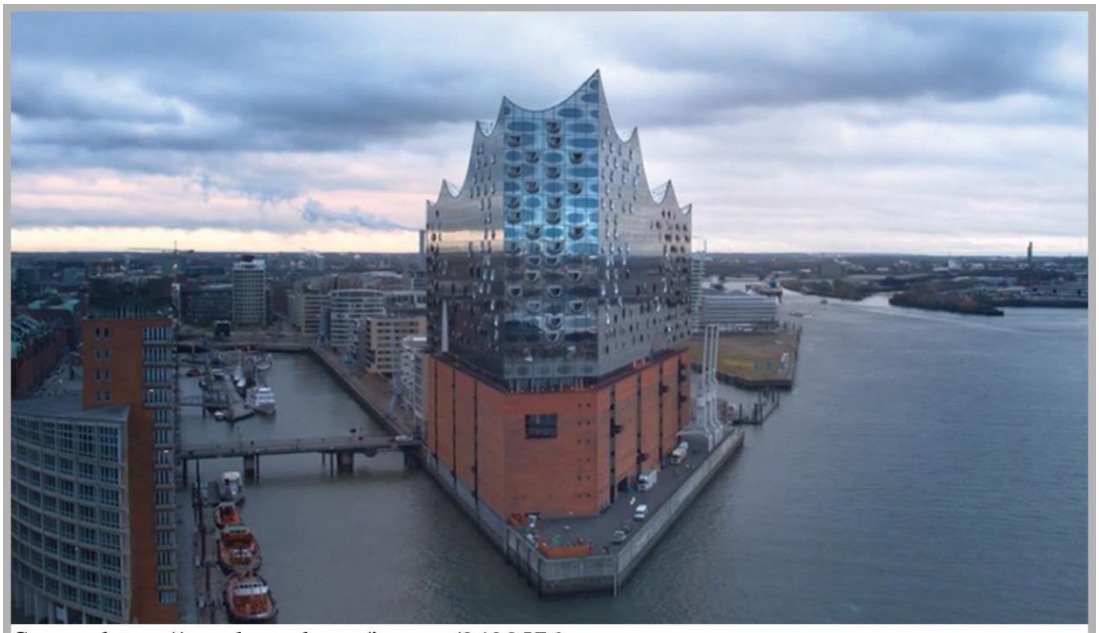
27. Elbphilharmonie Hamburg, 2016, Herzog & de Meuron, Germany



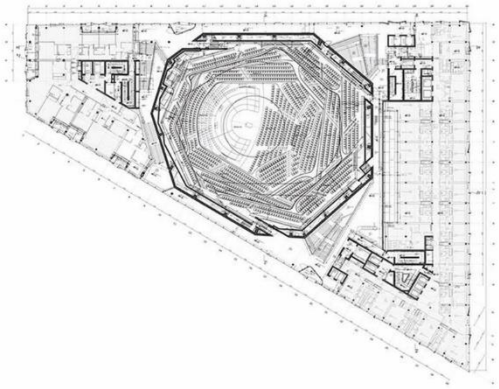
Source: https://www.yatzer.com/elbphilharmonie-hamburg



Source: https://tr.pinterest.com/pin/244109242288784098/?lp=true



Source:https://tr.redsearch.org/images/2438576



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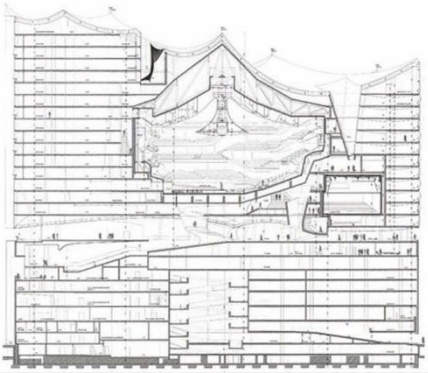
Source: https://www.pinterest.com/pin/181903272435381039/



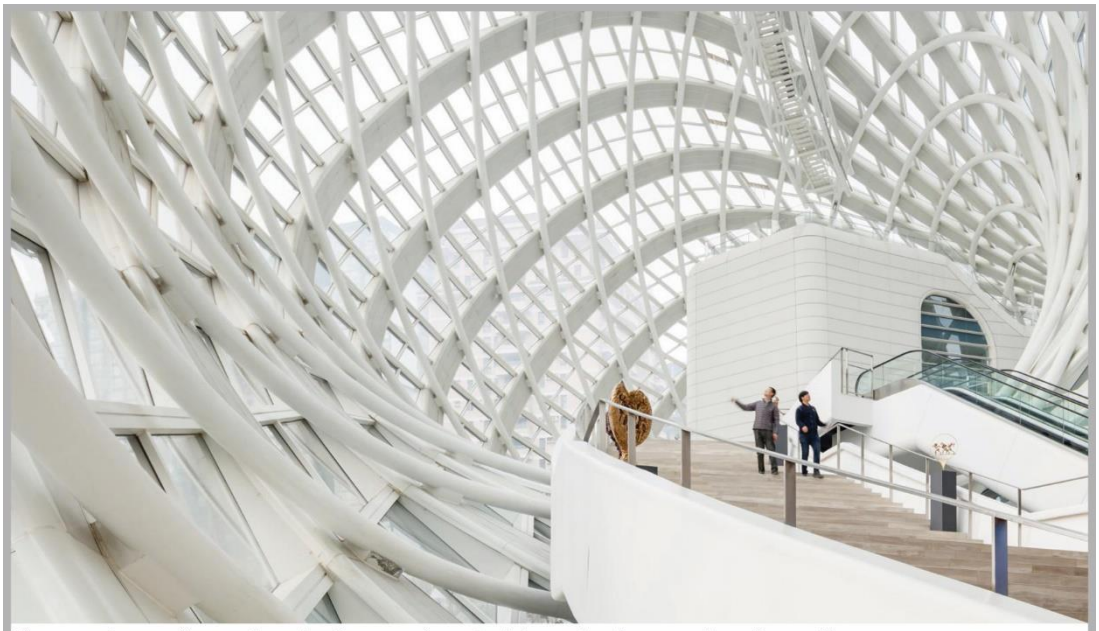
SECTION

Source: https://tr.pinterest.com/pin/239746380135604491/?lp=true

28. Phoenix International Media Center, in progress, BIAD, Beijing Shi, China

Source: http://www.goldmantis.com/jtl2013/en/al.asp?id=3151

Source: https://www.stylus.com/kmhtsf



Source: https://pawelpaniczko.com/works/phoenix_international_media_center

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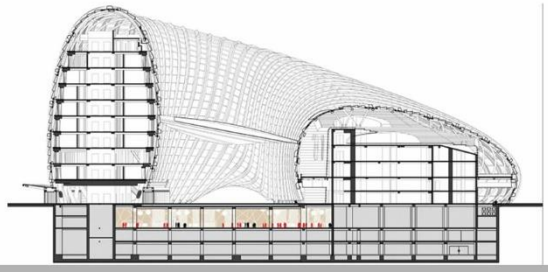
Source: https://www.archdaily.com/165746/in-progress-phoenix-international-media-center-biad-ufo/01-1st-floor-plan

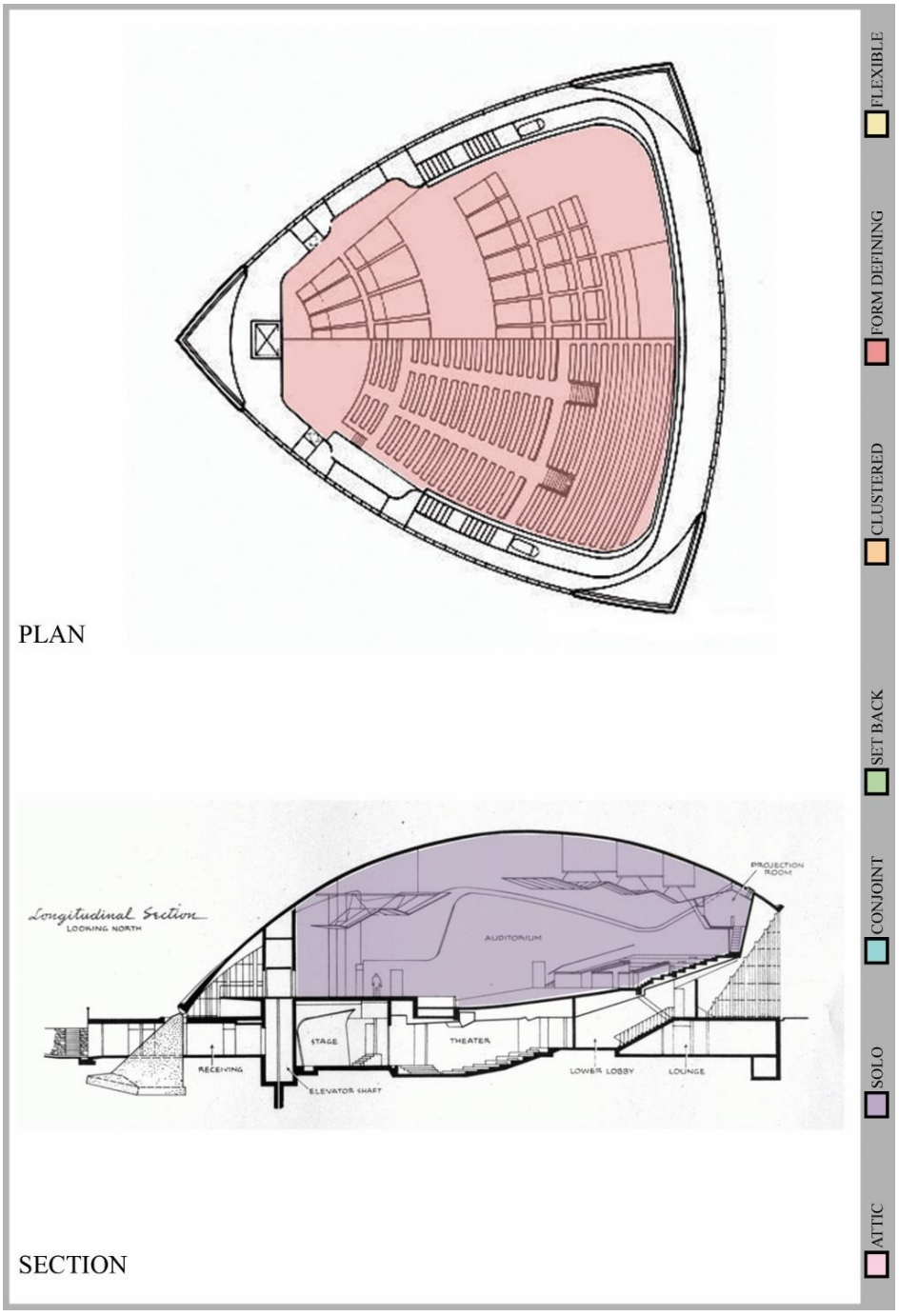


SECTION

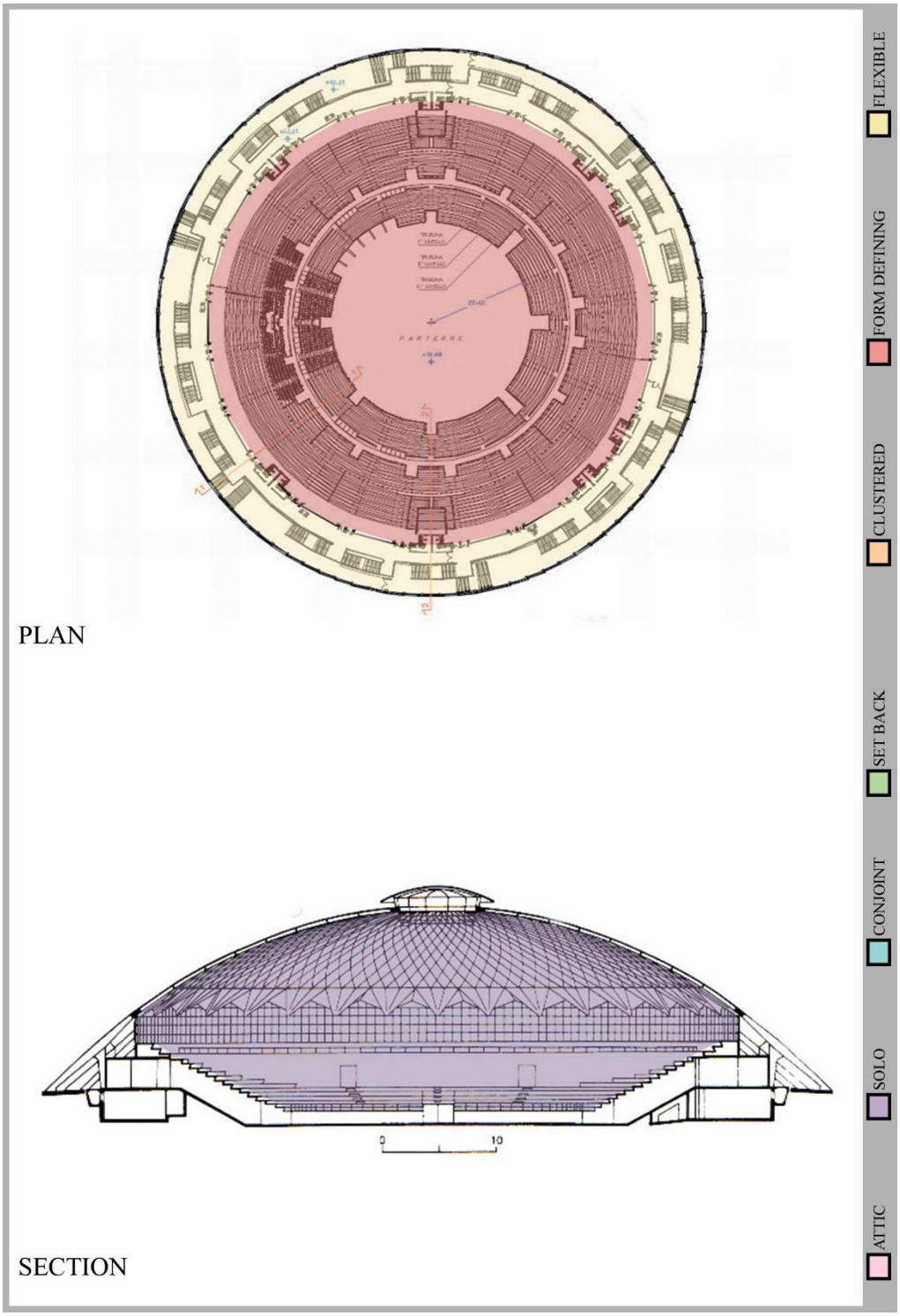
Source: http://shiyangming.blogspot.com/

B. CATEGORIZATION ON PLAN AND SECTION DRAWINGS

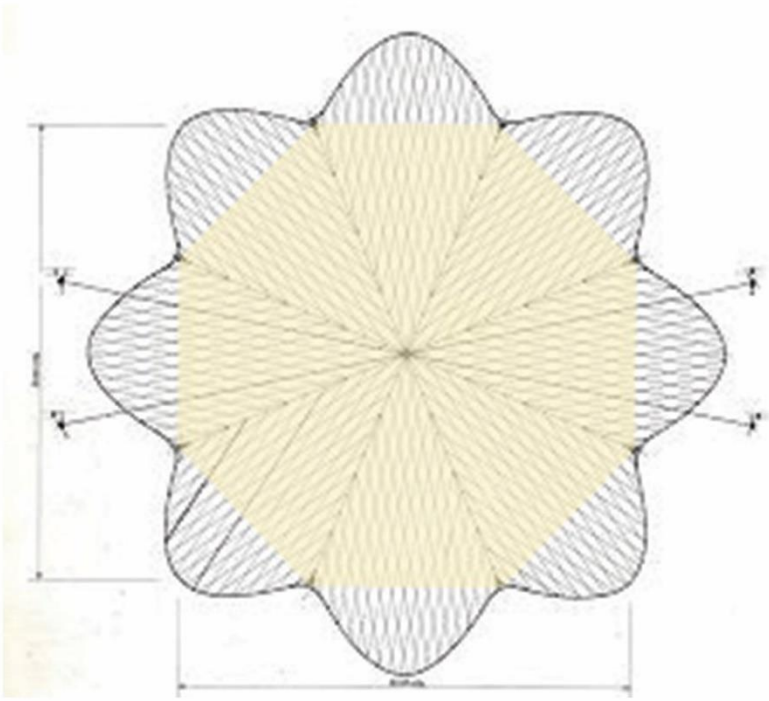
1. Kresge Auditorium, 1955, Eero Saarinen, Massachusetts, US



2. Palazzetto dello Sport, 1956, Annibale Vitellozzi, Pier Luigi Nervi, Rome, Italy



3. Los Manantiales, 1958, Felix Candela, Mexico



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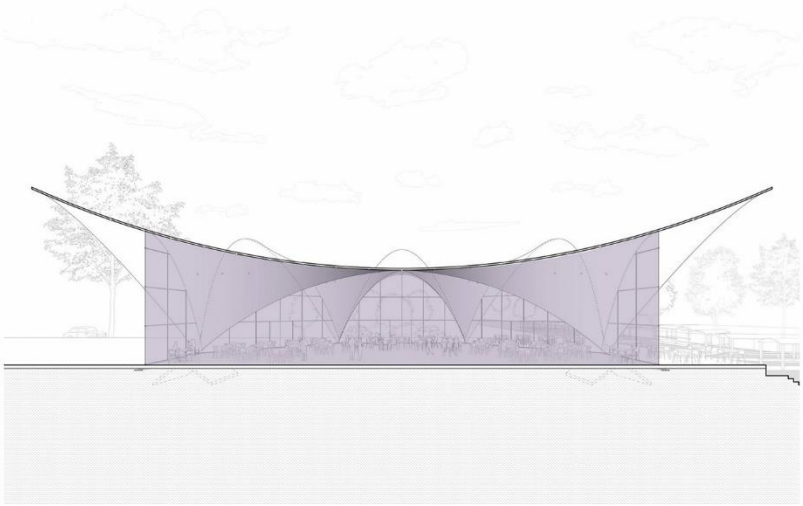

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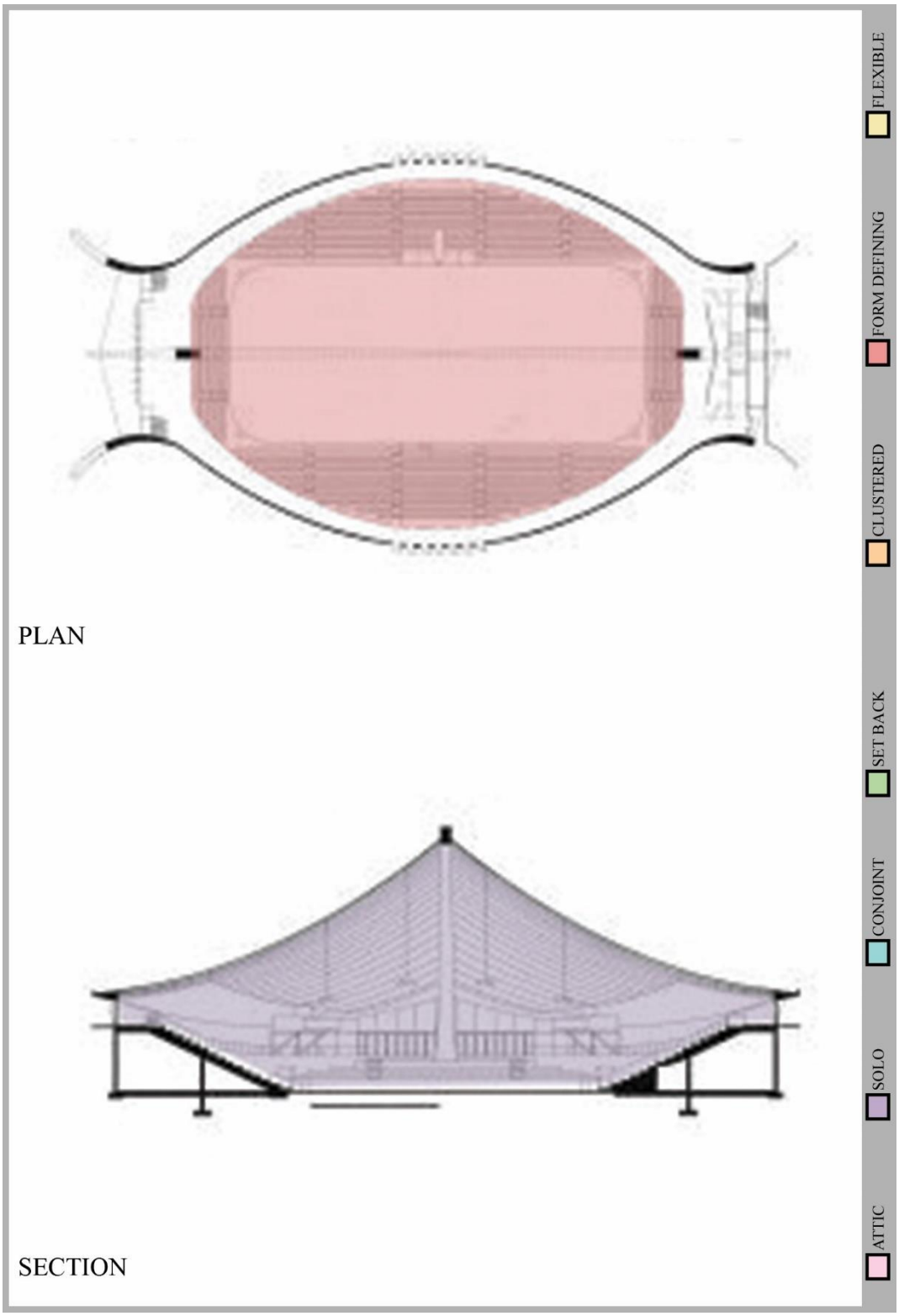
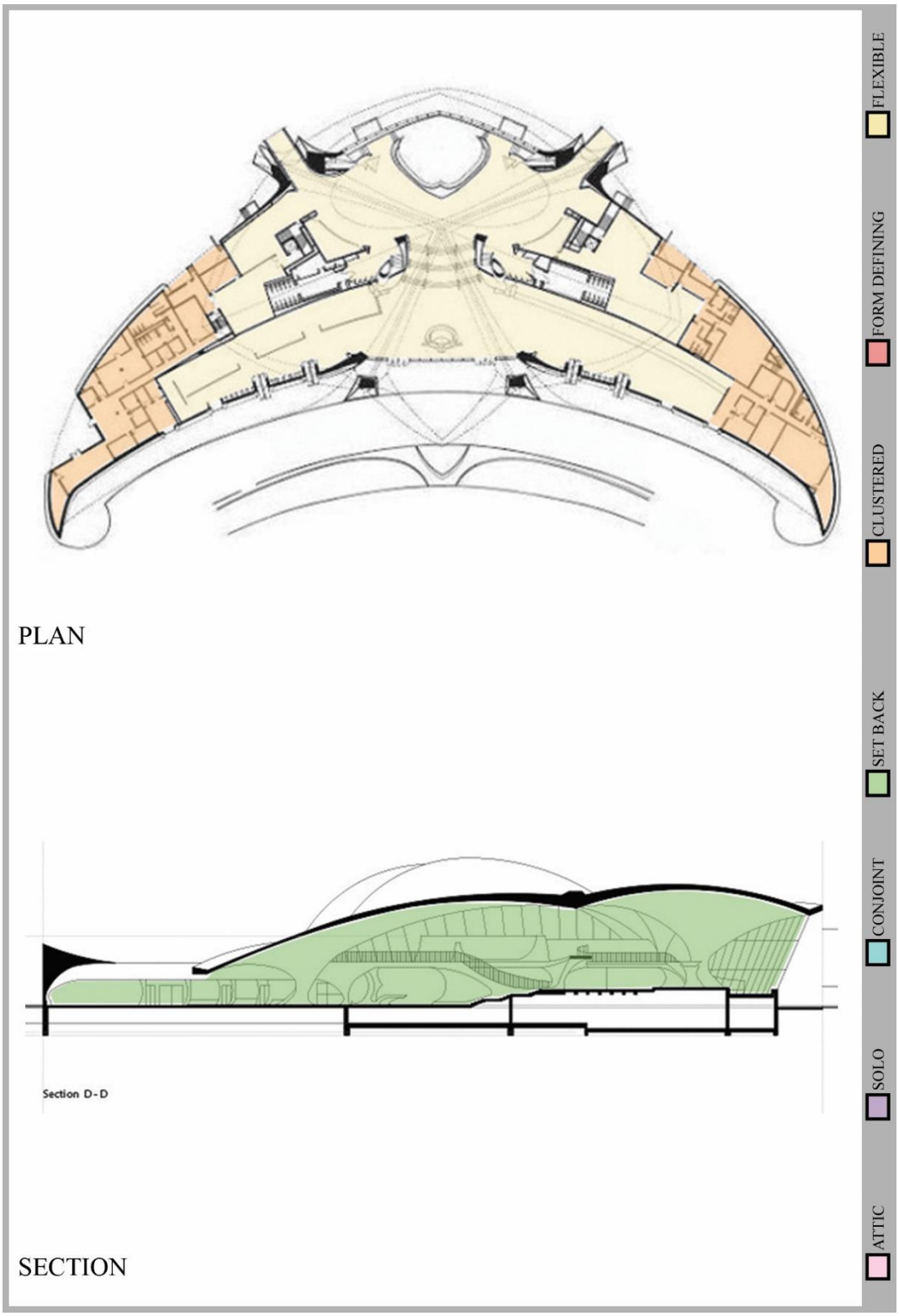
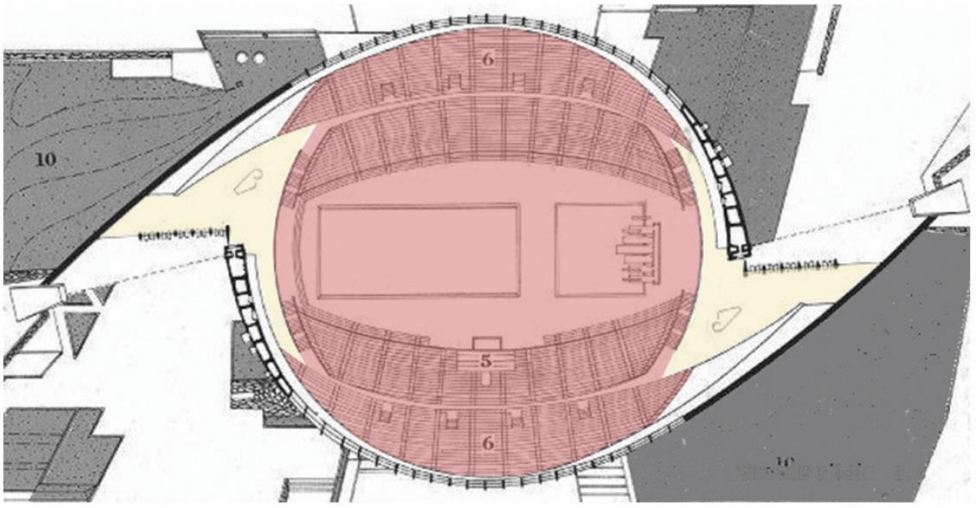
4. Ingalls Rink, 1958, Eero Saarinen, Connecticut, USA



5. TWA Flight Center, 1962, Eero Saarinen, NYC



6. Yoyogi National Gymnasium, 1964, Kenzo Tange, Tokyo, Japan



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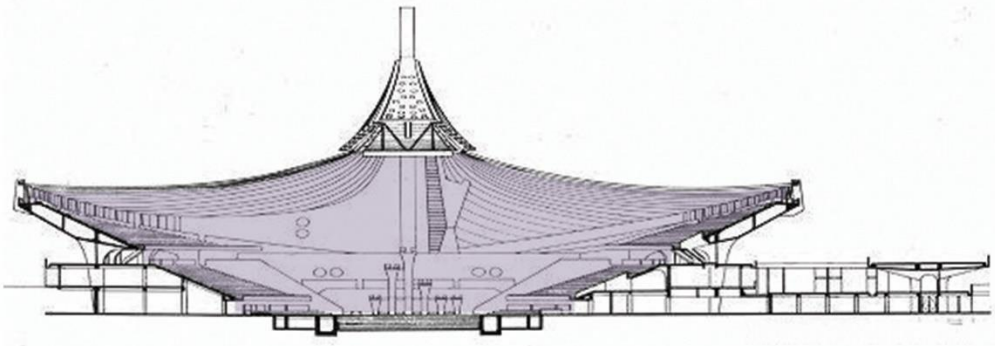

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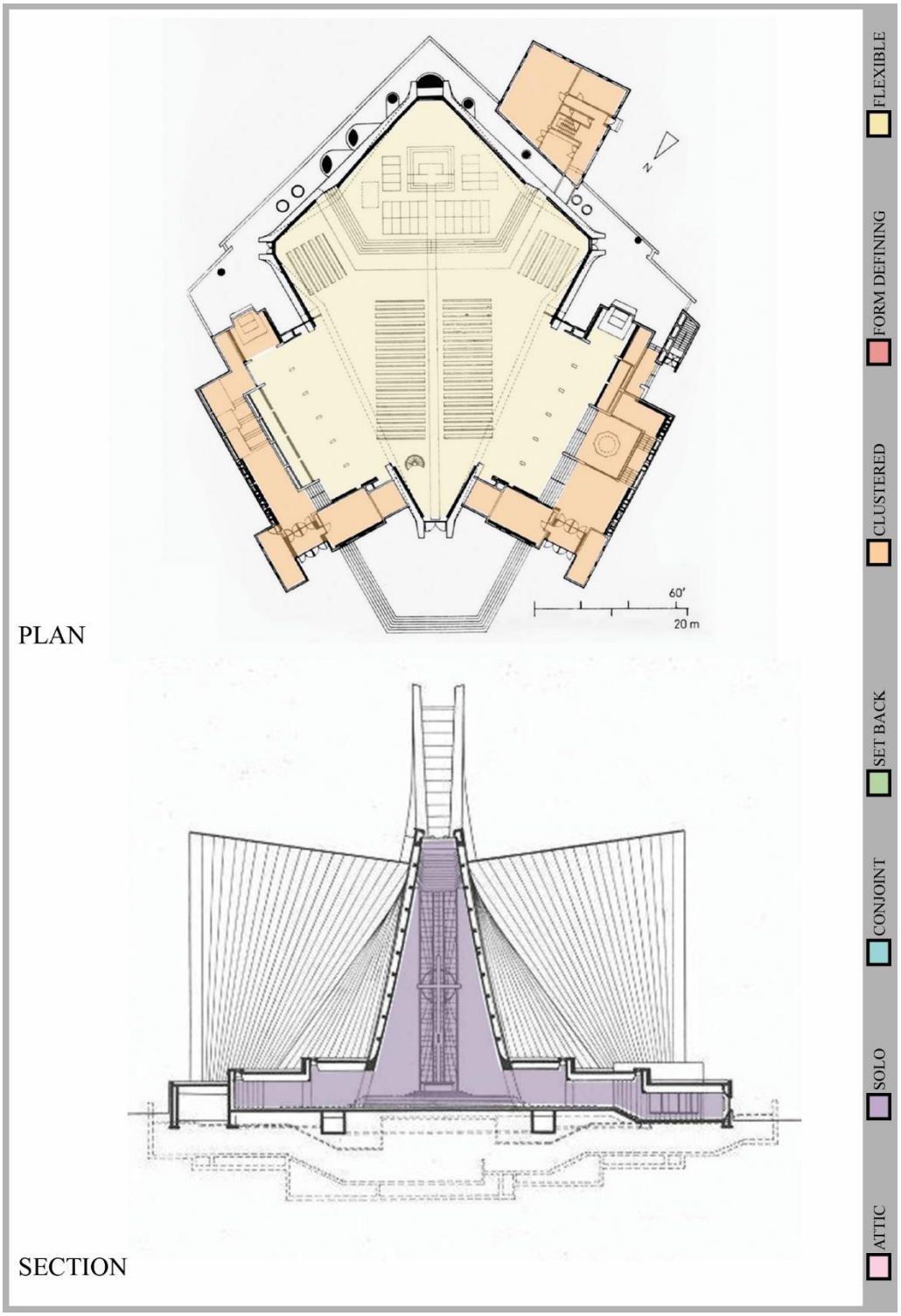
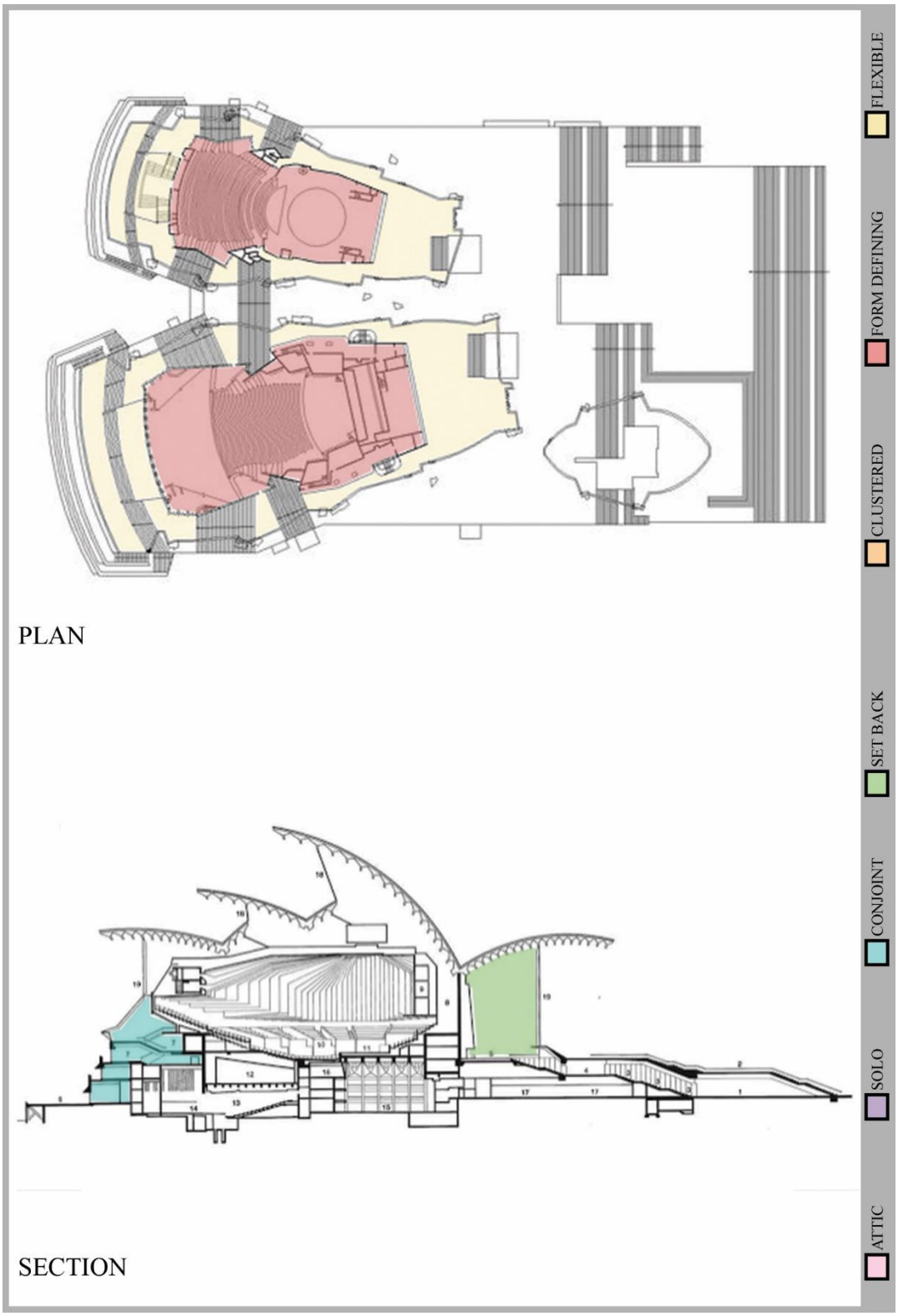
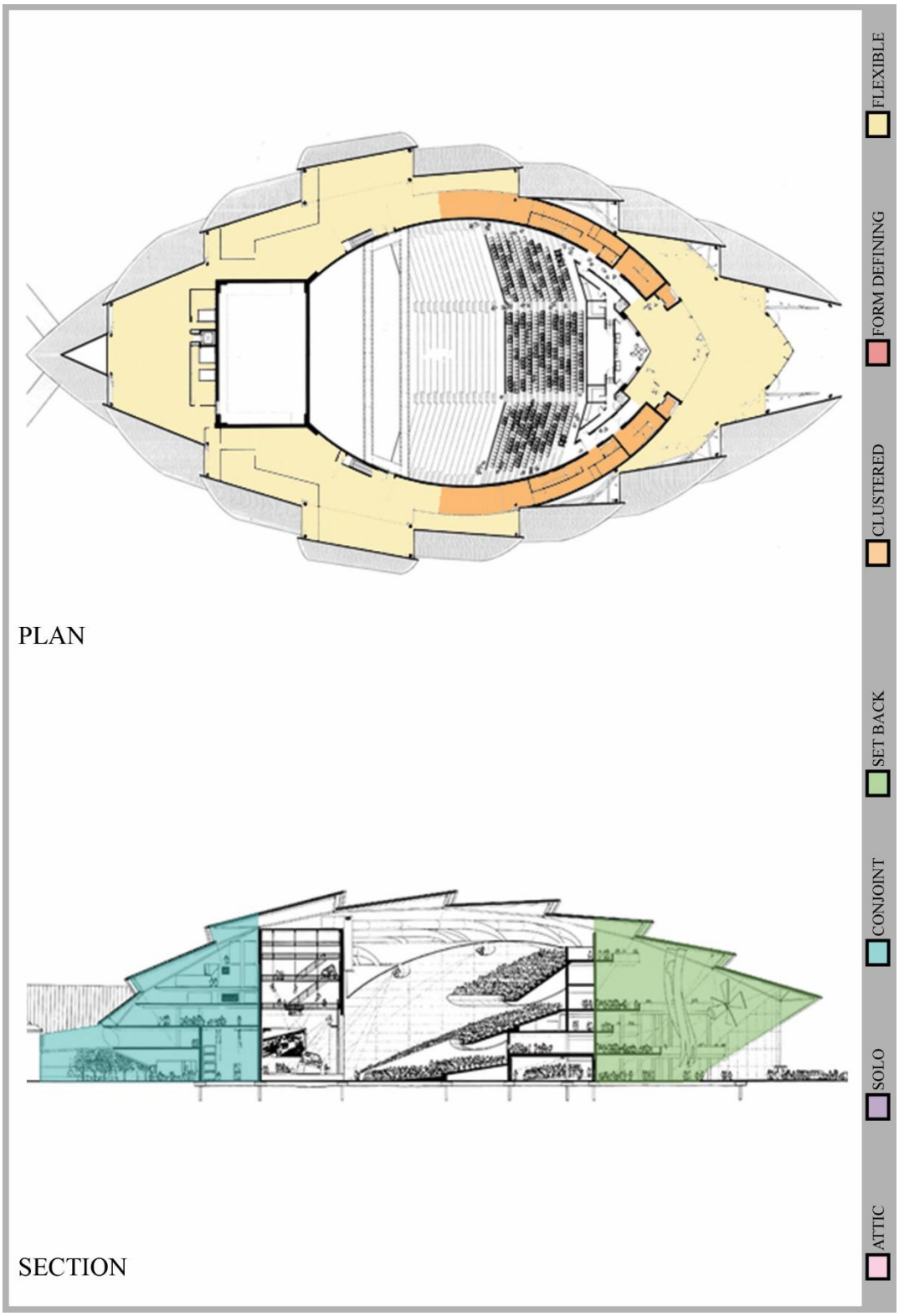
7. St. Mary Cathedral, 1964, Kenzo Tange, Taisei Construction Company, Tokyo, Japan



8. Sydney Opera House, 1973, Jørn Utzon, Sydney, Australia



9. SEC Armadillo, 2000, Norman Foster, Glasgow, Scotland



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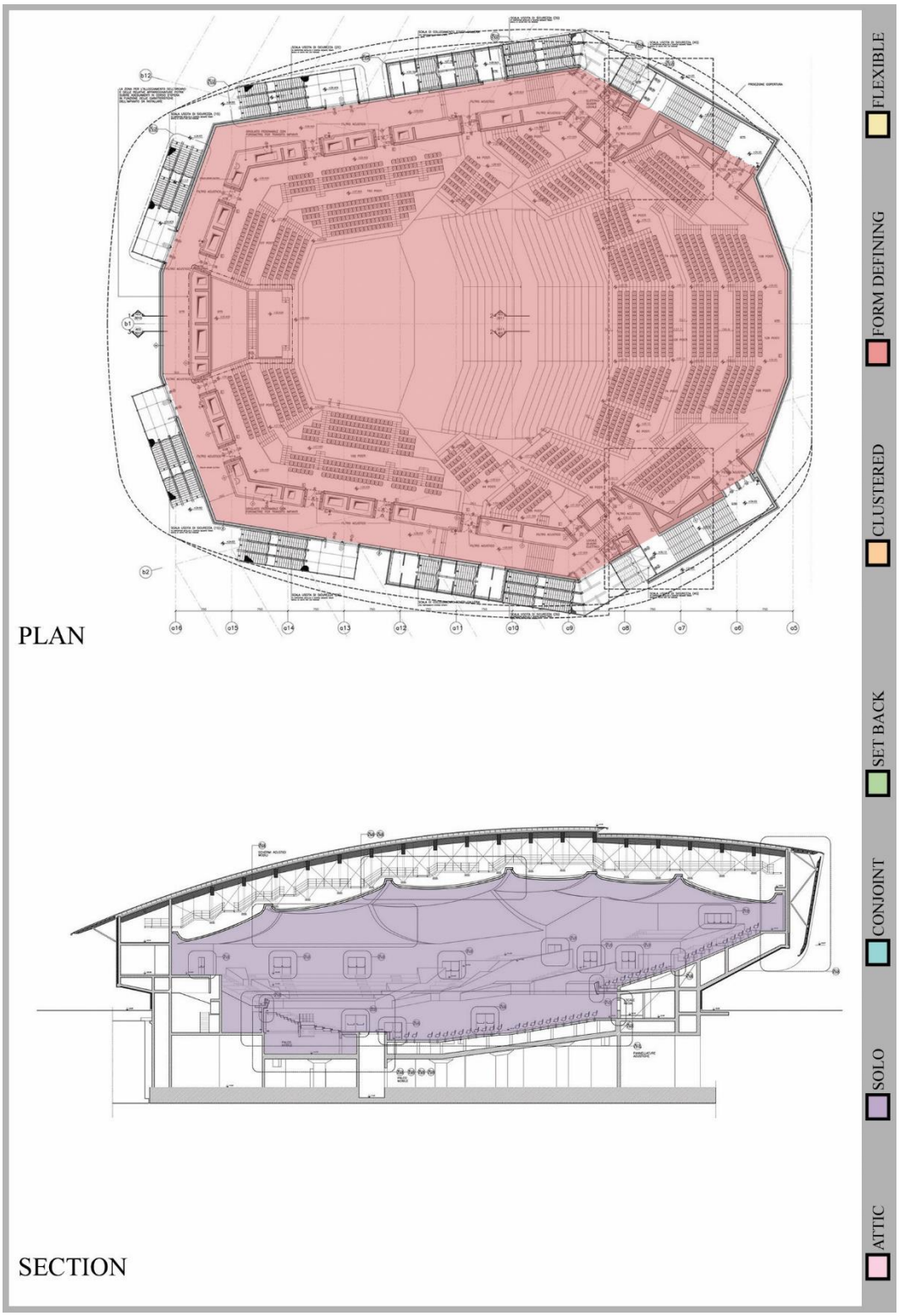
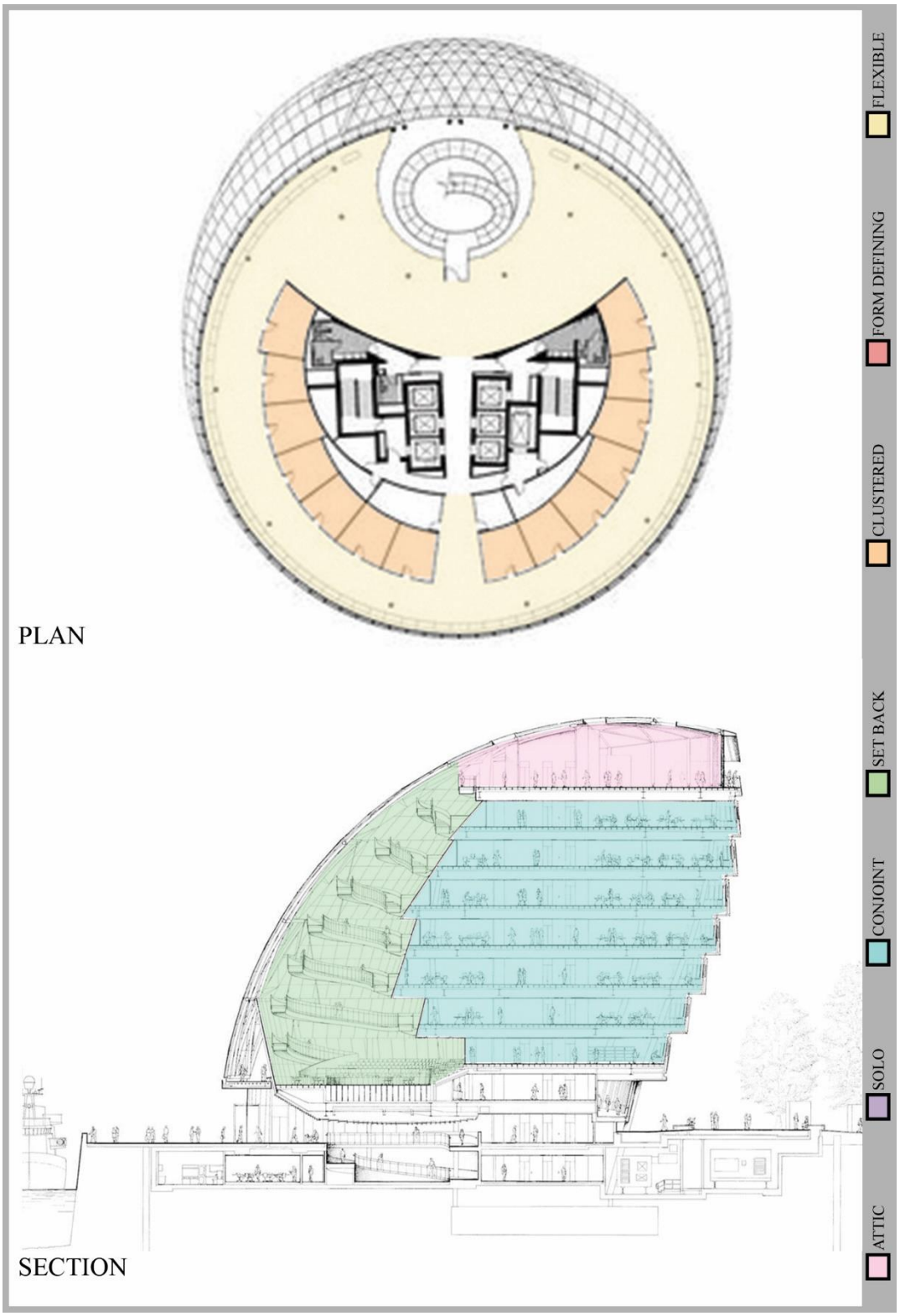
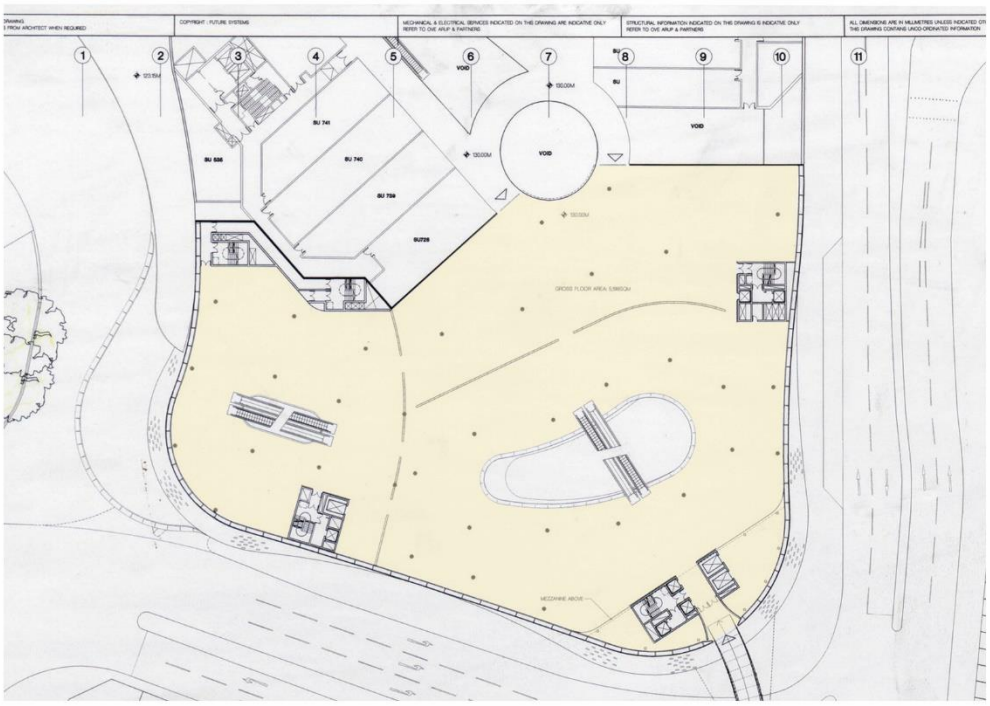
10. Auditorium Parco della Musica, 2002, Renzo Piano, Rome, Italy



11. City Hall, 2002, Foster & Partners, London, UK



12. Selfridges Department Store, 2003, Future Systems, Birmingham, UK



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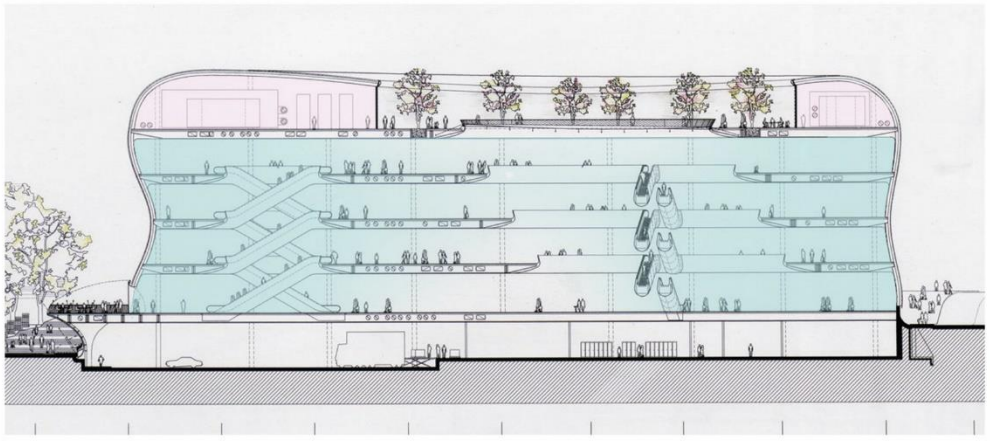

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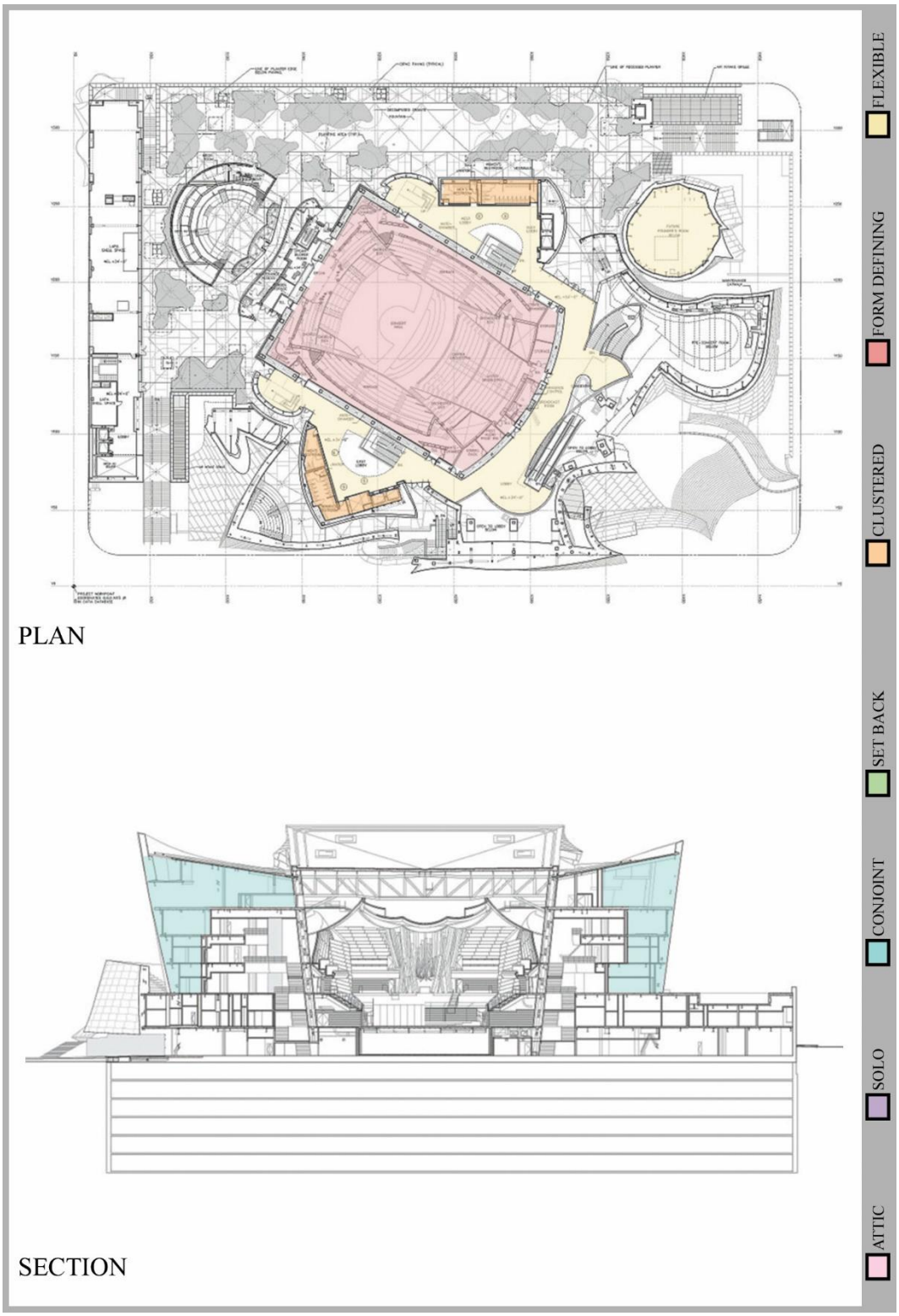
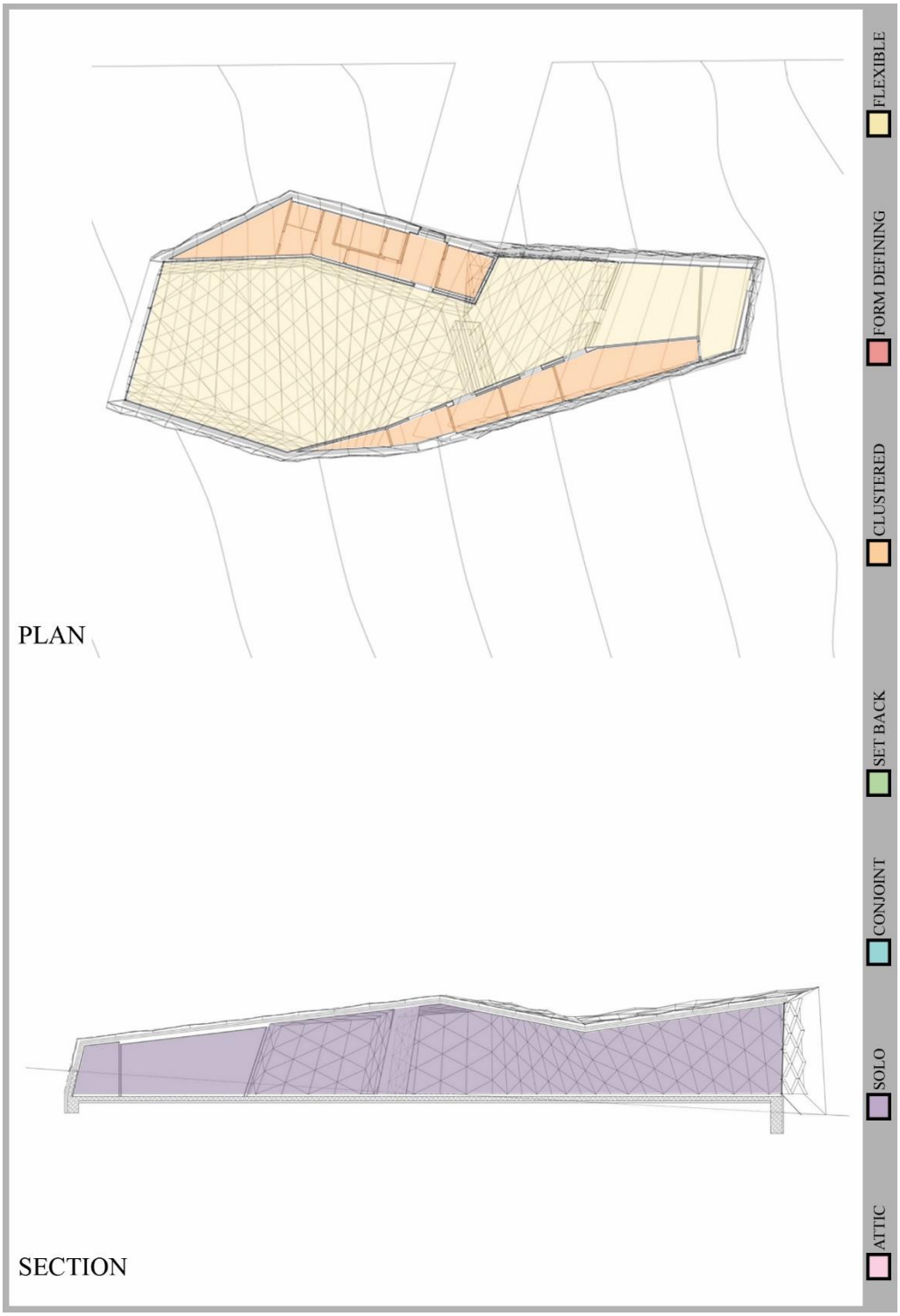
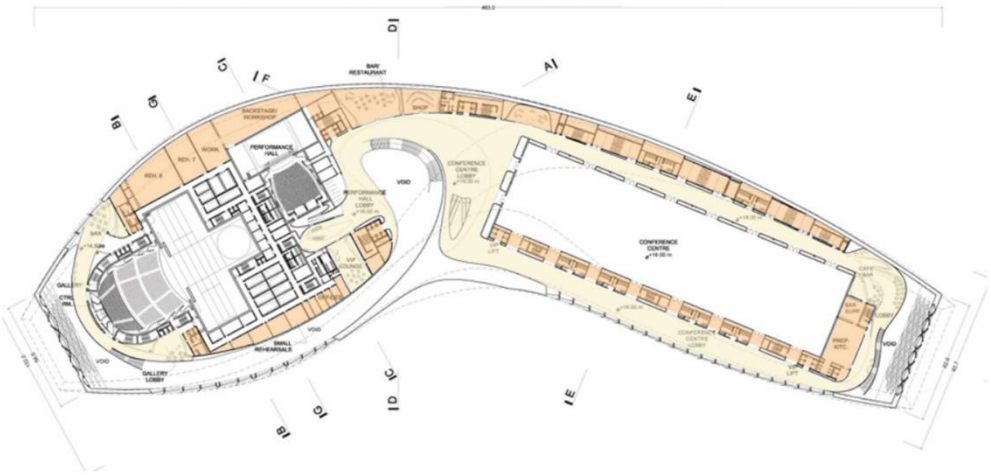
13. Walt Disney Concert Hall, 2003, Frank Gehry, California, USA



14. The Hinzert Museum and Document Center, 2005, Wandel Hoefer Lorch + Hirsch, Halle, Germany



15. Chengdu Contemporary Art Centre, 2007, Zaha Hadid, Chengdu, China



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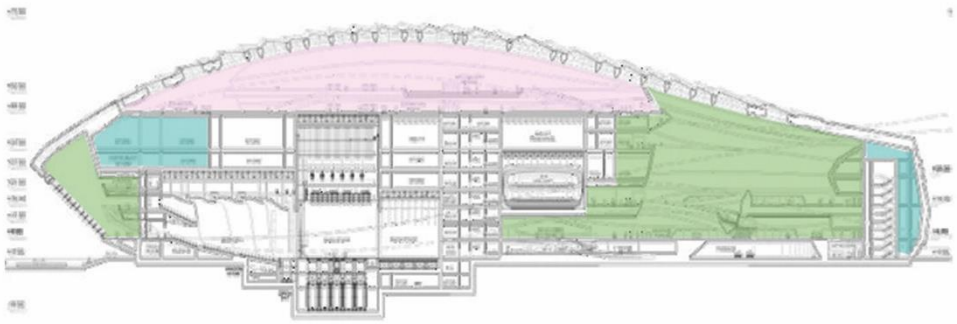

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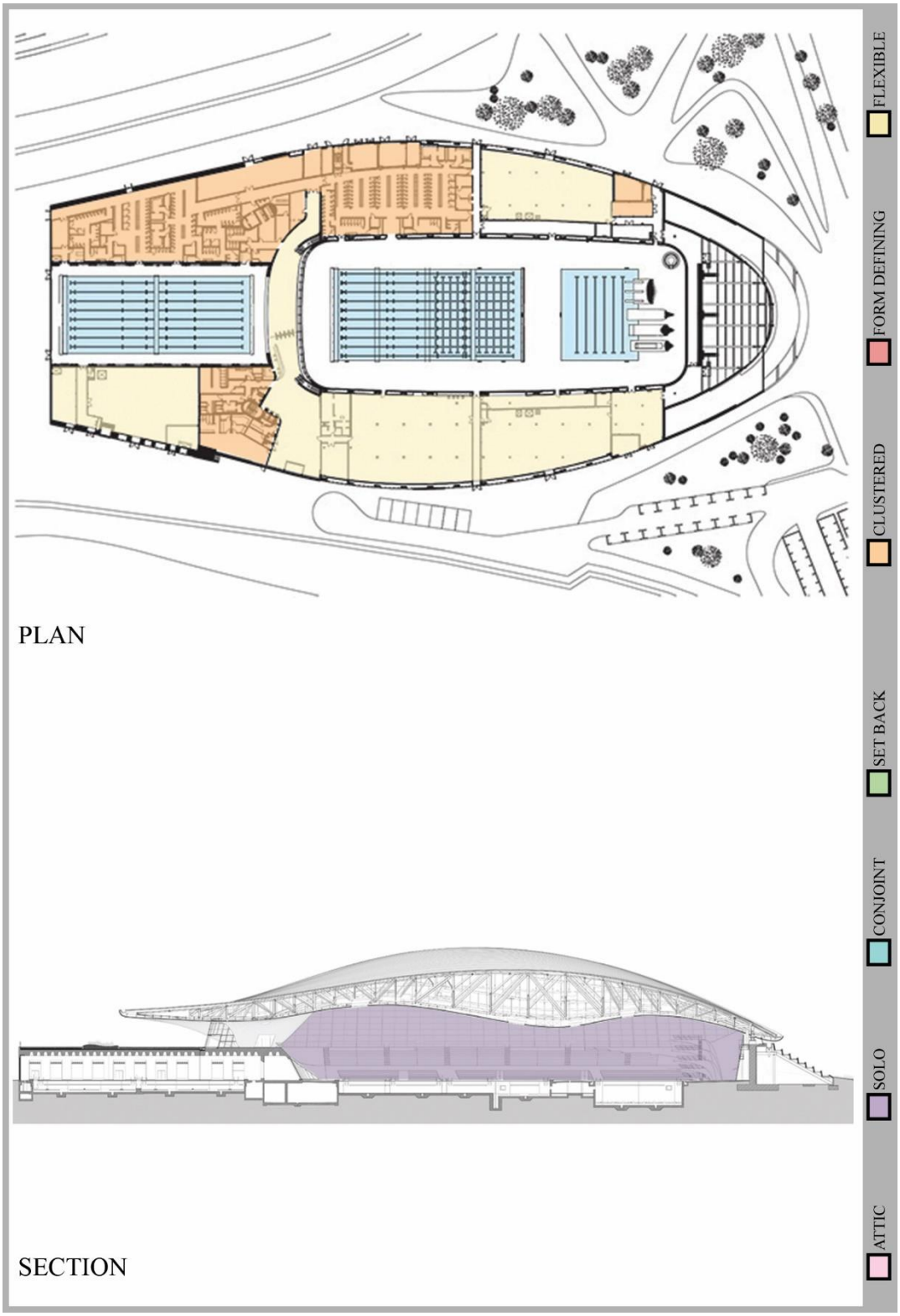
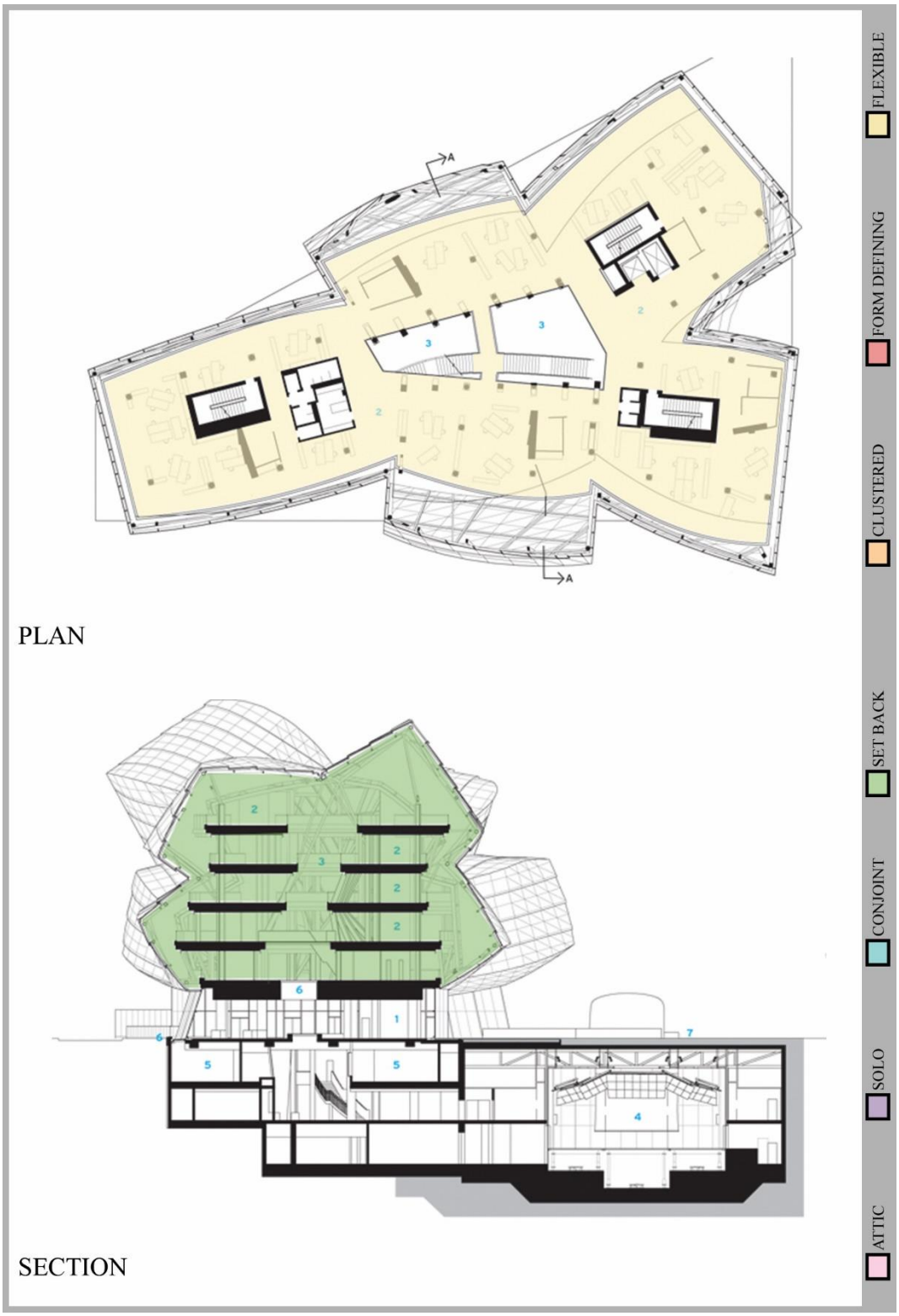
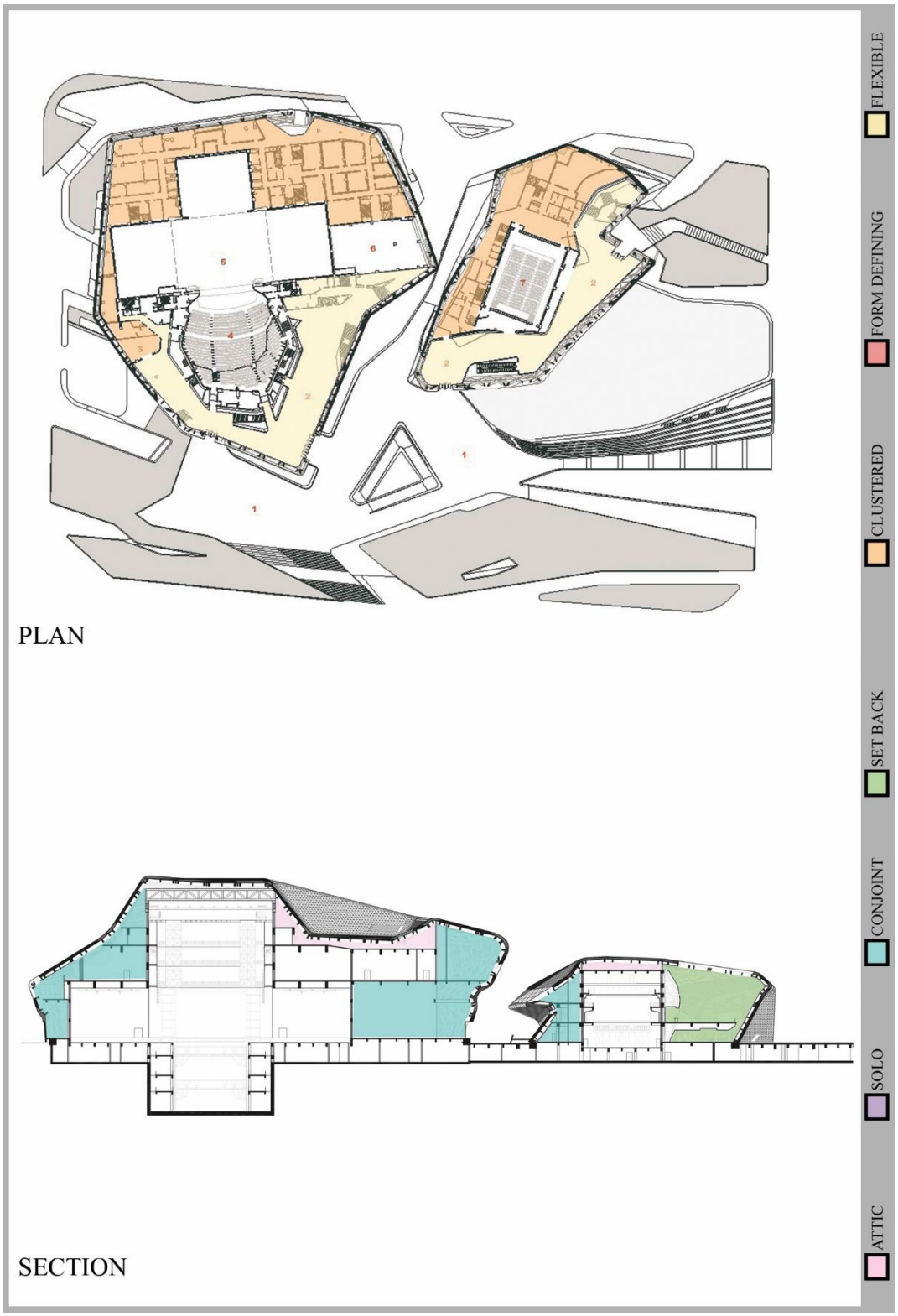
16. London Aquatics Centre, 2008, Zaha Hadid, London, UK



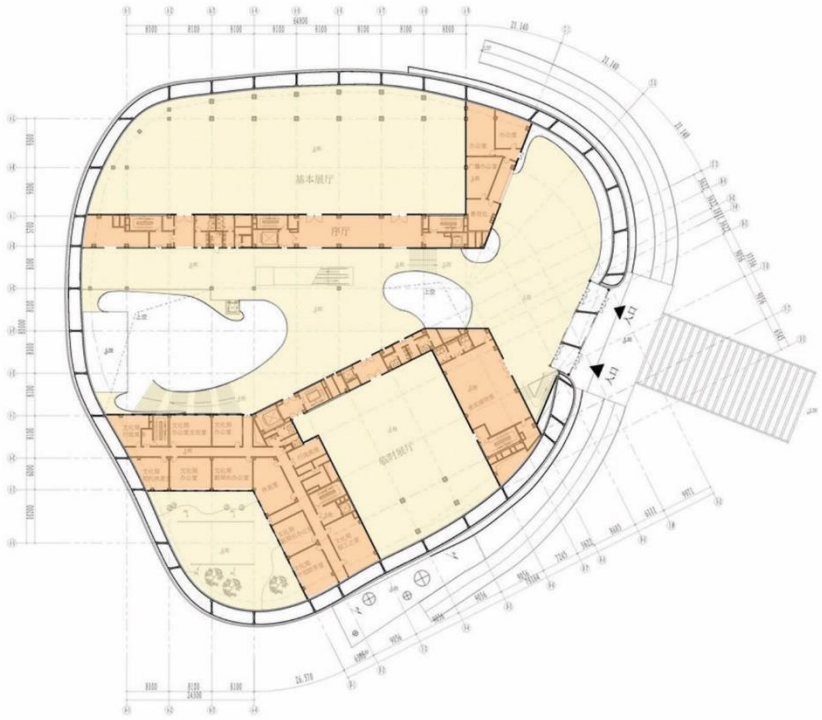
17. Novartis Pharma A.G. Campus, 2009, Frank Gehry, Basel, Switzerland



18. Guangzhou Opera House, 2010, Zaha Hadid, Guangdong, China



19. Ordos Art & City Museum, 2011, MAD Architects, China



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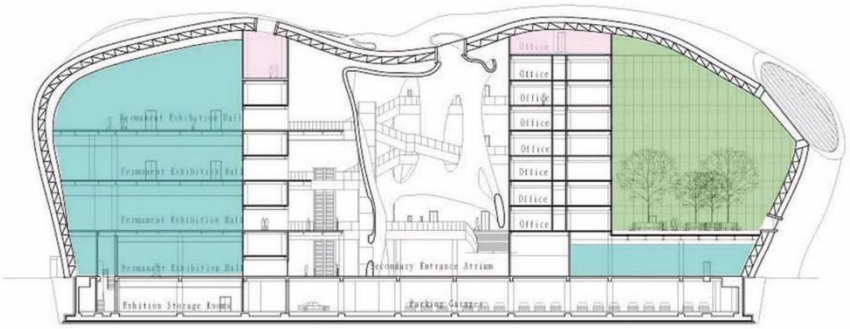

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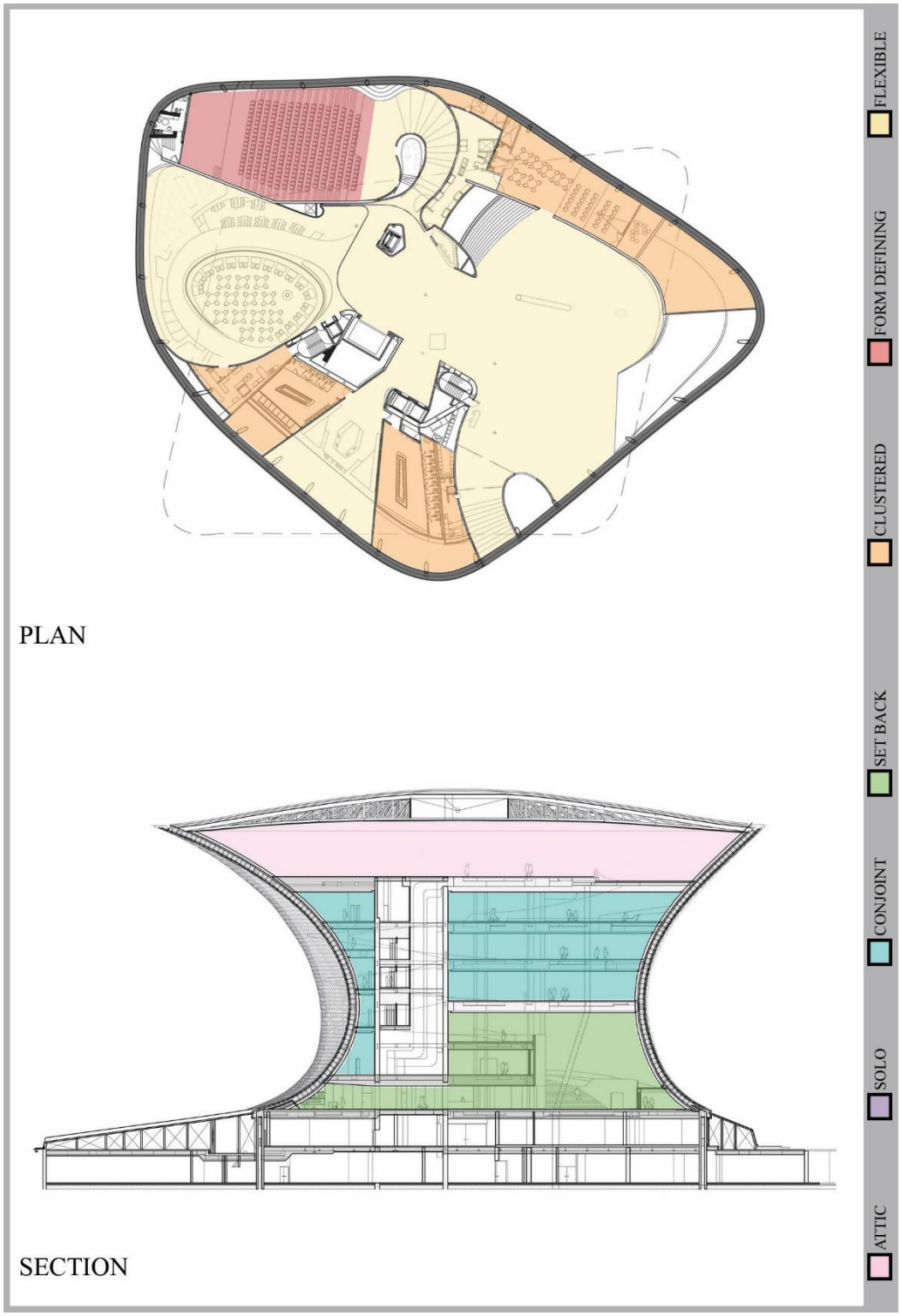
20. Soumaya Museum, 2011, FR-EE/ Fernando Romero Enterprise, Mexico City, Mexico



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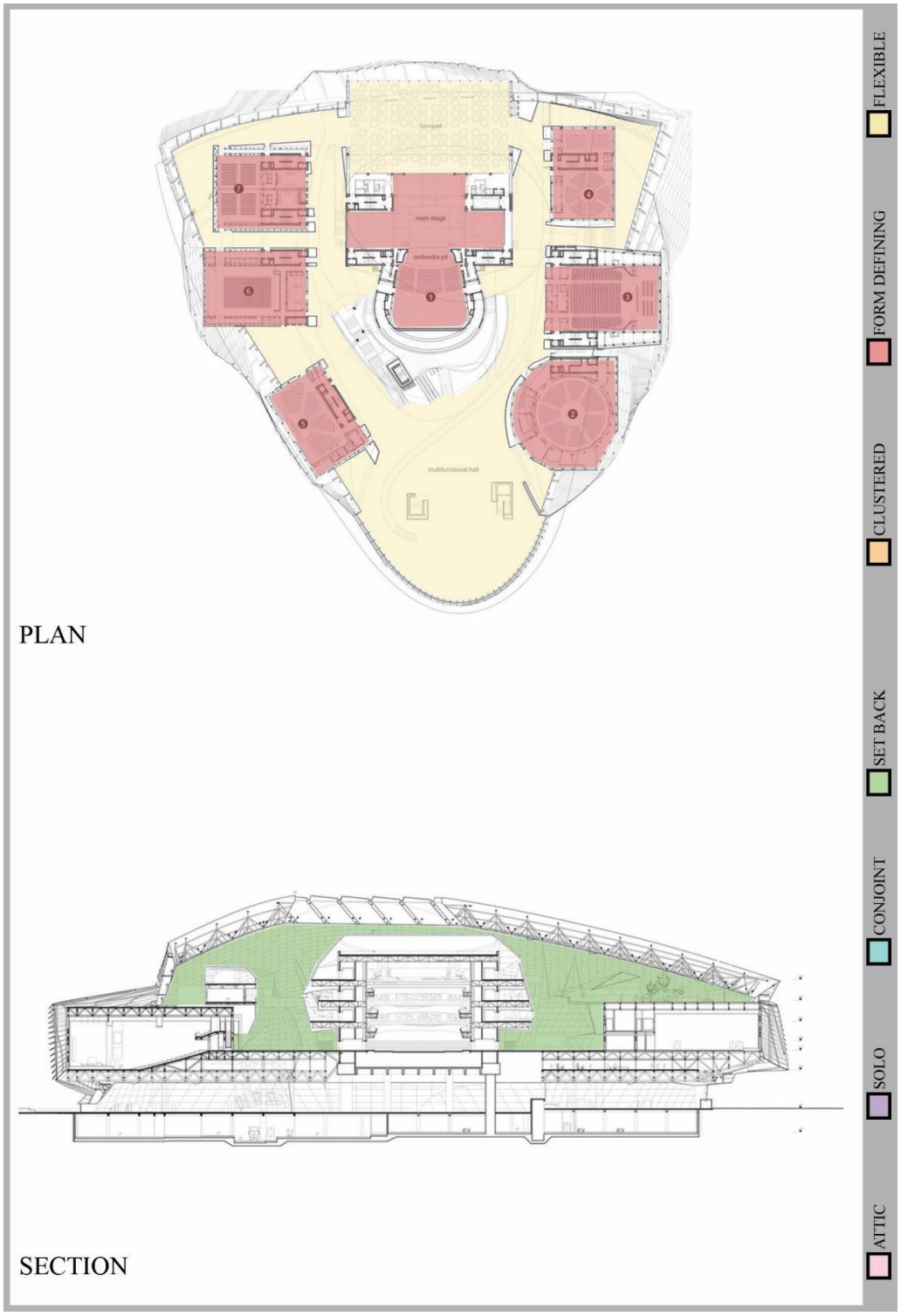
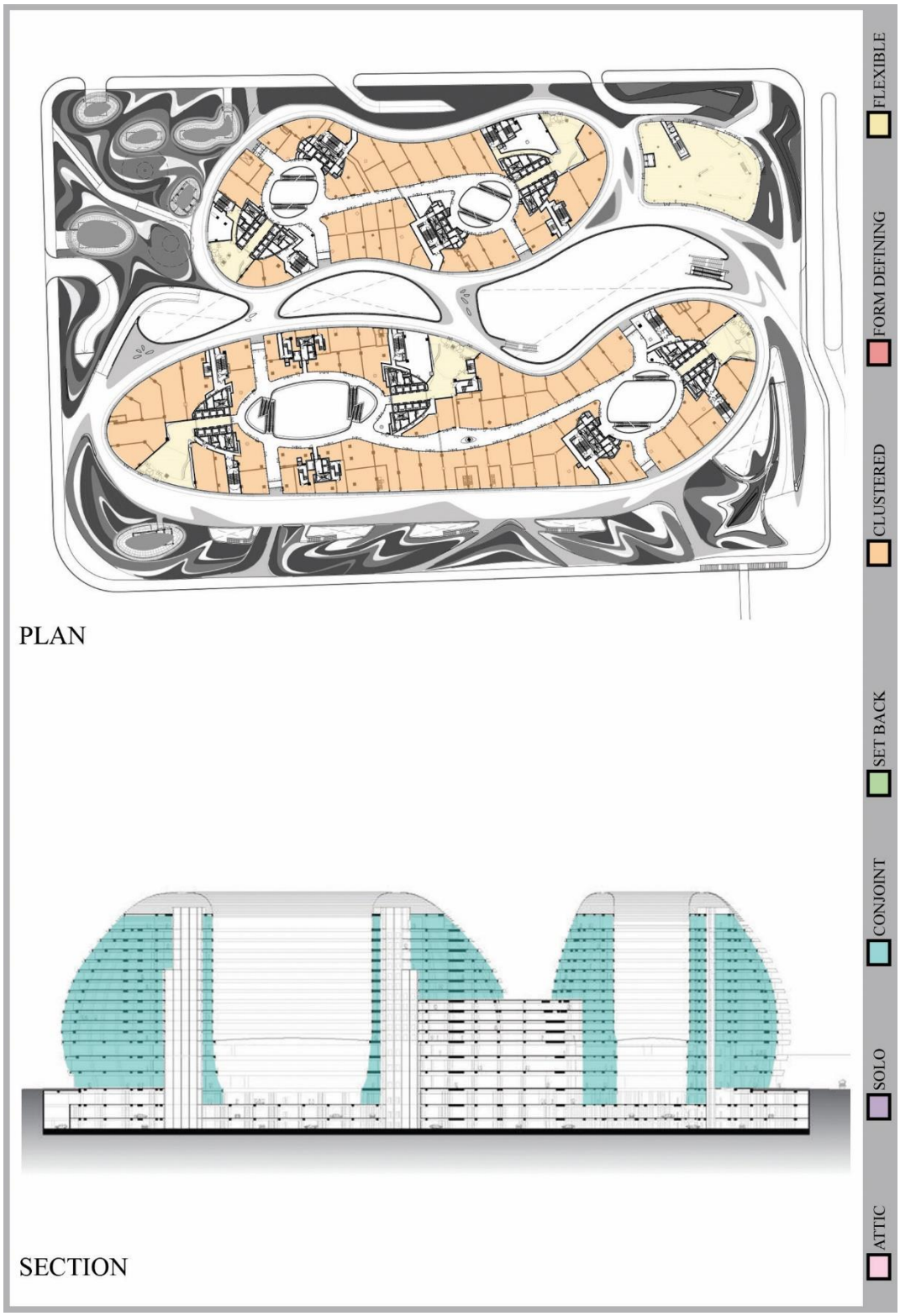
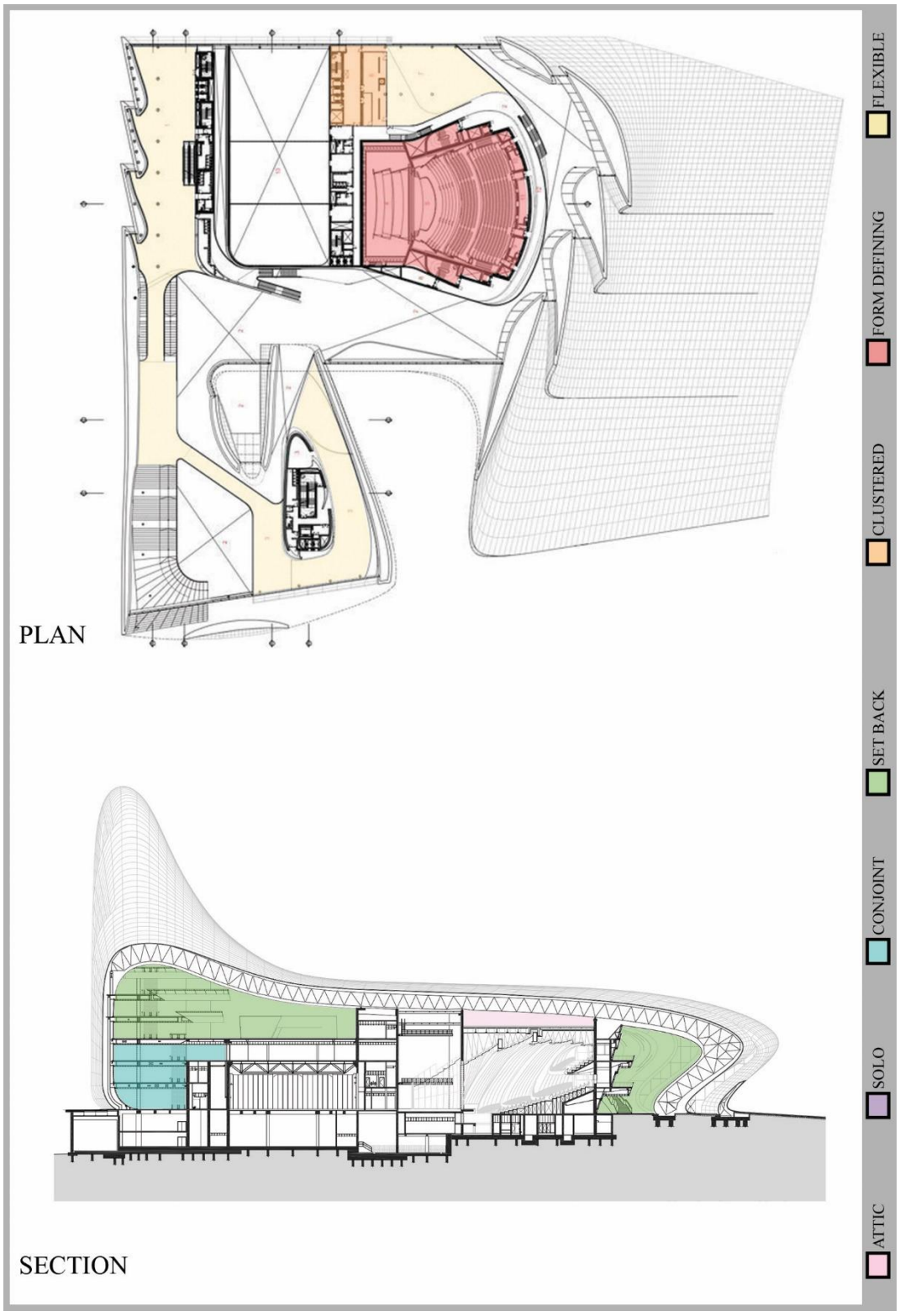
21. Dalian International Conference Center, 2012, Coop Himmelb(l)au, Dalian, China



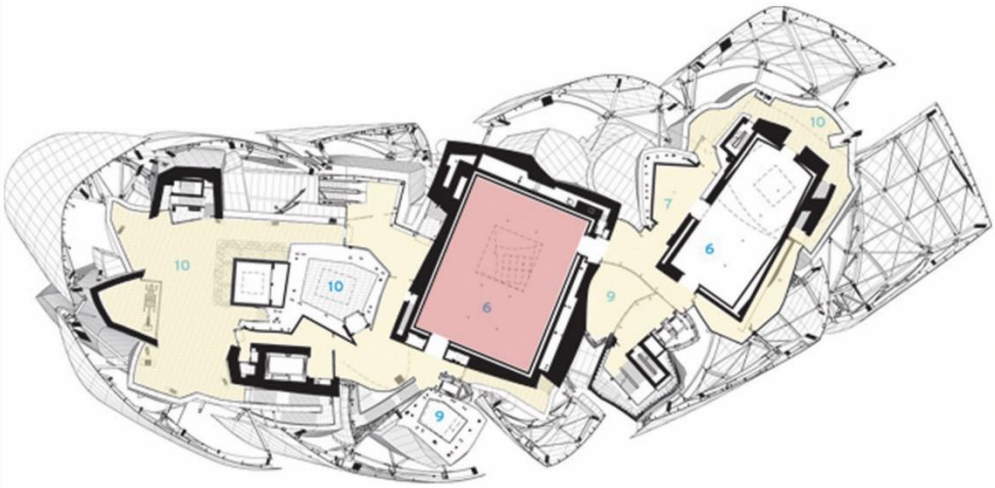
22. Galaxy SOHO in Beijing, 2012, Zaha Hadid, Beijing, China



23. Heydar Aliyev Center, 2013, Zaha Hadid, Baku, Azerbaijan



24. Fondation Louis Vuitton, 2014, Frank Gehry, Paris, France



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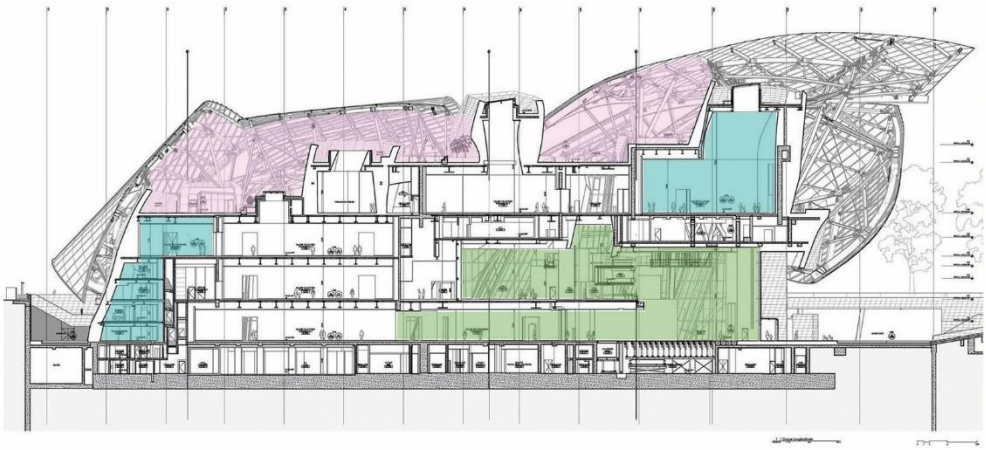

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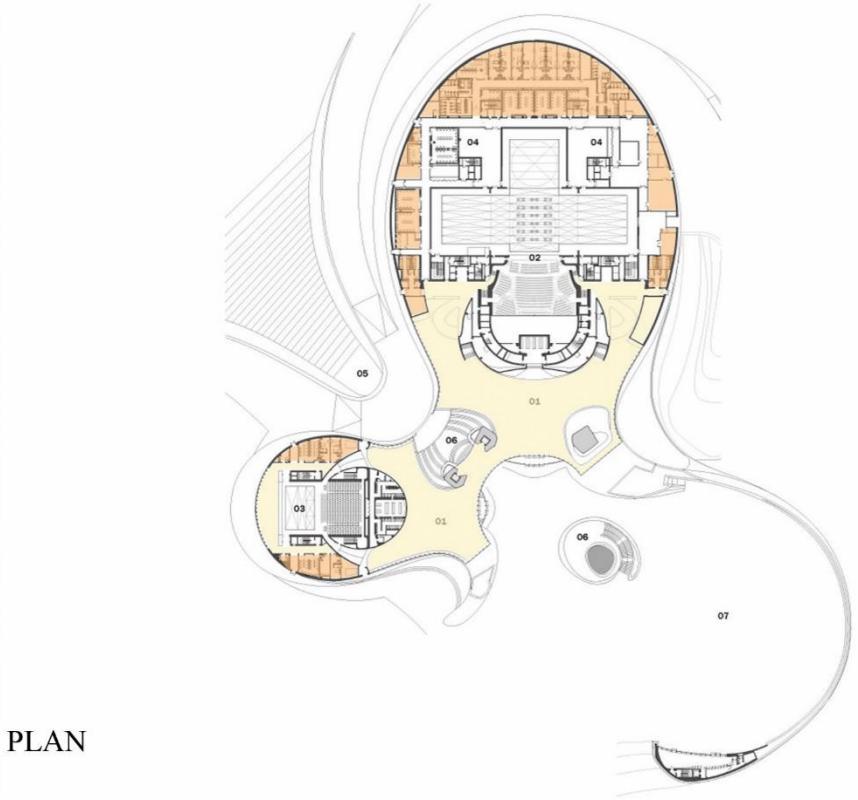
25. Harbin Opera House, 2015, MAD Architects, Heilongjiang, China



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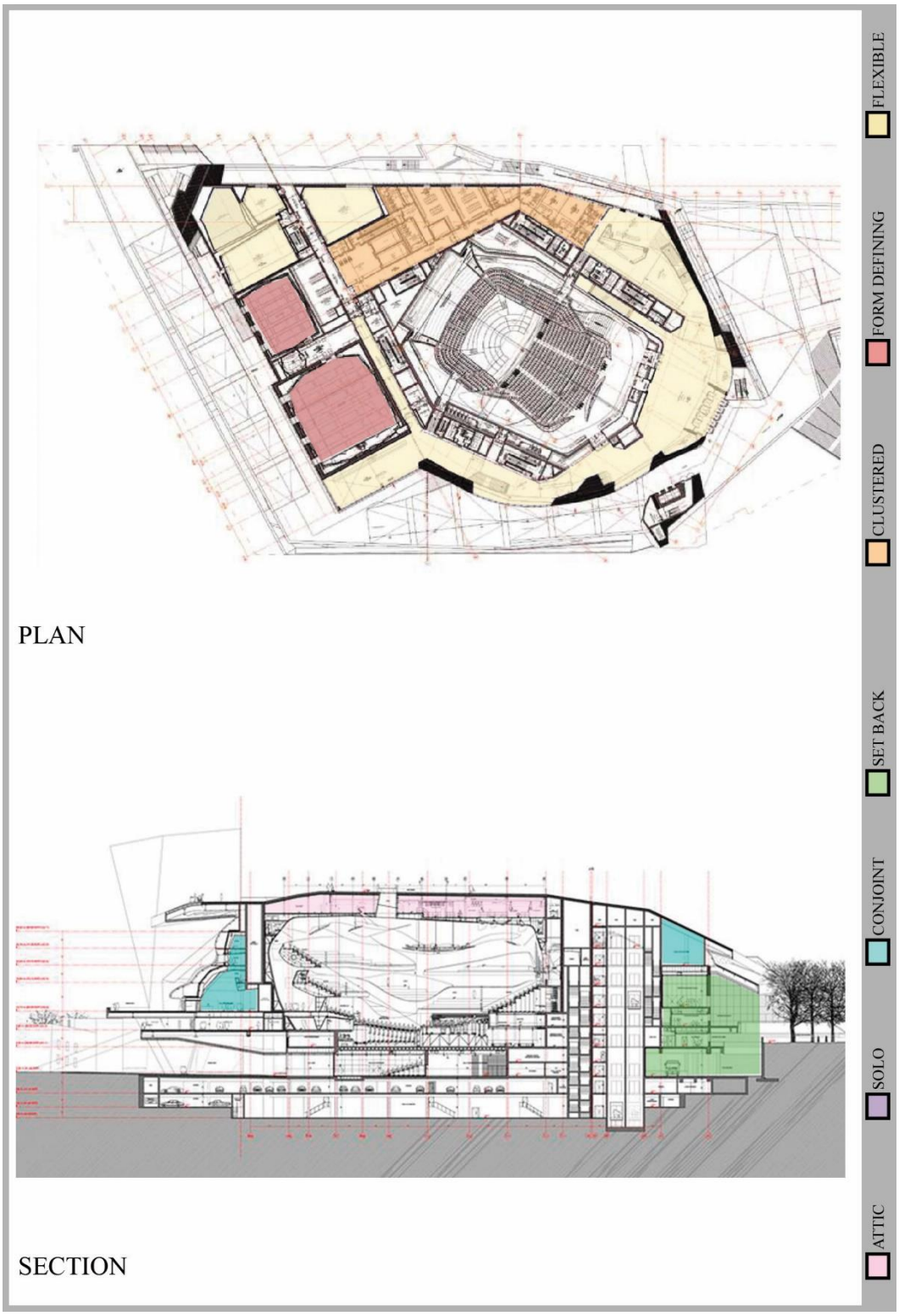
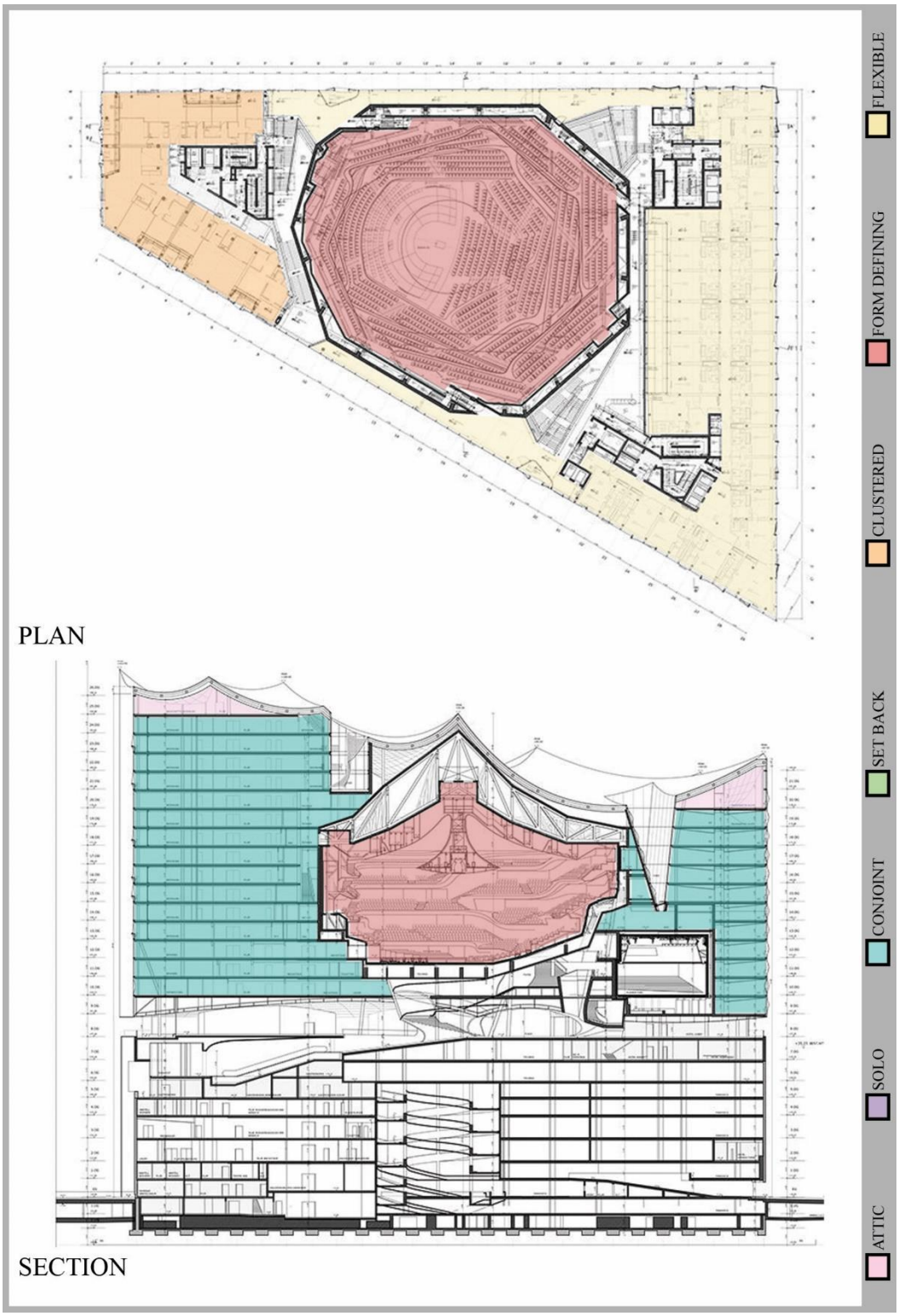
26. Paris Phillarmonie, 2015, Jean Nouvel, Paris, France



27. Elbphilharmonie Hamburg, 2016, Herzog & de Meuron, Germany



28. Phoenix International Media Center, in progress, BIAD, Beijing Shi, China