ARCHITECTURAL MODEL BETWEEN PHYSICAL AND DIGITAL: THE CASE STUDY OF THE ACC PRESIDENTIAL SYMPHONY ORCHESTRA CONCERT HALL IN ANKARA

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ABSTRACT

ARCHITECTURAL MODEL BETWEEN PHYSICAL AND DIGITAL: THE CASE STUDY OF THE ACC PRESIDENTIAL SYMPHONY ORCHESTRA CONCERT HALL IN ANKARA

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The architectural design process has been affected by technological developments and transformations, and the change it has experienced with the widespread use of computers and computational processes in the last decades is remarkable. The architectural model included in the architectural design process has been significantly affected by the change in the architectural design process. As one of the design mediums that includes diverse and multilayered information, the architectural model has been used throughout the ages to generate ideas, develop them, make them perceptible, and embody them. It triggers various design ideas and plays a role in the development of design.

The long-standing use of physical models in architecture has evolved with the introduction of digital models, CAD/CAM technologies, and computational design methods. This shift has significantly altered the production process and methodology of architectural models, creating an iterative loop that encourages experimentation in the design process. In line with these changes, this thesis aims to re-evaluate the role and potential of the architectural model in the design process and the impact of evolving technology on the model. Current architectural model classifications are deemed inadequate for updated models, prompting a reinterpretation using classification by Nick Dunn of the physical model as evaluative, predictive, exploratory, and descriptive, along with proposing an integrative model.

In this context, the ACC (Atatürk Cultural Center) Presidential Symphony Orchestra Concert Hall in Ankara was selected as a case study. Different project teams employed a range of models at distinct stages throughout the 29-year construction process of the project. To enhance comprehension of the architectural role of model, transformation, and impact within the design process, an evaluation of its utilization will be evaluated by considering this project.

Keywords: Architectural Model, Generic Model, Nick Dunn's Model Classification, Presidential Symphony Orchestra Concert Hall

ÖZ

FİZİKSEL VE DİJİTAL ARASINDA MİMARİ MODEL: ANKARA'DA AKM CUMHURBAŞKANLIĞI SENFONİ ORKESTRASI KONSER SALONU ÖRNEĞİ

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Çeşitli aşamalar ve araçlarla tanımlanan mimari tasarım süreci, teknolojideki gelişmelerden ve dönüşümlerden etkilenmiş olup; bilgisayarların, bilgisayar destekli süreçlerin ve sayısal fabrikasyon araçlarının yaygın kullanılmasıyla da son yıllarda dikkate değer bir değişim yaşamıştır. Yaygın ve etkili bir tasarım aracı olarak mimari model de bu değişimden önemli ölçüde etkilenmiştir. Farklı ve çok katmanlı bilgiler içeren tasarım araçlarından biri olan mimari model, çağlar boyunca fikir üretmek, geliştirmek, algılanabilir kılmak ve somutlaştırmak için kullanılmıştır. Bu sayede, çeşitli tasarım fikirlerini tetikler ve tasarımın gelişmesinde rol oynar.

Yıllardır mimari pratikte var olan fiziksel modellerin yaygın kullanımına rağmen, dijital modellerin ortaya çıkışı ve CAD/CAM teknolojilerinin ve hesaplamalı tasarım yöntemleri ve araçlarının tasarım sürecine girmesiyle, mimari modellerin mevcut üretim sürecinde ve metodolojisinde köklü bir değişim yaşanmıştır. Bu değişim, mimari modellerin üretim sürecini ve metodolojisini önemli ölçüde değiştirmiş ve tasarım sürecinde deneyselliği teşvik eden yinelemeli bir döngü yaratmıştır. Bu tez,

mimari maketin tasarım sürecindeki rolünü ve potansiyelini ve gelişen teknolojinin model üzerindeki etkisini yeniden değerlendirmeyi amaçlamaktadır. Mevcut mimari model sınıflandırmalarının güncellenen mimari model kapsamında yetersiz kaldığı tespit edilmiş; bu nedenle Nick Dunn tarafından fiziksel model için yapılan değerlendirici, öngörücü, keşfedici ve tanımlayıcı model sınıflandırması kullanılarak ve bütünleştirici model önerilerek mimari model yeniden yorumlanmıştır

Bu bağlamda, Ankara'daki AKM (Atatürk Kültür Merkezi) Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu bir vaka çalışması olarak seçilmiştir. Farklı proje ekipleri, projenin 29 yıllık inşaat süreci boyunca farklı aşamalarda bir dizi model kullanmıştır. Tasarım sürecinde maketin mimari rolünün, dönüşümünün ve etkisinin daha iyi anlaşılması için, bu proje göz önünde bulundurularak maket kullanımına ilişkin bir değerlendirme yapılacaktır.

Anahtar Kelimeler: Mimari Model, Jenerik Model, Nick Dunn'ın Model Sınıflandırması, Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu

to my family

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LIST OF ABBREVIATIONS

ABBREVIATIONS

2D Two-dimensional

3D Three-dimensional

CAD Computer-Aided Design

CAM Computer-Aided Manufacturing

CSO Presidential Symphony Orchestra

CNC Computer Numerical Control

RP Rapid Prototyping

CHAPTER 1

INTRODUCTION

Architectural representational media have been used in the history of architecture to realize and represent design ideas. These mediums serve not only to solve architectural problems but also to establish a language that incorporates verbal, visual, and diverse forms of expression. This array of mediums facilitates interaction, communication, and a richer experience of the environment, introducing diversity in the conditions and parameters it establishes.[1] This diversity, in turn, contributes to distinct stages in the architectural design process, giving rise to a variety of representation mediums such as sketches, drawings, architectural models, animations, diagrams, and photographs. Additionally, innovative tools such as photomontage and collage techniques are introduced in offices and design schools for representation.[2] This study specifically revolves around one of these design mediums—the architectural model.

> …the space of the model lies on the border between representation and actuality. Like the frame of a painting, it demarcates a limit between the work and what lies beyond. And like the frame, the model is neither wholly inside nor wholly outside, neither pure representation nor transcendent object.[3]

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[1] Mark Hewitt, "Representational Forms and Modes of Conception; an Approach to the History of Architectural Drawing," *Journal of Architectural Education* 39, no. 2 (1985): 2–3.

[2] Paul Emmons, "Drawing and Perspective," in *Architecture School: Three Centuries of Educating Architects in North America*, ed. Joan Ockman and Rebecca Williamson (MIT Press, 2012): 17.

[3] Christian Hubert, "The Ruins of Representation Revisited," *OASE*, no. 84 (January 1, 2011): 3.

According to architectural scholar Christian Hubert, the architectural model serves as a form of expression that elucidates the intricate relationship between representation and reality, extending beyond mere structure or design. In this respect, the model functions both as a link connecting representation to reality and as a fundamental instrument for understanding, exploring, and comprehending architecture.[4] However, it is evident that the use or purpose of the architectural model is not limited to this extent. The architectural model should be approached from various perspectives to comprehend this versatile usage. Initially, the term "architectural model" often brings about ambiguity regarding whether it refers to a physical or digital model. Clarifying this complexity is crucial for a more informed entry into discussions about the nature of the architectural model. In this regard, the thesis questions the architectural model and its place in the design process and how changing and developing technologies shape the architectural model. Within this context, the emerging questions have identified the main focuses of the thesis and contributed to directing the research. Among these questions are topics such as the role of the architectural model in the design process, its effectiveness in managing the process, and the impact of integrating digital technologies into the design process on the overall perception of the architectural model.

For centuries, architects have utilized the architectural model as a descriptive tool to assess planned design concepts.[5] While their usage dates back to ancient Egyptian times, there was a notable surge, especially during the Renaissance and Baroque periods.[6] However, the dominance of the drawing-oriented Beaux-Arts education system in the 19th century led to a decline in model usage. The influence of the

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[4] Albert C. Smith, *Architectural Model as Machine: A New View of Models from Antiquity to the Present Day* (Routledge, 2004): xxvi.

[5] Elvan Altan and Pelin Derviş, "Mimarlık Tarihi Bağlamında Maket," in *Düşünme ve Görselleştirme Aracı Olarak Türkiye'de Mimari Maket* (Ofset Yapımevi, 2020): 71.

[6] Criss B. Mills, *Designing with Models: A Studio Guide to Making and Using Architectural Design Models* (*John Wiley & Sons eBooks*, 2005): viii.

Bauhaus methodology in the early 20th century saw a reintegration of the architectural model into the design process at an early stage.[7] Subsequently, the use of architectural models expanded throughout the design process, gaining effectiveness. This trend persisted and grew in tandem with the evolution of modern architecture, resulting in the widespread adoption of models in the architectural design process.

The development of computer technologies initiated substantial transformations across different disciplines by the close of the 20th century.[8] In the 1970s, architectural practices began recognizing computer technologies, primarily using them for drawing and visualization. By the 1980s, the integration of computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies into the design process expanded their role in the initial stages.[9] NURBS (Non-Uniform Rational B-Spline) curves, foundational in many computer modeling software used in this process, offer advantages such as accuracy, flexibility, and efficient data representation, enabling fast processing. These developments have facilitated the convergence of design and production processes, enhancing the efficiency of the design process. It has swift creation and manipulation of complex architectural forms and structures, fostering an experimental approach.[10] However, the growing complexity posed challenges for exist manufacturing methods. To address this, CAM technologies were integrated into architectural practice alongside CAD, reshaping architectural models' production process and methodology. Digital

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[7] Mark Morris, *Models: Architecture and the Miniature* (Academy Press, 2006): 19-23.

[8] Branko Kolarevic, "Digital Morphogenesis," in *Architecture in the Digital Age: Design and Manufacturing* (Taylor & Francis, 2003): 17-45.

[9] Jim Glymph, "Evolution of the Digital Design Process," in *Architecture in the Digital Age: Design and Manufacturing* (Taylor & Francis, 2003): 149–70.

[10] John Pittman, "Building Information Modeling: Current Challenges and Future Directions," in *Architecture in the Digital Age: Design and Manufacturing*, ed. Branko Kolarevic, (Taylor & Francis, 2003): 254–58.

fabrication tools leverage data from the digital environment provided by CAD/CAM technologies to produce physical models.[11] Moreover, digitalization technology enables a reverse cycle, transitioning from physical to digital, fostering an iterative design process.

Diverse methods and tools and variations in the intended use of architectural models result in distinct types of models throughout the design process. For instance, conceptual models find frequent use in early design stages, while working models contribute to design development. Structure models concentrate on technical details, presentation models visually depict the final product, and generic models offer flexibility for data input and changes at different design stages due to their hybrid structure. Advancements in CAD/CAM technologies, the development of computational design tools and methods, and the impact of modeling programs on architectural models suggest that the distinction between physical and digital models is gradually blurring. However, considering that existing model classifications still maintain the differentiation between physical and digital models, it can be argued that existing classifications may be inadequate in certain aspects.

For these reasons, the thesis seeks to reinterpret and extend the architectural model from Nick Dunn's classification, which is created for physical models in his book *The Ecology of the Architectural Model*, encompassing evaluative, predictive, exploratory, and descriptive models that are deemed more inclusive and comprehensive than other classifications for architectural models, and the integrative model will be incorporated. Then, these models will be reevaluating with examples of architectural models. According to Dunn's classification, evaluative models describe or explore properties linked to the model but not evident in it, relying on external information. Descriptive models enhance understanding by delineating specific phenomena and elucidating relationships, often seen in presentation

[11] Branko Kolarevic, "Digital Production," in *Architecture in the Digital Age: Design and Manufacturing* (Taylor & Francis, 2003): 47-48.

models.[12] Explorative models vary parameters, refine judgments, and convey information to explore alternative realities, commonly used in early design stages. Predictive models emphasize quantitative data to forecast the future in established situations.[13] The integrative model, a new category, involves CAD/CAM technologies, computational design, and digital fabrication tools, promoting a cohesive approach to architectural model creation.

The main objective of this thesis is to reassess the architectural model, examine its role in the design process, and explore its potential in the context of CAD/CAM technologies and emerging computational design tools and methods. Despite the long-standing use of physical models in architecture, the emergence of digital models and their integration with computational design methods through computer technologies has led to a profound transformation in architectural models' production processes and methodologies. The intertwining of physical and digital models has created an iterative loop that promotes experimentation within the design process, and this integration allows for the evaluation of architectural models without strictly adhering to the physical-digital distinction. Subsequently, architectural models are examined based on their types, and existing classifications are analyzed in detail.

Another aim of this study is to reinterpret and expand the classification proposed for physical models by Nick Dunn, an academician and architect, considering that existing classifications may be insufficient in certain cases. This reinterpretation takes into account the evolving nature of architectural models and significant changes in this field. Within this framework, the ACC Presidential Symphony Concert Hall project in Ankara has been chosen as a case study to investigate the models utilized throughout the entire project process. To comprehend the design process and assess the impact of model usage, a site visit was conducted.

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[12] Nick Dunn, *The Ecology of the Architectural Model* (Peter Lang, 2007): 13-16.

[13] Dunn, *The Ecology of the Architectural Model*, 57-58.

Additionally, interviews were conducted with the project architects, and a visit to the architectural office was arranged, during which architectural models were documented through photography.

To enhance the reader's understanding of this study, it can be viewed in two parts. The initial section (chapters 1-3) offers contextual information derived from the literature review and associated analysis, leading to the development of a proposal. The subsequent section (chapters 4-5) involves a case study selection and analysis aligned with the criteria and information from the earlier chapters. This chapter provides a concise overview of the study, laying the foundation for the subsequent chapters.

The second chapter emphasizes the current definition of the model concept and its diversification due to its interdisciplinary nature. Subsequently, it moves the architectural model; the definitions of the architectural model by different researchers are delved into, exploring the most common types, namely conceptual, working, structural, and presentation models. A discussion ensues regarding their role in design processes, intended use, and current potential. In addition to these model types, introducing the generic model as a sub-heading for this study, the factors contributing to its development were evaluated. These developments and changes have led to variations in the architectural model's use, production process, and production method. With the integration of digital fabrication tools and methods into architectural practice, the physical model can transition to digital, and the digital model can shift to physical. This dynamic interchange creates an iterative process, gradually blurring the boundaries between physical and digital models.

In the third chapter, the examination focuses on examples of classifications that arise from the diversity in using the architectural model. These classifications take into account the differences between physical and digital models, exploring instances where they are evaluated separately. Introducing the generic model into architectural practice, a product of CAD/CAM technologies, computational design methods, and material integration eliminates this conventional distinction. In this context, the section re-interprets the architectural model, utilizing Dunn's classification of the physical model as an evaluative, predictive, exploratory, and descriptive model, proposing the "integrative model." The re-evaluation incorporates illustrative examples to enhance clarity.

In the fourth chapter, the ACC Presidential Symphony Concert Hall project was chosen as a case study due to its effective use of architectural models over its 29-year project process. Initially, the project's overall structure is broadly assessed, followed by a detailed examination of the architectural model. The use of models throughout the project design process is categorized into three main phases: competition phase models, design-development phase models, and construction phase models. These assessments consider changes in the architectural model, analyzing both those prepared by the architectural team and those by the technical teams associated with the project. In the fifth and final chapter, an overall evaluation of the thesis is provided, emphasizing key findings and discussing conclusions from a general perspective.

CHAPTER 2

ARCHITECTURAL MODELS AS A FORM OF EXPRESSION

This chapter examines the architectural model as a means of expression within a broad context. Comprehending the role of the "architectural model" in architectural practice begins by delving into the detailed concept of a "model," acknowledging its diverse usage and different definitions. Subsequently, the discussion extends to exploring definitions and classifications regarding the architectural model provided by different researchers. This analysis includes considerations of the model's purposes, significance in design processes, and potential impact.

The subsequent sections highlight the historical and contemporary utilization of architectural models, tracking their evolution and the influence of digital technologies on this evolution. Architectural models, created for diverse purposes in the design process, are assessed through conceptual, working, structural, representation model, and generic models—commonly referenced in architectural literature. Furthermore, integrating digital fabrication tools into architectural design is underscored, emphasizing the gradual dissolution of boundaries between digital and physical models, showcasing their transformability. Finally, the chapter concludes by addressing the transformations induced on the architectural model by computer-aided design tools and methods.

2.1 The Concept of Model and Model Culture

The term "model" has its origins in the Italian "modello," the Latin "modellus," and the French "modèle," a shortened version of "modellus." The Latin root "modellus" denotes "measure(m)." [14] As the etymology implies, the term "model" is closely tied to the concept of measurement. While the architectural model aligns with this definition, a more comprehensive understanding can be gained by examining it under the subtitle model. In its simplest form, a model can be described as a measured representation. However, given the diverse applications of the term, multiple researchers have formulated distinct definitions of the model within different contexts.

In his work *"Models: A Discussion,"* Echenique, an academician and architect, defines a model as a representation of reality expressing the relevant properties of the observed reality. In this context, reality encompasses existing or potential objects.[15] According to this perspective, a model can be seen as a tool for understanding reality or as a framework that brings together observed realities. In *"Architectural Model as Machine,"* Smith, an academic specializing in architectural history, theory, and criticism, broadens the definition of a model. He characterizes a model as the methods that produce an object and a situation. According to Smith, a model representing a series of situations does not necessarily have to be a reduced version of an entity.[16] It may sometimes propose an alternative approach for representing and testing a non-existent state or offer a distinct perspective in reflecting an organization. This definition, independently interpreted in the context of architecture, underscores the model's capacity to represent an organization. While this thesis does not provide a specific definition, it is noteworthy that a variety of researchers have contributed to the discourse on the versatile nature of architectural models, enriching the ongoing discussion with their diverse interpretations and definitions.

[14] Smith, *Architectural Model as Machine*, 61-62.

[15] Marcial Echenique, *Models: A Discussion*, 1968, 25.

[16] Smith, *Architectural Model as Machine*, 62.

One significant reason for the extensive range of model definitions lies in its interdisciplinary nature. Each discipline adopts a model approach tailored to its unique needs and objectives, resulting in a broad spectrum of uses. Exploring the different types of models and understanding their interdisciplinary applications is crucial for comprehending the use of architectural models and establishing connections between different model types. Smith categorizes the model concept into four main groups: Mathematical models provide numerical representations for analyzing natural systems and suitable forms for building systems.[17] Physical models serve to illustrate known relationships and represent familiar concepts, while qualitative models aid in understanding the fundamental properties of a given object.[18] Engineers utilize design models to simulate systems that are challenging to comprehend at the prototype level or to reflect their physical behavior.[19] Additionally, a subjective model is mentioned, particularly rooted in the opinions of individuals working in the fields of human nature and society. These conceptual models, developed by philosophers and sociologists, are subjective and rely on mental production.[20]

The architectural model, encompassing different model types mentioned earlier to some degree, stands out for its uniqueness and versatility. Undertaking diverse roles across different phases of the design process, it presents an opportunity to assess design from different perspectives. This adaptability allows for the consideration of the architectural model as both an object and a comprehensive design tool, incorporating spatial, cultural, and social factors. In the context of this thesis, the architectural model is regarded as a design tool within the design process rather than

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[17] John L. Casti, "Alternate Realities: Mathematical Models of Nature and Man," *Choice Reviews Online* 27, no. 02 (October 1, 1989): 266-67.

[18] Smith, *Architectural Model as Machine*, xx.

[19] Dieterich J. Schuring, *Scale Models in Engineering*, 1977.

[20] Peter Adam Angeles, *Dictionary of Philosophy*, 1981.

a representation of the end result. Subsequent sections aim to provide a broader understanding of models and their varied intended uses. To this end, the distinctions in the intended use of the architectural model and how these distinctions are manifested through niche examples in the historical process will be elucidated. Furthermore, in order to grasp the architectural model's place and potential in the design process, different definitions and viewpoints from different architectural researchers about the architectural model will be presented and analyzed.

2.2 Architectural Model

Architectural models serve as potentially rich and vital resources by representing design data in three dimensions (3D). They have been integral to architectural practice since ancient times, created for diverse purposes. Models have played multifaceted roles, whether crafted for symbolic significance, as a representation tool, as the culmination of the design phase, or as an instrument shaping the design process. The historical transformation, influenced by cultural, scientific, and technological changes, has been instrumental in shaping this diversification in the utilization of architectural models.[21]

The earliest surviving models, originally not intended for architectural purposes, served diverse functions. They acted as offerings for tombs and found practical applications in areas like land management and military education. Pre-twentieth-century models have symbolic purposes rather than being part of the design.[22] For example, the earliest model discovered in Bulgaria dates back to 4600 BC and takes the form of a terracotta grave gift.[23] While this model is considered the oldest

[21] Kolarevic, "Digital Morphogenesis," 17.

[22] Smith, *Architectural Model as Machine*, 32.

[23] Jon Astbury, "Architects Do It with Models: The History of Architecture in 16 Models - Architectural Review," *Architectural Review*, February 2014.

discovered, uncertainties persist regarding the use of models in earlier periods. The challenge lies in preserving a model compared to a sketch or drawing. The difficulty in maintaining architectural models has necessitated a continuous historical process for the limited surviving examples.[24] A comparable symbolic use is evident in a 10th-century church mosaic, where Emperor Constantine is depicted presenting the model of Constantinople and Emperor Justinian presenting the Hagia Sophia to Mary.[25]

Figure 2.1- Mosaic in Hagia Sophia depicting Emperor Constantine presenting the model of Constantinople and Emperor Justinian presenting the Hagia Sophia to Mary.

In addition to their symbolic uses, evident in many historical examples, models have primarily served representational purposes throughout history. Models crafted after the Renaissance have played a significant role in guiding design and construction for centuries. In Greek and Roman architecture, precise scale models were created for certain aspects of complex structures, such as triglyphs or column capitals.[26] Another

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[24] Mark Burry et al., *Modelling Ideas*, 2007.

[25] Altan and Derviş, "Mimarlık Tarihi Bağlamında Maket," 78.

[26] Mark Burry et al., "Shifting Dimensions: The Architectural Model in History: Nova," in *Modelling Ideas* (The University of Newcastle's Digital Repository, 2007): 142-43.

notable example is the scale model constructed by Filippo Brunelleschi in the 15th century, currently exhibited at the Opera del Duomo Museum in Florence.[27] While the use of models saw an increase during the Renaissance and Baroque periods, the prominence of the Beaux-Arts education system in the 19th century shifted the emphasis to drawing, resulting in a decline in the use of models.[28]

Figure 2.2- Wooden model of the Florence Cathedral, Filippo Brunelleschi 15th century.

[27] Astbury, "Architects Do It with Models: The History of Architecture in 16 Models." Architectural models continue to serve both symbolic and representational purposes today, with the latter remaining one of the most prevalent uses. While these applications are often discussed separately, there are instances where models embody both functions simultaneously. Occasionally, a model establishes its distinct identity, distancing itself from the design process and acquiring symbolic significance. A notable example is Philip Johnson's model of the AT&T building featured on the cover of Time magazine, as discussed by Altan and Derviş in 'Mimarlık Tarihi Bağlamında Maket' within the book 'Düşünme ve Görselleştirme Aracı Olarak Türkiye'de Mimari Maket.'

[28] Altan and Derviş, "Mimarlık Tarihi Bağlamında Maket," 71.

Indeed, a parallel practice can be identified within Ottoman architecture. The absence of perspective drawing in Ottoman architectural representations suggests that architectural models served as the principal means of tangibly visualizing three-dimensional designs.[29] As an illustration, European travelers frequently documented the presence of small wooden or ivory models suspended within mosque domes, often enclosed in glass cases.[30] Similarly, there is a miniature in the Surname depicting several people carrying a large-scale model of the Süleymaniye Mosque in a procession in 1582.[31] The miniature in Figure 2.3 stands out as evidence that Ottoman architects used architectural models for representational purposes.

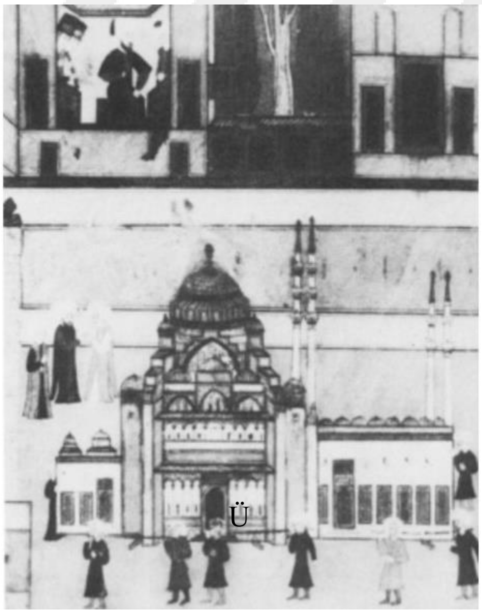

Figure 2.3- Süleymaniye mosque model during festival, Topkapı Palace Museum Library.

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[29] Gülru Necipoğlu-Kafadar, "Plans and Models in 15th- and 16th-Century Ottoman Architectural Practice," *Journal of the Society of Architectural Historians 45*, no. 3 (September 1, 1986): 236.

[30] Necipoğlu-Kafadar, "Plans and Models in 15th- and 16th-Century Ottoman Architectural Practice," 237.

[31] Necipoğlu-Kafadar, "Plans and Models in 15th- and 16th-Century Ottoman Architectural Practice," 239.

While the use of models increased during the Renaissance, Baroque, and the subsequent periods, the prominence of the Beaux-Arts education system in the 19th century shifted the emphasis to drawing, resulting in a decline in the use of models. In the early decades of the twentieth century, the Bauhaus school's innovative approach to design education and practice solidified the model's role in architectural design.[32] Walter Gropius, the founding architect of the school, opposed the prevalent reliance on drawing and instead promoted the use of models for exploring and experimenting with design thinking.[33] This has led to the widespread adoption of models in modern architecture and architectural education. As Oliver Elser highlights, the surge in the use of architectural models has coincided with the rise of modern architecture.[34] Today, numerous renowned projects integrate the architectural model as a crucial design element in the design process. One of the most notable examples is the Sydney Opera House, chosen in a competition in 1957. The realization of Jørn Utzon's innovative structural design for the Sydney Opera House, unprecedented for its time, became feasible through the creation of models in different scales during the design process.[35]

[32] Altan and Derviş, "Mimarlık Tarihi Bağlamında Maket," 72.

[33] Dunn, *The Ecology of the Architectural Model*, 30.

[34] Wallis Miller, "A Review of das Architekturmodell: Werkzeug, Fetische, Kleine Utopie / The Architectural Model: Tool, Fetish, Small Utopia," *Architectural Histories* 1, no. 1 (January 30, 2013): 2.

[35] "Utzon’s Camera - Google Arts & Culture," Google Arts & Culture.

Figure 2.4- Conceptual model for the Sydney Opera House, by Jørn Utzon, 1961.

While model-making has been widely embraced in architectural design, the advent of digital technologies in architectural practice during the 1980s brought about substantial changes to the architectural model. Initially embraced as the final stage of architectural design, digital technologies evolved to redefine the role of the digital model. Subsequently, they became integral to form generation and related experimental studies in subsequent periods.[36] Nevertheless, the continually evolving architectural model is commonly regarded as a crucial element in the architectural design process, actively contributing to design development. Presentation models, in particular, exemplify this integration. Frequently accompanied by sketch models and subsequent working models, these collectively serve as fundamental design tools in architectural practice.

The infusion of digital design tools and methods into architectural practice has not only expanded the potential of architectural models but has also endowed them with the versatility for diverse applications. These encompass 3D printing, performance analysis, simulated environments, parametric design, and augmented reality. This transformation has consequently influenced the definitions of architectural models. Given the broad spectrum of their applications, numerous architecture researchers

[36] Glymph, "Evolution of the Digital Design Process," 152.

have defined models, emphasizing their diverse possibilities, purposes, and methodologies. For instance, Criss Mill regards the architectural model as an exploratory tool that guides the design process.[37] As per Mill's perspective, the model assumes a pivotal role in idea development and design shaping, becoming an integral part of the process. Dunn, on the other hand, defines the architectural model as an abstract reflection of reality, underlining its limitation in fully capturing the complexity of reality.[38] The author emphasizes the abstract nature of the model and contends that it cannot fully represent reality. From a distinct perspective, Maltzan defines models as tools facilitating space formation by establishing relationships between programs in the design process. His focus lies on technical aspects such as materials, details, and structure.[39]

On the contrary, he underscores the contribution of models to the design process through tangible elements, centering on technical details. Like these varied definitions, numerous architectural researchers have provided insights into the architectural model, employing classifications to comprehend the extensive range of uses and methods associated with models. The diversity in the roles of models within the design process reflects the rich and multifaceted position of the model in the discipline of architecture.

2.2.1 Types of Architectural Models

The variety of architectural models serves as a significant indicator, mirroring the intricacy and comprehensiveness of the design process. This diversity poses a challenge in capturing all potential design aspects within a single model, particularly

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[37] Mills, *Designing with Models: A Studio Guide to Making and Using Architectural Design Models*, 10.

[38] Dunn, *Architectural Modelmaking*, 30.

[39] Michiel Riedijk and Michael Maltzan, "The Model," in *Architecture as a Craft: Architecture, Drawing, Model and Position*, 2010, 199.

during the early stages when the final outcome remains uncertain.[40] Hence, a range of model types plays a crucial role in advancing and comprehending the design by representing specific facets across dimensions, scales, and levels of abstraction. The diverse array of models aids creative thinking, offering designers numerous perspectives. These models address functional and aesthetic requirements at different stages of the design process.

The models explored in this chapter are among the most commonly used and encountered in architectural practice. These include conceptual models employed in the early stages, followed by working models, structural models utilized for design development, and presentation models employed in the final design phase. [41] Lastly, alongside these model types, the chapter will also assess generic models. Developed with the widespread adoption of digital design tools and influenced by computational design techniques, generic models can be integrated at different stages of the design process. The evaluation will consider the specific design stages in which these models are produced.

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[40] Dunn, *Architectural Modelmaking*, 8-9.

[41] Wolfgang Knoll and Martin Hechinger analyze architectural models in three categories—conceptual, design development (working), and presentation—in their book 'Construction Techniques.' In 'Architectural Supermodels: Physical Design Simulation' by Porter and Neale, the authors build upon Knoll and Hechinger's framework, further categorizing architectural physical models into conceptual, design development, structural, and presentation. They also introduce additional categories such as volume, space, interior, lighting, wind tunnel, exhibition, and life-size models. Despite the inclusion of new model types in other classifications, the study consistently considers conceptual, working, structural, and presentation models in the broadest sense. Unlike other classifications that evaluate these models through physical representation, this study examines them within a more conceptual framework, without distinguishing between physical and digital. Additionally, a general model category, present at every stage of the design process with digital design tools and methods, is included. Wolfgang Knoll and Martin Hechinger, *Architectural Models Construction Techniques*, 1992. - Tom Porter and John M. Neale, *Architectural Supermodels: Physical Design Simulation*, 2000.

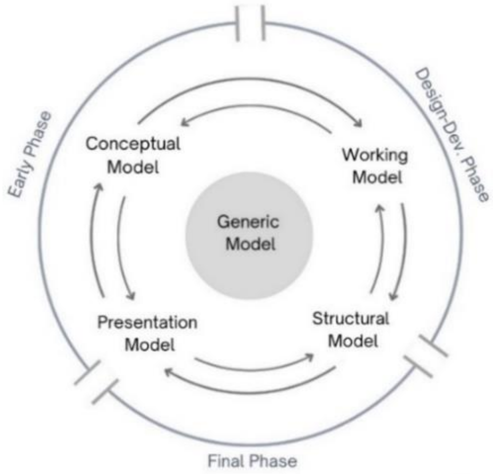

Figure 2.5- Categorization of the models is based on their relevance to different stages of the design process.

2.2.1.1 Conceptual Model

Conceptual models represent the initial three-dimensional manifestations of design ideas among different model types. This model, detached from specific materials, often conveys an abstract language. It serves as a bridge between the designer's theoretical concepts and the practical aspects of the design, encompassing architectural structure and functional requirements. Widely employed in architectural education and theoretical research, conceptual models play a vital role in concretely expressing ideas and hold significant relevance in the early stages of the design process.

> … The use of conceptual models as a medium of thought not only facilitates the design process of the model maker but also enables his initial creative impulses or intentions to be communicated to others.[42]

Employing conceptual models as thinking tools streamlines the designer's design process and effectively communicates their initial creative impulses or intentions to

[42] Dunn, *Architectural Modelmaking*, 111.

others.[43] During the early stages of design, engaging with models can be likened to creating an embryonic outline of the work. It provides the opportunity to test ideas throughout the design process, offering an engaging and assertive representation, particularly as these models address specific design problems.[44]

At the initial stage of the design process, conceptual models often operate at a metaphorical level. These models exhibit flexibility and versatility, serving the same purpose in both physical and digital formats, albeit in different ways. In physical conceptual models, materials play a role. Ideas are translated to the third dimension using easily shaped materials, allowing the physical model to extend beyond the visual, incorporating texture, weight, balance, and material resistance as essential elements in the ideation process.[45] Conversely, leveraging the benefits of computer technologies and software has led to the development of a process wherein digital architectural models serve as a design tool. Digital conceptual models, crafted in the early stages of design, enable swift iteration, easy reproduction, and exploration of diverse design variations. This approach facilitates the formation of initial design concepts and ensures the continuity of the design trajectory in a seamless manner.

2.2.1.2 Working Model

Working models in design are typically crafted to progress the design during the early phase, featuring ease of design and quick manipulability. They serve as a natural extension of conceptual models.[46] Dunn characterizes working models, or design development models, as the cumulative output of time, effort, and thought

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[43] Morris, *Models: Architecture and the Miniature*, 37.

[44] Porter and Neale, *Architectural Supermodels: Physical Design Simulation*, 20-21.

[45] Dunn, *Architectural Modelmaking*, 112.

[46] Porter and Neale, *Architectural Supermodels: Physical Design Simulation*, 24.

dedicated to researching design ideas throughout the design process.[47] The purpose of working models is to capture the progress achieved in the design process rather than aiming for the final product. Often termed design development models in the literature, they typically depict the transformation of a design. Through the inherent nature of trial and error, working models advance the process by rigorously testing the design.

> Perhaps most significantly, design development models communicate a "journey" rather than a "destination," as they explicitly illustrate the thought, effort, and time committed to investigating design ideas. They often represent the evolution of a design and showcase the sometimes trial-and-error nature of the creative process.[48]

Working models are not obligated to strive for precision; they can be shaped exclusively for their own purposes and may diverge from the intended goal of the final design.[49] They do not necessarily encompass the entire design nor require accuracy or consistency. Working models can address the design at different scales. "A model built to explore an aspect of a project at one scale may be seized upon as the solution to the whole in another."[50]

Whether digital or physical, working models are crafted during the design development stages of a design process. They are integral to this iterative process of representation and interpretation.[51] This iterative state allows the design to evolve and progress in the process. The process usually starts with shaping the overall

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[47] Dunn, *Architectural Modelmaking*, 122.

[48] Dunn, *Architectural Modelmaking*, 122.

[49] Morris, *Models: Architecture and the Miniature*, 37.

[50] Morris, *Models: Architecture and the Miniature*, 43.

[51] Corneel Cannaerts, "Models of / Models for Architecture: Physical and Digital Modelling in Early Design Stages," *Proceedings of the 27th International Conference on Education and Research in Computer Aided Architectural Design in Europe eCAADe*, (January 1, 2009): 782.

design. It continues with the development of circulation flow and geometric relationships over time.[52] Subsequently, a variety of design elements are scrutinized and refined through these models, ensuring the gradual development of the design process.

2.2.1.3 Structural Model

> This type of model varies from basic models that may simply indicate different loadbearing elements such as walls and frames, to considerably more detailed examples that investigate the structural systems of a design with a higher degree of architectural analysis.[53]

Structural models play a crucial role in the design process by elucidating the structural system and tectonics of the design. They establish a reciprocal relationship between static principles, material properties, and spatial qualities, subsequently shaping the details of the design. These models, more mature than working models in the design development phase, can be viewed as architectural analyses incorporating the structural elements of the design. They facilitate the testing of structural concepts and design decisions by introducing a performance dimension through load and force tests.[54]

Numerous architects and structural engineers utilize physical, structural models throughout the design process to ascertain the tectonics and structural systems and even delve into the structural loads on these systems. Visionaries like Otto, Gaudí, and Santiago Calatrava have effectively employed physical, structural models as tools to resolve intricate structural challenges. These models serve not only in

[52] Dunn, *Architectural Modelmaking*, 123-124.

[53] Dunn, *Architectural Modelmaking*, 134.

[54] Porter and Neale, *Architectural Supermodels: Physical Design Simulation*, 28.

determining the design of the structural elements but also in testing the performance of the design.[55]

In the realm of digital models for structural design, advancements in digital design approaches and techniques have profoundly enhanced the creation of digital models throughout the design process. Models aimed at finding solutions or addressing design problems have reshaped the design process, introducing complex interactions between users, tools, and design environments. This transformation incorporates design concepts such as performance design, structural durability, geometry, and material expression.[56] Notably, performance-based design plays a vital role in shaping the overall design.

In summary, structural models are indispensable tools that promote performance-based design throughout the design process, delineating the design's structural system, tectonics, and spatial quality. Physical and digital models, serving the same purpose through distinct approaches, contribute to optimizing the design's functionality, energy efficiency, sustainability, and other performance criteria. They achieve this through both physical test models and computer-aided performance analysis. Furthermore, these models empower designers to make more informed, data-driven decisions, enhancing the overall effectiveness of the design process.

2.2.1.4 Presentation Model

In the realm of architectural models, the presentation model is often among the foremost types that come to mind. While architectural models may vary based on their intended use (exhibition, competition, building sales models), presentation

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[55] Hatem Ahmed Hadia. "Model Making as a Value-Added Tool in Public, Educational and Professional Domains." PhD diss., (Middle East Technical University, 2015): 131.

[56] Rivka Oxman, "Theory and Design in the First Digital Age," *Design Studies* 27, no. 3 (May 1, 2006): 229–65.

models are crafted to represent the final stage in the design process. However, these models are typically not open to interpretation in terms of design. They are primarily created for informational purposes.[57] Presentation models serve as highly effective forms of architectural representation, particularly in conveying a completed design project. Unlike other forms of architectural documents, which can be challenging for individuals without architectural education to interpret, presentation models are comprehensible to a broader audience.[58]

Presentation models effectively communicate the intended information to the audience, although they may not always precisely reflect the actual details of the design.[59] While some presentation models directly incorporate material information to mimic the design, others are intentionally abstract, providing an alternative perspective or highlighting specific aspects of the design to draw attention in different directions. Despite these variations, presentation models remain more comprehensible to a broader audience compared to other models. [60]

In physical presentation models, viewers can engage with the design from all sides, understanding the spatial perception comprehensively. While the directness and intuitiveness of the digital model may be enhanced, a variety of techniques, including animation, have been developed to address these aspects.[61] Animation, as a dynamic image technique, is generated by sequencing images from digital models.[62] This

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[57] Smith, *Architectural Model as Machine*, xxx.

[58] Cannaerts, "Models of / Models for Architecture: Physical and Digital Modelling in Early Design Stages," 782.

[59] Morris, *Models: Architecture and the Miniature*, 65.

[60] Cannaerts, "Models of / Models for Architecture: Physical and Digital Modelling in Early Design Stages," 782.

[61] Cannaerts, "Models of / Models for Architecture: Physical and Digital Modelling in Early Design Stages," 783.

[62] Fulya Özsel and Necati İnceoğlu, "Bilgisayar Destekli Tasarım ve Üretim Teknolojilerinin Mimarlıktaki Kullanımları," *YTÜ Mimarlık Fakültesi E-Dergisi* 2, no. 4 (2007): 245.

approach enhances the dynamic perception of the design and introduces it from different angles.

2.2.1.5 Generic Model

The integration of digital design and computational design methods into architectural design literature has transformed the tools and methods used in different stages of architectural production, such as design, fabrication, and representation. Key elements driving these changes include CAD/CAM technologies and three-dimensional modeling and visualization, all underpinned by the digital transformation in architectural design processes. This transformation has significantly reshaped architectural practice, fostering faster and more efficient design. The shift in methods and tools has also impacted the production language of architectural models, leading to the development of the generic model concept. As a result of the changes in the architectural model, the concept of a generic model, defined by its common language and usability at every phase of the design, has been included in architectural design practice.

The generic model can be defined as a type of model that is appropriate for general and multi-purpose use instead of a specific purpose. It is more continuous and hybrid than other model types in architectural processes. Furthermore, it facilitates the incorporation of new data inputs and modifications, offering flexibility across all stages of the design process. This approach allows for the creation of models that fit specific needs and purposes, like structural, conceptual, working, or presentation models, based on generic models. In today's context, this model tends to use a common language and continuous development, emphasizing the continuity and complexity of design. This shift reflects changing dynamics in the role of architectural models and the evolving principles of design thinking. By enabling a continuous flow of data across interwoven phases of design, analysis, representation, and fabrication, it defines intricate relationships between different stages and mediums of architectural production.

A notable characteristic of the generic model is its adaptability, allowing the designer or architect to interact with it at any moment. This feature not only triggers flexibility in responding to specific needs but also acknowledges that these models can serve diverse purposes. They can initiate the design process, aid in material analysis, or contribute to form exploration, showcasing their versatility in diverse aspects of architectural work. By enabling creativity and transformation into a sketch model, it also allows testing the tectonics of the design by studying a selected interval of the model at any specified time, transforming it into a structural model. Thus, the generic model emerges as a dynamic tool capable of evolving into different types of models throughout architectural design, triggering designers' versatility and customization.

The generic model, as referenced in the context of this thesis, can integrate, design, and function with past model methods, variants, and classifications through the utilization of digital design tools and methods. To comprehend the potentials of the generic model and its implications for architectural practice, it is crucial to stay abreast of pertinent developments and analyze CAD/CAM and Non-Euclidean geometries. Additionally, exploring the architectural methodologies of computational design—parametric design and algorithmic design —is necessary.

2.2.2 Development of CAD/CAM and Non-Euclidean Geometries

The discipline of architecture underwent significant changes at the beginning of the 20th century. These changes mainly came from scientific and cultural developments, and architecture's interaction with other disciplines, especially philosophy, psychology, sociology, and mathematics, played a crucial role. Prior to this era, architects had been shaping the formal structure of non-digital architecture using Euclidean geometry. The fundamental geometric shapes in architecture, such as lines, circles, squares, planes, and the Platonic solids, were extensions of Euclidean geometry and its foundational elements.[63]

By the beginning of the 20th century, the incomprehensibility of Euclid's Postulate V had begun to question Euclid's theorems and axioms in mathematics.[64] This reconsideration, coupled with the contributions of mathematicians such as Karl Fredrich Gauss, Nikolai Ivanovich Lobachevsky, Janos Bolyai, and Bernard Riemann, gave rise to the development of non-Euclidean geometry and studies in n-dimensional geometry.[65] The field of architecture, closely intertwined with mathematics, also felt the impact of this shift, prompting a reexamination of the perception of space and spaces designed within Euclidean forms.

In the past two decades, computational design tools have become integral to architectural practice, significantly impacting the design process. Computer-aided design (CAD) has streamlined design procedures and rapidly empowered architects to create more intricate designs. For instance, numerous computer modeling software packages rely on NURBS (Non-Uniform Rational B-Spline) curves. These mathematical curves, extensively utilized in CAD and 3D modeling, are favored for their capacity to offer precision and flexibility. They efficiently handle data representation, allowing for fast processing.

Each NURBS curve is defined by a collection of control points and a corresponding set of weights.[66] The configuration of these control points shapes and directs the curve. In contrast, the weights govern the influence of these points.[67] This feature

[63] Kolarevic, "Digital Morphogenesis," 19.

[64] Marvin J. Greenberg, *Euclidean and Non-Euclidean Geometries: Development and History*, 1974, 20.

[65] Linda Dalrymple Henderson, *The Fourth Dimension and Non-Euclidean Geometry in Modern Art*, 1983.

[66] Les Piegl and Wayne Tiller, *The NURBS Book* (Springer Science & Business Media, 1996).

[67] Kolarevic, "Digital Morphogenesis," 21.

makes NURBS curves particularly well-suited for crafting precise and intricate surfaces.[68] Moreover, computer modeling utilizing NURBS curves allows for the connection of control points at non-uniform intervals. Consequently, NURBS curves provide designers with greater creative freedom and enable complex operations that may be challenging in a physical modeling environment.[69]

The architectural design process underwent a notable transformation in the 1980s with the integration of computational technology into architectural practice. Essential CAD tools became accessible to the field of architecture during this period. Initially recognized for drafting, these tools gained increased acknowledgment and usage, particularly during project presentation phases.[70] While digital technologies were initially employed in the representation process, considered the final stage of architectural design, they later became more integrated into the overall process, contributing to form creation and related experimental studies.[71] Computer-aided design (CAD) software has facilitated the production of intricate and cost-effective architectural models within shorter timeframes. Introducing the new digital environment has sparked excitement among architects, leading to the exploration of more experimental processes in architectural design.[72] Computer-aided modeling (CAM) introduces a novel dimension and methodology to the process, offering a fresh approach and configuration compared to existing methods. Some modeling techniques involve design forms developed through mathematical equations, allowing for adaptability and differentiation as needed.

[68] Kolarevic, "Digital Morphogenesis," 22.

[69] Piegl and Tiller, *The NURBS Book*.

[70] Glymph, "Evolution of the Digital Design Process," 149-76.

[71] Glymph, "Evolution of the Digital Design Process," 149-76.

[72] Pittman, "Building Information Modeling: Current Challenges and Future Directions," 348-354.

Architects actively shape an architectural model scenario that smoothly adapts to changes in the background, enhancing flexibility and dynamism through the utilization of design parameters. This novel approach in the architectural modeling process allows for a radical restructuring of the relationship between design and production, forming a cyclical pattern.[73] The architectural model undergoes digitization, and the digitized model is materialized, or vice versa, establishing a productive and iterative method. This iterative process involves a series of repeated steps, moving forward and backward to regulate the overall procedure. In this case, CAD technologies and the accompanying manufacturing tools evolving concurrently introduce a new method capable of self-control, ensuring cumulative progress. Furthermore, CAD/CAM technologies and their accompanying computational design tools and methods enable the development of a generic model that incorporates each stage of the architectural design process. To understand this model, it is crucial to examine the computational design methods, such as parametric and algorithmic designs.

2.2.2.1 Parametric Design

> Rather than the designer creating the design solution (by direct manipulation) as in conventional design tools, the idea of parametric design is that the designer establishes relationships by which parts connect, builds up a design using these relationships by observing and selecting from the results produced.[74]

Parametric design involves the designer applying mathematical formulas and parametric values to create entities within a predefined framework.[75] When

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[73] Kolarevic, "Digital Production," 46-87.

[74] Robert Woodbury, *Elements of Parametric Design*, 2010, 24.

[75] Kolarevic, "Digital Morphogenesis," 25.

considered in the design process, the ability to change parameters provides the freedom to change the model. This flexibility allows updating the model, redefining the output according to differing parameters, and revisiting different process stages. These shifts bring a non-linear dimension to the design process, enabling the simultaneous shaping of the process alongside the design itself. Integrating data into the model at different design stages ensures that the design updates synchronously with minimal effort.

When assigned diverse parameter values, a parametric model can present a range of form studies rather than a single fixed solution, resulting in subsequent variations. By assigning different parameter values, it becomes possible to generate a variety of configurations The parametric design embraces flexibility, rejecting fixed solutions and promoting the exploration of infinitely variable potentials. [76] The parametric design establishes a range of potential outcomes, discards fixed solutions, and promotes the exploration of endlessly variable possibilities. Also, parametric design allows for the creation of an unlimited number of models and provides a means to manage the unpredictable.

2.2.2.2 Algorithmic Design

In the realm of CAD tools and mediums, designers have the flexibility to employ diverse methods throughout the design process, and one such method is algorithmic design. Different perspectives exist regarding algorithmic design. The first viewpoint considers it an approach developed based on parametric design tools.[77] Conversely, some argue that algorithmic design and generative design represent similar

[76] Mark Burry, "Paramorph: Anti-Accident Methodologies," in *Hypersurface Architecture II*, ed. Stephen Perrella (Chichester: Academy Editions, 1999): 78-83.

[77] Malgorzata A. Zboinska, "Hybrid CAD/E Platform Supporting Exploratory Architectural Design," *Computer-Aided Design* 59 (February 1, 2015): 64–84.

approaches, sharing a common foundation with parametric design.[78] In the context of this thesis, the assessment will align with this framework.

Terzidis defines *algorithmic design* as an approach employing rule-based logic in architectural programs, typologies, structural codes, and the nature of language.[79] In this view, computer programs utilize rule-based logic to generate "space and form" during the design process. The resulting model relies fundamentally on algorithms, and the algorithm and the model operate in tandem. This setup empowers designers to define and intervene in the algorithms shaping specific parts of the model, facilitating direct intervention through scripting.[80] Therefore, the process focuses on the design practice rather than the final product. Consequently, in algorithmic design, the product or potential family of products emerges spontaneously from the established rules and relationship system.[81]

2.2.3 Blurring the Distinction Between Physical and Digital Models through Digital Fabrication Tools

The incorporation of CAD into architectural practices has instigated a profound transformation, significantly diversifying design processes and modeling techniques. Advancements in CAD technology have opened up new possibilities for architectural design as complex structures and forms can be defined and studied. However, managing the increasing complexity of these developments within

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[78] Richard Garber, *BIM Design: Realising the Creative Potential of Building Information Modelling*, 2014.

[79] Kostas Terzidis, Javier Isorna, and Vinod Srinivasan, "Algorithmic Design: A Paradigm Shift in Architecture?" *eCAADe Proceedings* (January 1, 2004): 203.

[80] Natália Queiroz et al., "Designing a Building Envelope Using Parametric and Algorithmic Processes," *Proceedings of the 19th Conference of the Iberoamerican Society of Digital Graphics* (November 1, 2015), 797.

[81] Özsel and İnceoğlu, "Bilgisayar Destekli Tasarım ve Üretim Teknolojilerinin Mimarlıktaki Kullanımları," 243.

existing construction methods has become a challenge. To address this, CAM technologies, as an extension of CAD, have been introduced to architectural practice. CAM tools, utilizing CAD files with design data, can physically produce objects in formable materials.[82] This direct integration of design with manufacturing and assembly processes through CAM tools fosters creativity, complexity, and originality in architectural design, enabling the realization of truly unique projects.

Digital fabrication tools seamlessly integrate CAD/CAM technologies within the design cycle. They leverage data from the digital environment to facilitate the transformation of this data into a physical model.[83] The integration of these technologies has progressed so much that it has enabled the creation of physical objects directly from digital models while equally enabling the process of digitizing physical objects. This interrelationship has made design processes iterative and cyclical.

2.2.3.1 From Physical to Digital Model

The conversion of a physical object or physical model into a digital model and 3D scanning in this process have become increasingly common in design. This transformation process starts with technologies such as 3D scanning and creating a

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[82] Chris Yessions, "Is There More to Come?," in *Architecture in the Digital Age: Design and Manufacturing*, ed. Branko Kolarevic, (Taylor & Francis, 2004): 355–56.

[83] Fabrication is the making and production of something through a series of processes or steps. William j. Mitchell, while defining fabrication tools, used the expression machines that automatically transform a digital object in the design world into a material reality. Digital fabrication encompasses all the tools and methods used for physically producing digital designs. Existing production predominantly depends on manual labor and the use of specialized tools, often necessitating a skilled workforce with technical expertise and manufacturing experience. In contrast, digital fabrication tools are more accessible, eliminating the need for extensive specialization or prior experience. For more, see; Fiona Ragheb, Jean-Louis Cohen, and Mitchell John William, "Roll over Euclid: How Frank Gehry Designs and Builds," essay, in Frank Gehry, Architect (New York: Solomon R. Guggenheim Foundation, 2001).

digital replica of the physical model. The resulting digital model can offer designers an environment that can be updated, flexible, analyzed, and reproduced.

Unlike other known digital production tools, 3D scanners, which enable the transition from physical to digital, capture information from any physical model without questioning the interface through which it was produced and convert it into digital data. This process, often termed "reverse engineering," involves employing sophisticated scanning techniques to create a "point cloud" technique representing the surface data of the scanned object. Subsequently, transformation software analyzes this point cloud data, generating a digital replica that closely approximates the model's geometry. The stages of acquiring and interpreting the point cloud are known as "digitization" and "mathematical processing," respectively.[84] The resulting digital copy, representing the physical object, can then be modified to the desired extent using various design programs. The profound contribution of 3D scanners to architecture lies in fostering a seamless design process by bridging the physical representation of the design with its digital counterpart. [85]

Digital scanning establishes an inversely proportional relationship between physical and digital models, particularly in the context of CAM technologies. Early adopters of digital scanning in architectural practices, such as Gehry Partners, paved the way for innovative design processes. Frank Gehry, using CATIA (Computer-Aided Three-Dimensional Interactive Application developed by his office), treated it as a "translation" tool bridging physical and digital media. Gehry seamlessly integrated point scanning, facilitated by 3D scanners for digitizing physical models, with

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[84] ***Digitalization*** is recording the coordinates of a series of points on the surface via position sensors. This is done by two techniques: contact and noncontact. The contact technique involves using a digitizing position probe that traces the surface of the physical model and transmits the coordinates of the surface points to the computer. It can be derived manually by digitizing arms or automatically by Coordinate Measuring Machine (CMM) that is mechanically kept in contact with the surface to be scanned. The noncontact technique is performed by using laser light that illuminates the surface of the scanned object, producing a pattern of bright dots, lines, or grids captured by optical sensors, which are later processed to construct the 3D photographic relief.

[85] Gehry, Ragheb, and Cohen, "Roll over Euclid: How Frank Gehry Designs and Builds," 352–63.

cutting-edge technologies like stereolithography and laminate object modeling, producing 3D print outputs.[86] This approach empowered Gehry to fluidly navigate between the physical and digital realms fluidly, fostering a more adaptable and flexible design process.

2.2.3.2 From Digital to Physical Model

Digital design tools and methods can transform production at any stage of the design process into physical output with the data received from the digital model. These digital design tools, which can be evaluated based on diverse criteria in terms of production processes, can be classified according to factors such as material properties, production technique, and production environment. This thesis is based on the classification approach developed by Moritz Hauschild and Rüdiger Karzel.

Hauschild and Karzel have classified digital fabrication tools into four main groups, each representing distinct working methods during the transition from digital to physical.[87] These categories encompass two-dimensional, formative, subtractive, and additive fabrication. ***Additive fabrication***, for instance, involves the automated materialization of CAD-generated data through CNC technologies for three-dimensional production. In these processes, relevant software analyzes and segments the digital model into two-dimensional layers.[88] Consequently, the model can be rapidly produced as a tangible object using a 3D printer.

"Rapid prototyping" is frequently employed to characterize the production process facilitated by 3D printers. All rapid prototyping methods are initiated by digitally

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[86] Frank O. Gehry et al., *Archaeology of the Digital: Peter Eisenman, Frank Gehry, Chuck Hoberman, Shoei Yoh*, ed. Lynn (Sternberg Press, 2013): 15.

[87] Moritz Hauschild and Rüdiger Karzel, *Digital Processes: Planning, Designing, Production*, 2011, 45.

[88] Kolarevic, "Digital Production," 56.

creating horizontal design sections in layers. The fabrication tool's head sequentially prints or processes a 3D physical product in layers throughout this procedure. This is achieved by utilizing the shape of the raw material, laser light, heat, or chemical processes to generate each digital layer..[89]

A crucial distinction exists between "rapid prototyping" and " manufacturing." Rapid prototyping is geared towards generating scale architectural models, whereas manufacturing is focused on directly producing 1:1 scale final products. Like many digital fabrication tools, 3D printers necessitate prepared digital data before initiating production.[90] Once the numerical design data is transferred to 3D printers, the printing process commences seamlessly without user intervention.

In the realm of additive fabrication, the robotic arm stands out as a versatile and functional tool alongside 3D printers. The end part of the robotic arm, known as the "end effector," can be programmed to incorporate tools with various functions, enhancing its efficiency in performing complex operations. These end effectors are capable of handling, positioning, milling, welding, and scanning tasks. With its multi-articulated structure, the robot arm offers a substantial advantage in producing complex geometries, leveraging its ability to position itself precisely about the material being processed. [91] Typically, a 6-axis robot arm is mounted on a horizontal motion assembly, substantially expanding the working area. Operating with high precision, the robotic arm is well-suited for both repetitive tasks and dynamic, changing operations.

The concept behind subtractive fabrication involves electrochemical or mechanical reduction methods to carve out a specific solid portion. The CNC milling machine

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[89] Nick Dunn, *Digital Fabrication in Architecture* (London: Laurence King Publishing, 2012): 102.

[90] G. Ryder et al., "Rapid Design and Manufacture Tools in Architecture," *Automation in Construction* 11, no. 3 (April 1, 2002), 280.

[91] Dunn, *Digital Fabrication in Architecture*, 111.

achieves the desired shape by rapidly rotating a hard and sharp tool to remove material from a block. There are two types of CNC milling machines: milling and routing. Milling is more suitable for metal materials, while routing is more appropriate for wood and plastic materials. Like 3D printers, CNC milling machines enable the production of mock-ups and prototypes using materials such as wood and foam. These machines come in different sizes, ranging from small desktop versions to larger models capable of producing full-scale metal parts.[92]

For Nick Dunn, the CNC milling machine serves two essential purposes.[93] The first is to carve volumetric material to produce the desired component. Architects prefer this method to produce complex geometries and fluid forms precisely and efficiently. The second approach involves producing the mold to be cast later rather than directly manufacturing the component.

Formative fabrication is a process that employs methods such as mechanical forces, confining forms, heat, or steam to transform a material into a desired shape. The goal of this process is to permanently change the material's structure by pushing its limits, making it softer, or subjecting plates to heat under steam and bending them. This technique is typically not employed in architecture.

Two-dimensional fabrication is a widely employed method of digital fabrication. The cutting principle for various cutting technologies, including laser beams, waterjets, and plasma arcs, is determined by the relative movement of the cutting head with the sheet material in two axes. CNC cutting tools, such as laser beams and water jetting, involve a two-axis cutting process on sheet material. Some tools have both the cutting head and the product bed movable.[94]

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[92] Dunn, *Digital Fabrication in Architecture*, 99.

[93] Dunn, *Digital Fabrication in Architecture*, 96.

[94] Kolarevic, "Digital Production," 52.

CNC laser cutting is widely utilized by architects today, particularly in the production of mesh and panel elements for building facades. Large-scale CNC laser cutting tools often play a crucial role in this application. On the other hand, CNC jet cutting is predominantly employed in heavy industry, offering the ability to cut rigid materials. Another tool in the digital fabrication toolkit is the CNC hot wire cutting tool, which features a heated wire moved with computer control. This tool effectively cuts materials like Styrofoam, making it suitable for producing large-scale forms. [95]

In summary, the digital fabrication tools mentioned above have significantly impacted the architectural model, blurring the lines between the digital and physical realms. The integration of digital production tools and methods has broken the standardization of existing architectural models, leading to formal innovation and differentiation. This shift has not only influenced the design and planning of production methods but also prompted a reevaluation of design approaches. The methods employed by digital fabrication tools empower the creation of forms, details, and variations that were once deemed impossible.[96] The unique processes stemming from these innovative fabrication techniques in the digital realm profoundly influence the production of architectural models.

2.3 Re-evaluation of the Architectural Model in Digital Design Environment

Definitions of the architectural model from different perspectives and for different purposes are discussed in this thesis for a clearer understanding. There are diverse interpretations of architectural models in the literature, and several researchers have offered their insights, presenting classifications of model to enhance comprehension. An additional crucial factor prompting these classifications is the need for clarity, they are also a reduction and simplification. When architectural models are examined

[95] Kolarevic, "Digital Production," 52.

[96] John K. Thornton, "Fabrication Research," *Architectural Design 75*, no. 4 (July 1, 2005): 103.

in this context, it is possible to trace a clear distinction between physical and digital models. However, there is still some confusion regarding architectural models, and it is unclear whether physical or digital models are meant by architectural models. Although this situation has different reasons, the relatively effective one gradually blurs the distinction between physical and digital with the developing digital technology. In other words, developing computer technologies has been instrumental in connecting digital intangibility and physical tactility and bringing the two models closer together. Today, there is a tightly integrated dialogue between physical and digital. The digital-physical design dialog is more complex and bidirectional.[97]

The incorporation of CAD/CAM technologies into architectural practice, enhanced capabilities of modeling programs, and the integration of computational design tools and approaches have increased the use of the digital model. Digital models have gone beyond simply replicating what already exists and are actively involved in every stage of the design process. These shifts have disrupted existing standardization in architectural design, fostering formal innovations and enabling the creation of designs in more intricate forms. The potentials unleashed by CAD technologies and computational design tools have facilitated the realization of forms, details, and variations that were once challenging to achieve.

Considering the ontological need of the design process, it can be said that with the introduction of developing technologies, especially digital fabrication technologies (three-dimensional modeling, rapid prototyping, three-dimensional scanning) into architectural practice, the physical and digital models are increasingly intertwined both conceptually. The ability to transform models into each other enables the design to progress in a controlled manner, navigating ebbs and flows while simultaneously fostering an iterative process. At this point, it is noted that the terminologies of physical and digital models, which are polarized in the literature, can be gathered

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[97] Andrzej Zarzycki, "Integrating Physical and Digital Assemblies," *International Journal of Architectural Computing* 11, no. 2 (June 1, 2013): 247–66.

under the concept of the "architectural model." In this context, the examination of conceptual, working, structural, and presentation model, which are the most recurrent model categories within the model classification and the generic model that digital changes have enabled to develop, categorized under "model types," is conducted within the framework of architectural modeling in the chapter.

Summarizing what has been discussed about the architectural model, Antoine Picon believes that architects need to think differently and, as a result, make it possible to design directly in three dimensions. [98] This transformation not only reshapes the architect's conceptualization of design but also transforms the architectural model's language, purpose, and definition. The architectural model, propelled by digital technologies, computational design tools, and digital fabrication tools, is now integral at every stage of design. It serves as both a design tool, a guide, and the embodiment of the process itself. This redefined role of the architectural model becomes pivotal in shaping design, sparking a debate about the utilization of digital design tools, techniques, and the evolving definition of the architectural model.

Architectural models have been classified by many architectural researchers to address their various uses, their versatility and to reduce the complexity inherent in their use in the design process. The types of models examined in this chapter and the examples of classifications that follow reveal that architectural models are often categorized based solely on their use. Nevertheless, in certain instances, classifications may prove insufficient in categorizing models. And so it follows that the classification created by Nick Dunn for physical models, which is more comprehensive and inclusive compared to other classification examples, has been reinterpreted and expanded to encompass the term "architectural model" in the next chapter. Unlike other classification examples, the purpose of choosing this classification is that it can examine and explain the model in a more comprehensive

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[98] Antoine Picon, "Robots and Architecture: Experiments, Fiction, Epistemology," *Architectural Design* 84, no. 3 (April 16, 2014): 54–59.

and in-depth way by moving away from the approach of reducing the model to categories of use.

The reinterpreted classification, referenced from Dunn's classification, allows greater flexibility compared to other model classifications. It has the potential for proposed model types to evolve over time based on when and how they are utilized or how they can transform into multiple model types contingent upon usage. This flexibility not only allows for adaptability over time, but also lends itself to a broader consideration of the role of architectural model use in the design process. Thus, it sheds light on the potential inherent in the use of models and contributes to a comprehensive understanding of the approach to architectural design.

CHAPTER 3

ARCHITECTURAL MODELS CLASSIFICATION: REFERENCE TO NICK DUNN'S FRAMEWORK

According to Pérez-Gómez and Louise Pelletier, "... the architect has not 'made' buildings; rather, he or she has made the mediating artifacts that make significant buildings possible. These artifacts from words, to many kinds of inscriptions and drawings, to full-scale mock-ups - and their relation to buildings, however, have not remained constant throughout history".[99] "Making" here entails not only constructing physical structures but also developing the tools that facilitate their construction. Consequently, architectural representation tools and techniques designed to convey design ideas and bring the fiction of design to life have taken varied forms across different historical periods.

Architectural models serve as a representation language, capturing the essence of design. Designers leverage these models to interrogate and enhance design ideas from multiple angles, fortify the design narrative, and streamline the design process. This diversification in the use of architectural models has given rise to various classifications. The categorization of architectural models has been a topic of interest and discussion among architects and researchers. Academicians and researchers have proposed diverse classifications to comprehend the models' purposes and applications better. Rolf Janke, in his book *Architectural Models*, classified architectural physical models into five categories: building models, construction and detail models, interior-space models, urban planning models, and unique models.[100]

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[99] Alberto Pérez Gómez and Louise Pelletier, *Architectural Representation and the Perspective Hinge*, 1997, 7.

[100] Rolf Janke, *Architectural Models,* 1968.

Janke's approach focuses on showcasing the design's end product through model representations, without introducing a specific category for utilizing the model in the design process.

In their work *Architectural Supermodels*, Tom Porter and John Neale expanded on Janke's classification, further categorizing architectural physical models into conceptual, site design development, volume, space, structural, interior, lighting, wind tunnel, presentation, exhibition, and life-size models.[101] However, they did not establish a clear basis for these categories, whether based on the purpose of production, production technique, or model potential.

In contrast, Wolfgang Knoll and Martin Hechinger, in *Architectural Models: Construction Techniques*, proposed a more concise and simplified classification for physical models. Their classification comprises conceptual, design development, and presentation model.[102] Knoll and Hechinger approached this classification by considering the models' use in the design process and their intended purpose.[103]

In his book, *Designing with Models: A Studio Guide to Making and Using Architectural Design Models*, Criss Mills explores the classification established by Porter and Neale, organizing models under similar subheadings. Mills, however, takes a different approach, categorizing models based on the most commonly used types. According to the book, "Model types can be classified according to the model contents into primary (sketch, diagram, concept, massing, solid/void, development, presentation/finish) and secondary (site contour, site context, site foliage, interior, section, facade, framing/structure, detail/ connections) types." [104] Mills simplifies the

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[101] Porter and Neale, *Architectural Supermodels: Physical Design Simulation*, 20-46.

[102] Knoll and Hechinger, *Architectural Models: Construction Techniques*, 1992, 13.

[103] Knoll and Hechinger, *Architectural Models: Construction Techniques*, 1992, 13.

[104] Mills, *Designing with Models: A Studio Guide to Making and Using Architectural Design Models*, 2.

classification by emphasizing the content of the models, dividing them into primary and secondary types for better understanding.

Shifting the focus from physical to digital models, Porter and Neale characterize digital models as "Model in the machine." [105] They highlight the precision and speed with which digital models can generate design products. Moreover, digital models seamlessly integrate into a connected design process encompassing stages like design, production, representation, and fabrication. Porter and Neale underscore the advantage of digital models being produced at significantly smaller scales than existing methods, facilitating early adjustments to details in the manufacturing processes and contributing to the efficiency of the construction process.

In the article "Measuring the Impact of Media on Architectural Design" by Ataman, the examination focuses on the influence of digital media on the design process. Digital media, employed as a cognitive tool, plays a pivotal role in fostering structural thinking and overcoming perceptual constraints.[106] Ataman argues that the impact extends beyond measurable design parameters, altering the very nature of the design product. But he also adds that "limitations in the design can result from the limitations of the media".[107] Ataman's insights suggest that physical constraints shape not only design but also the characteristics of the media, methods, and tools utilized. Consequently, the selection of digital media is a critical factor influencing the designer's thought process.

While Ataman provides a comprehensive evaluation of digital tools, Rivka Oxman, in her article "Theory and Design in the First Digital Age," delves into a more detailed categorization of digital models. Oxman classifies digital design models into

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[105] Porter and Neale, *Architectural Supermodels: Physical Design Simulation*, 151-54.

[106] Osman Ataman, "Measuring the Impact of Media on Architectural Design," (paper presented at Constructing the Digital Space, 4th SIGRADI Conference, Rio de Janeiro, Brazil, 2000,) 1.

[107] Ataman, "Measuring the Impact of Media on Architectural Design," 1.

five paradigms: CAD, generative, formation, performance, and integrated compound models.[108] Oxman's classification helps designers understand different aspects of digital design models, focusing on the various relationships between conceptual content, applied design processes, and design objects.[109]

Previous classifications have commonly focused on the distinctions between physical and digital models, adopting a purposeful approach. However, given the current state of the architectural model—referred to as the generic model—shaped by transformations through CAD/CAM technologies, computational design methods, and material integration, such distinctions become less apparent. Within the architectural design process, this model emerges as a dynamic tool adaptable to various types based on needs. Due to its hybrid structure, it facilitates new data entry and changes at every design stage. Observations of these developments in the language of architectural model production reveal insufficiencies in existing classifications. The classification proposed in this chapter draws from Nick Dunn's evaluative, predictive, explorative, and descriptive model classification for physical models in *The Ecology of the Architectural Model*, proving to be more inclusive than other frameworks.[110] This discussion of the architectural model establishes a general framework, and, in addition to Dunn's classification, the term "integrative model" will be proposed in the subsequent sections.

3.1 The Evaluative Model

Architectural models play a crucial role in expressing design ideas, going beyond mere representation. They serve multiple functions, including articulating the

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[108] Oxman, "Theory and Design in the First Digital Age," 245-46.

[109] Toni Kotnik, "Digital Architectural Design as Exploration of Computable Functions," *International Journal of Architectural Computing* 8, no. 1 (January 1, 2010): 1–16.

[110] Dunn, *The Ecology of the Architectural Model*, 13-18.

designer's thoughts, fostering new ideas, making design decisions, and shaping the design process. Architectural modeling offers additional benefits, such as exploring diverse perspectives, navigating through different scales, and assessing design functionality. Some model applications may overlap, leading to a shift in model type based on the intended use and purpose. For instance, an evaluative model can evolve into a predictive model by providing both qualitative and quantitative information. Ultimately, the model becomes a means of communication, effectively conveying the current or potential state of reality through its behavior.[111]

Dunn defines the purpose of the evaluative model as describing or exploring properties or experiences not evident in the model itself but linked to it.[112] Unlike predictive and explorative models, which aim to aid understanding of a reality or specific phenomenon, the evaluative model seeks to facilitate such comprehension through utilization, relying on external information and actions.[113] Evaluative models are designed to provide qualitative data, in contrast to predictive models that generate measurable, quantitative data.[114] Qualitative data involves properties with variable effects that can be perceived rather than measured.[115] Consequently, evaluative models are typically employed during the later stages of the overall design process, once many design variables have been established. Examples of this model can be found within the same scope as the design-development model or the working model, as observed in previously examined models.

Evaluative models significantly stimulate cognitive development and foster architectural thinking within the design process. They serve as a foundation for new

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[111] Dunn, *The Ecology of the Architectural Model*, 25.

[112] Dunn, *Architectural Modelmaking,* 189.

[113] Dunn, *Architectural Modelmaking,* 189.

[114] Dunn, *Architectural Modelmaking,* 182.

[115] Dunn, *The Ecology of the Architectural Model*, 113-114.

project explorations, necessitating accessibility, ease of use, quick expressiveness, and flexibility for necessary changes. Porter and Neale characterize these models used in the design phase as "personal and embryonic sketches in the third dimension." According to their perspective, designers should promptly create these "embryonic design models" using simple, workable materials, establishing a flexible medium that enables rapid adjustments.[116]

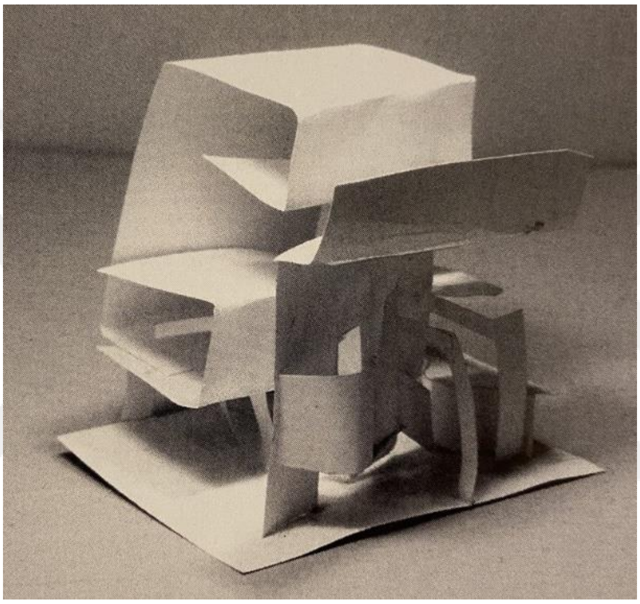

Figure 3.1- Embryonic design model created José Oubrerie, French Cultural Center, 1980.

"Embryonic design models" serve as a crucial starting point for exploring various aspects of design. Designers can experiment with diverse forms, materials, and construction techniques and consider different scales of production. Factors like feasibility research, detailing, and the relationship with environmental factors are addressed in the ongoing process.

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[116] Porter and Neale, *Architectural Supermodels: Physical Design Simulation*, 21.

The Elbphilharmonie Hamburg building, designed by Herzog & de Meuron, exemplifies the application of architectural models. Designers utilized the model as an evaluative model at the project's outset. It serves not only as a tool to establish spatial organization but also to configure the main mass's form, define spatial relationships, and ensure visual integrity with the underlying mass.

Figure 3.2- Architectural models created during the design of Herzog & de Meuron's Elbphilharmonie Hamburg Building (2001-2006).

In the first design phase, designers create evaluative models inspired by the semi-preserved historic Kaiserspeicher building on the site.[117] The model takes on a roughly distorted rectangular form, expanding around its short sides.[118] In its

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[117] The Elbphilharmonie Hamburg is a social, cultural and leisure complex of concert halls, a hotel, a restaurant, a bar, etc. located on the banks of the Elb River in the south of Hamburg. It is one of the largest and most acoustically advanced concert halls in the world. At 108 meters high, it is also the tallest building in Hamburg, referring to the important church towers in Hamburg's Old Town. Herzoq & De Meuron 2002-2006: El Croquis, 2006, 441.

[118] The Kaiserspeicher is a historic building designed in 1875, but damaged during World War II, it was redesigned by Werner Kallmargen in 1963-1966 and used to store cacao beans. The facade was preserved and used as a load-bearing structure, which became the hotel of the new philharmonic building. "230 Elbphilharmonie Hamburg – Herzog & de Meuron," Herzog & De Meuron.

simplest form, the newly designed mass, made of Styrofoam, sits atop the existing mass. A wooden plate acts as a buffer, separating the two masses. Wooden blocks are arranged on the model, representing the estimated size of the large and small concert halls. Designers experiment with gray playdough, shaping it in diverse forms on the existing building. These simple and readable models aim to bring together seemingly independent parts and explain the spatial relationship between them in a scale-free and abstract manner.

Figure 3.3- Evaluative Models of Elbphilharmonie Hamburg, Herzog & de Meuron.

The multiplicity and diversity of models produced and used in the design process play a crucial role in decision-making and shaping the final product. This ongoing, cumulative process fuels the design's development, leading to a characterization of the model as cumulative. As the project advances, this cumulative progress prompts changes in model details, scale, and the communication of ideas. Finalized decisions and changes are seamlessly integrated into the evolving model. The experimentation with façade design in the section model serves as an illustrative example of this dynamic process.

Figure 3.4- Section Model of Elbphilharmonie Hamburg, Herzog & de Meuron.

The models of Elbphilharmonie Hamburg encompass significant details regarding the design's floor heights, roof structure, its interaction with the existing building, the planned structural system, and the number of floors for construction. Notably, the model highlights glass openings in its facade design. The crystal glass facade reflects the sky, water, and the city, producing an optical illusion.[119] Organic openings in the glass panels, observed in certain areas, contribute to this illusion, forming an amorphous surface. The exploration of surface design is an integral part of the model.

In Figure 3.5, architectural models employed during the design phase are presented. The physical model facilitates the analysis of the sizeable 5000-seat hall's design in a variety of scales and forms. Complementing this, the digital model illustrates the placement of the grand hall and its relationship with the overall design. According to Jacques Herzog, the continuous integration of both digital and physical models

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[119] *Herzoq & De Meuron 2002-2006: El Croquis*, 441.

into the design process ensures enhanced efficiency, feasibility, and integration with architectural concepts.[120] Consequently, architectural modeling in this project has established a complementary design process, where the use of both physical and digital models at every stage contributes significantly to the decision-making process. The physical model allows for detailed analysis and scale variations, while the digital model showcases integrity within the overall design context. This integrated process offers a more comprehensive understanding of the development, evaluation, and communication of architectural ideas..

Figure 3.5- Physical and Digital Models of Elbphilharmonie Hamburg, Herzog & de Meuron.

[120] Brady Peters, "Realising the Architectural Idea: Computational Design at Herzog & De Meuron," *Architectural Design* (March 1, 2013): 6.

Another illustration of the utilization of architectural models for evaluation is found in UN Studio's Mercedes-Benz Museum building in Stuttgart. [121] Understanding the overall project, particularly from sections, elevations, and plans, presents a challenging task. The museum comprises six clover-shaped floors with ramps connecting them.

> Shifts in the floor levels challenge the symmetry of the trefoil plan in section. Spatially, the building is structured as a double helix. The leaves of the trefoil rotate around a triangular void, forming six horizontal plateaus which alternately occupy single and double floor heights, resulting in six double-height and six single height exhibition spaces. The organization does not involve a continuous, single surface; the six plateaus themselves are level, with slowly sloping ramps bridging the height differences between them.[122]

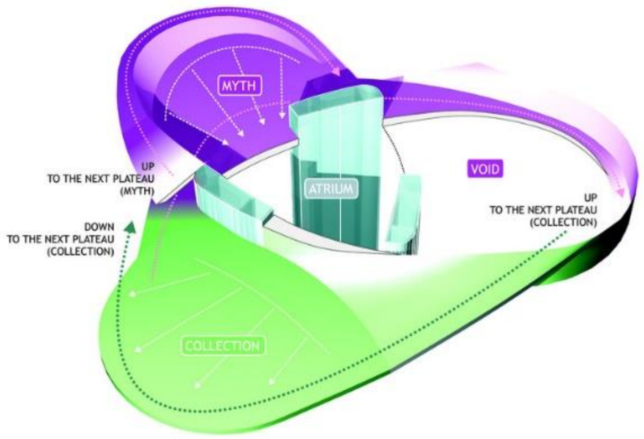

Figure 3.6- Representation of the trefoil plan in the digital model Mercedes-Benz Museum, UN-Studio (2001-2006).

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[121] The Mercedes Benz Museum, designed by UN Studio in 2006, is in Stuttgart. It consists of a double spiral ramp that dominates the entire building. One of the routes tells the history of the Mercedes Benz brand, while the other shows the cars placed chronologically. The atrium in the center of the ramp is called "the void" and provides a view of the overall museum structure. "Mercedes-Benz Museum," UNStudio.

[122] Ben van Berkel and Caroline Bos, Mercedes-Benz Museum UN Studio Office fact sheet.

Ramps serve as structural elements that accentuate the authenticity of the Mercedes-Benz Museum building. While the use of ramps in the museum draws parallels with Frank Lloyd Wright's Guggenheim Museum, it exhibits greater complexity in form and the narrative it constructs.[123] Several factors contribute to this complexity. Firstly, all team members, ranging from engineers to exhibition designers, access the same model, organize data, and collaborate on a single platform.[124] This integration allows for the simultaneous utilization of both physical and digital models generated from the generic model used since the project's inception. The oscillation between digital and physical processes at every project stage significantly contributes to design development. By addressing several aspects of the design, the advantages of both digital and physical models complement each other. Changes made on the digital platform are tested on the physical model, and issues identified in the physical model are rectified on the digital platform. This integrated approach enhances the design's stability, complexity, and overall impact.

The initial evaluative models for the museum consist of pins and tires, aiming to illustrate the circulation of the space. Paper models depict the spatial flow using arrows and letters, while a cardboard model proposes the utilization of ramps. The ramp system developed around the atrium with paper becomes a fundamental element in subsequent draft models following the adoption of the ramp design. In these models, areas represented by yellow foam exclusively indicate spaces manipulated from the space, whereas blue foam models outline the architectural program. This simplified expression and the absence of scale in the models are attempts to convey ideas clearly and comprehensibly, facilitating the progression of the design.

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[123] Morris, *Models: Architecture and the Miniature*, 32.

[124] "Mercedes-Benz Museum," UNStudio.

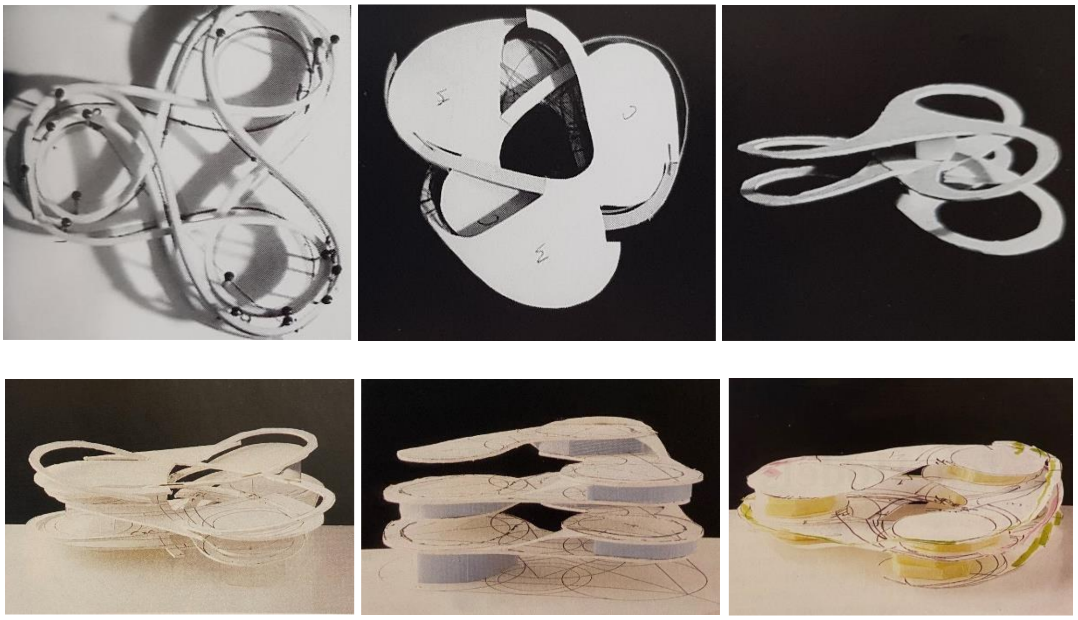

Figure 3.7- Evaluative models that made for the ramp of Mercedes-Benz Museum, UN-Studio.

In the middle of the process, 3D printers generated simplified cross-sectional models, facilitating precise assessments of ramp slopes, ceiling heights, and visual references. The objective is to unveil scenarios, whether experienced or inexperienced, and illustrate the intended circulation routes.[125] This model also elucidates the design's relationship with its surroundings and the decisions made as a consequence. Following this, a physical large-scale model is constructed, addressing aspects such as the quality of light, facade composition, the interplay between service cores and gallery spaces, and the oblique view between slabs and the ground plane relationship.

The design necessitates shifts in scale, driven by the distinct purposes it aims to communicate and process. The model often directly highlights unknown situations and occasionally features, particularly on a small scale, which are then "scaled" into

[125] Morris, *Models: Architecture and the Miniature*, 32-33.

a larger context, yielding more realistic solutions to specific design problems.[126] Furthermore, these models frequently serve to affirm or negate certain conclusions related to spatial functionality, structural feasibility, and visual aesthetics.

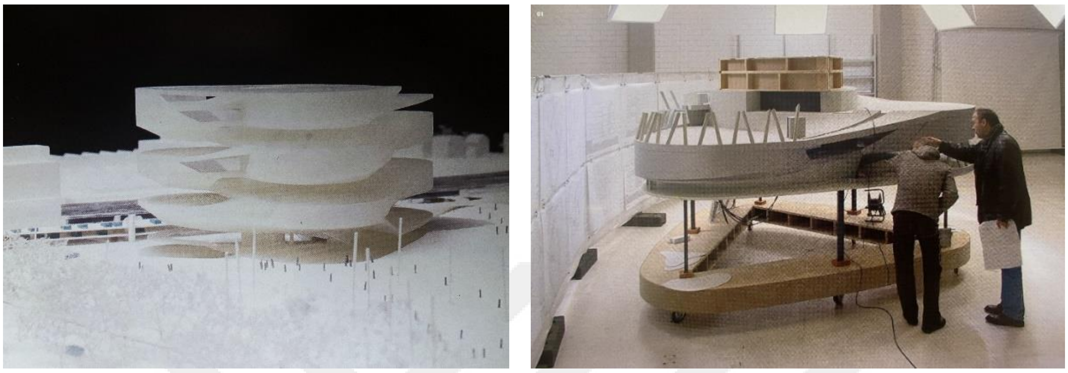

Figure 3.8- Mercedes-Benz Museum models made in different scales and materials.

In this process, architectural modeling was tailored to meet the project's specific needs. For instance, a model designed to align with the demands of the construction phase and enhance project details was employed alongside the digitally generated model. [127] This dual-model approach significantly expedited the design process, allowing for more efficient prototyping, easier testing of ideas, and consistent support at every stage of construction. By leveraging these models, designers not only articulated their concepts but also ensured a smooth transition from the design phase to the construction phase, ultimately ensuring the successful implementation of the project.

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[126] Albena Yaneva, "Scaling Up and Down," *Social Studies of Science* 35, no. 6 (December 1, 2005): 867–94.

[127] Morris, *Models: Architecture and the Miniature*, 32.

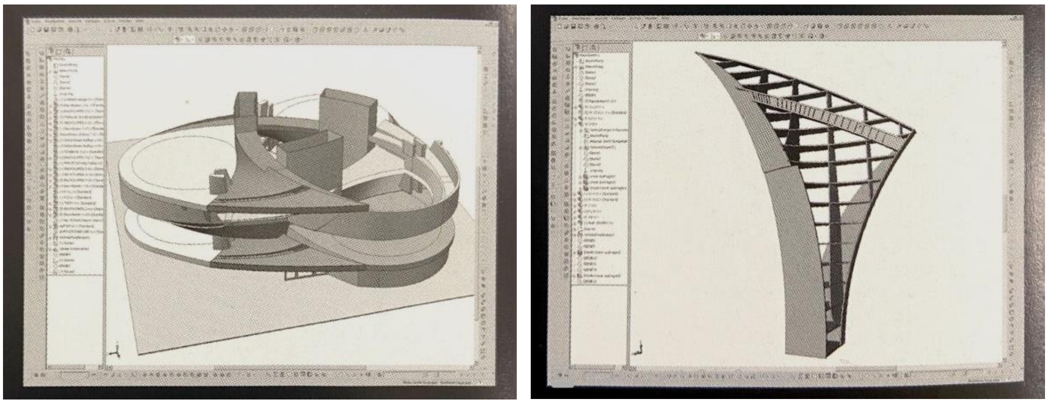

Figure 3.9- Mercedes-Benz Museum Digital model of ramp and column, UN-Studio.

The primary distinction between the two instances lies in the utilization of models within the design process. The Mercedes-Benz Museum emphasized spatial perception and spatial fiction, while the Elbphilharmonie Hamburg design concentrated on form-oriented design, advancing the design in that direction. Consequently, when employing the evaluative model, the designer can approach the design from diverse perspectives, offering various orientation possibilities and broadening its use scope based on the designer's focal point.

3.2 The Descriptive Model

Architectural models can function as a dynamic platform supporting the development and transformation of design, extending beyond a mere representation of the final outcome. Descriptive models, commonly employed in the concluding stages of the design process, do not solely depict the finished product. Instead, these models express their externality, appearing complete and serving as signifiers.[128]

[128] Morris, *Models: Architecture and the Miniature*, 37.

Moreover, they typically resist interpretation regarding design possibilities and predominantly aim for realism to ensure precise communication. [129]

> But the truth of the model does not lie in its referential nature since, as simulacrum, the model denies the possibilities of its own autonomous object hood and establishes the building as the ultimate referent, as a reality beyond representation. It is perhaps the articulation of representation itself which seeks a resuscitation of a "reality" beyond the limits of the sign. Because some models represent either something that will be built or something that has been built, others are in the position to assert the same privilege of representation and receive similar attention with no real aim of being built.[130]

Architectural models, as described by Christian Hubert, often serve as descriptive models. In their role as representational models, they go beyond merely depicting the final product of a design; they transcend representation boundaries, creating meaning within themselves. This pursuit of "reality" beyond signs suggests the model constructs its own reality, seeking a dimension beyond mere representation. Some models represent designs that can be or have been built, while others exist without a tangible purpose. The existence of these models implies not only the representation of a specific design but also the embodiment of meaning beyond mere representation.

According to Dunn, the purpose of a descriptive model is to enhance the understanding of reality by delineating the emergence of a specific phenomenon and elucidating relationships between relevant factors.[131] Its primary intention is to provide explanation. However, any description of reality brings with it various issues concerning accuracy. The most familiar type of descriptive model in architecture is

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[129] Smith, *Architectural Model as Machine*.

[130] Hubert, "The Ruins of Representation Revisited," 19.

[131] Dunn, *The Ecology of the Architectural Model*, 57.

the "presentation model." [132] Generally, the presentation or descriptive model illustrates the complete and fully detailed arrangement of an architectural solution, often within the context of its immediate surroundings. A notable characteristic of the presentation model is that it usually denotes the conclusion of a critical stage—and even, at times, the culmination—of the design process.[133] Distinguishable from the exploratory architectural model used for design development, this application of a model incorporates miniature components of the architecture represented in detail and as a complete, finished entity. [134]

One instance of a descriptive model is the Great Model of St. Paul's Cathedral designed and constructed by Sir Christopher Wren.[135] This 17th-century London descriptive model provides a detailed representation of the cathedral, offering insights into architectural styles and methods of the era (see figure 3.10). It serves as a valuable historical resource, aiding in the comprehension of St. Paul's Cathedral's architectural layout. Wren's Great Model illuminates how architectural elements are proportioned, emphasizing meticulous attention to details and serving as a supportive element in the construction process. Alternatively, it can come to life as a product in its own right, existing in reality without further design.

Another example is the unrealized project by Vladimir Tatlin in 1919, the Monument to the Third International, which gained fame for its physical model. This project aimed to be a towering symbol of modernity, surpassing the Eiffel Tower in height.

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[132] Dunn, *Architectural Modelmaking*, 171.

[133] Dunn, *The Ecology of the Architectural Model*, 65-66.

[134] Dunn, *The Ecology of the Architectural Model*, 65-66.

[135] "The Great Model - Sir Christopher Wren, Edward Woodroffe, and William Cleere - Google Arts & Culture."

However, abrupt shifts in social, political, and artistic policies impeded the project's completion.[136]

Figure 3.10- Wren’s Great Model of Paul’s Cathedral, 1647 - Tatlin Tower, 1919-1920.

Descriptive models cater to diverse audiences — customers, colleagues, students, and academics — through representative expressions. Realism varies, sometimes mirroring one-to-one reality and at times offering a transformed interpretation. Models employ different materials like glass, wood, or foam, abstracting reality in unique ways. In some cases, designers include colors to emphasize specific design ideas or approaches.[137] For example, in the models in Figure 3.11, program elements and spatial relationships are depicted in red shades, entrance circulation and its connection to the street in green, and the street-facing side in ice blue windows.[138]

[136] Astbury, "Architects Do It with Models: The History of Architecture in 16 Models - Architectural Review."

[137] Porter and Neale, *Architectural Supermodels: Physical Design Simulation*, 26.

[138] Morris, *Models: Architecture and the Miniature*, 105.

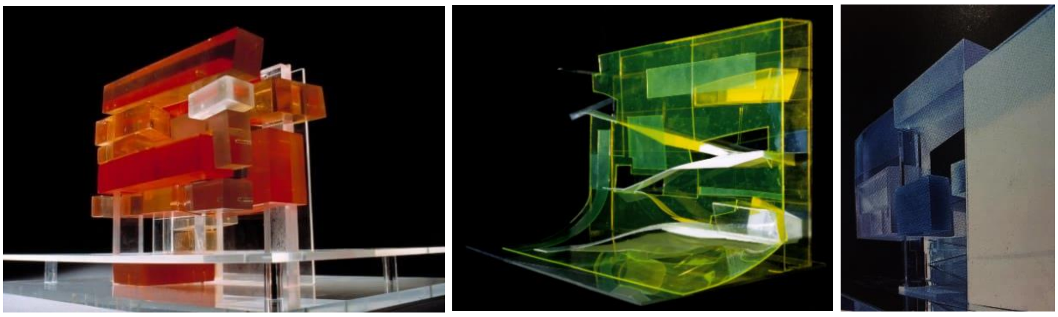

Figure 3.11- Rosenthal Contempoary Art Center, Zaha Hadid Architects, Cincinnati, Ohio, USA, 1997.

In the realm of models, diversity arises from various criteria such as material choices, texture, color, construction technique, model scale, level of detail, and degree of abstractness. Expressing ideas constituting the design through abstract models is an attempt to present a reality beyond mere representation. It's crucial to briefly delve into the concept of virtuality at this juncture. Virtuality involves crafting an alternate reality by manipulating perceptions of non-existent elements, transcending the existing reality. Gilles Deleuze contends that virtuality, far from being solely potential, is as real as possibility.[139] The integration of digital technologies in architectural design challenges conventional tools, offering fresh perspectives on the interplay between the virtual and the real. In this context, the incorporation of digital technologies in architectural design exemplifies the realm of digital architectural designs.

Furthermore, digital technologies reshape the design process, prompting a reevaluation of architectural model design. The architectural model, in its digital transformation, introduces the designer to "invisible relationships, new connections,

[139] Gilles Deleuze and Claire Parnet, "The Actual and the Virtual," in *Dialogues II* (The Athlone Press, 1987), 148–52.

new sensitivities."[140] These gained sensitivities can be harnessed through advancements in digital modeling, influencing established construction practices. For instance, heightened resolution in digital models facilitates the production of more precise models through technologies like 3D printers, a prominent tool in digital fabrication.

Figure 3.12 showcases examples of utilizing digital technologies in architectural models. This 1/75 scale descriptive model, created for a Marmaris hotel and recreational facility competition, represents a single unit. In the broader design, identical units combine in diverse configurations to shape the main design fiction. The model, consisting of three separable parts, elucidates vertical circulation between floors, as well as floor plans, structural systems, and facade openings. The wooden structure, crafted from balsa material and 3D printed components, is painted brown to mirror the intended wood usage. The detachable piece representing the wooden structure facilitates the examination of joint details and the interplay between sunshades and windows. The Plexiglas water element beneath the wooden structure mimics water, aligning with the chosen materials in the overall design. This meticulous material selection and usage in the model serve as a detailed reference to the intended design. In this example, the model's scale, level of detail, material variety, and construction technique collectively contribute to the creation of an architectural object.

[140] John Rajchman "The Virtual House: A Description," *ANY: Architecture New York 19/20* (1997): 20.7

Figure 3.12- Hotel and recreation facility invitational competition model in Marmaris, 2023, photography by the author.

The integration of the digital age into the architectural process not only transformed the model but also unveiled new possibilities. A notable illustration is the transparent model presented by Vienna-based architects Coop Himmelb(l)au for the 2001 BMW Welt competition in Munich.[141] This model aimed not only to exhibit the general design form but also to elucidate its contextual relationship, surrounding context, and the overall perception of the envisioned space. Throughout the conceptualization, the design team, led by Wolf Prix and Helmut Swiczinksy, carefully considered the connections between the BMW company's headquarters, museum, Olympic Park, and the broader environment.

The design team, led by Wolf Prix and Helmut Swiczinksy, adopts a versatile approach to model creation, rejecting the notion that any model is a finished product,

[141] The BMW building's primary concept aimed to improve the existing arrangement of the BMW Tower and Museum by introducing a new element to create a unified, inventive, and identity-defining architectural complex. Coop Himmelb(l)au's design proposal highlights a generous, transparent hall with an artistic roof and a double cone, inspired by the current corporate headquarters building. BMW Welt is structured into five distinct sections: Hall, Premiere, Forum, Gastronomy, and Double Cone. Coop Himmelb(l)au, "BMW Welt," Coop Himmelb(l)au, n.d., https://coop-himmelblau.at/projects/bmw-welt/.

considering each as a step toward the final design.[142] Working from a generic model, they engage in collaborative efforts with both physical and digital models, leveraging the complementary strengths of each in the production process. The transition between physical and digital models is seamless, facilitated by digital production tools. In instances where the physical model faces limitations in materials and colors, a collaborative effort between physical and digital models results in the creation of photorealistic vignettes.[143]

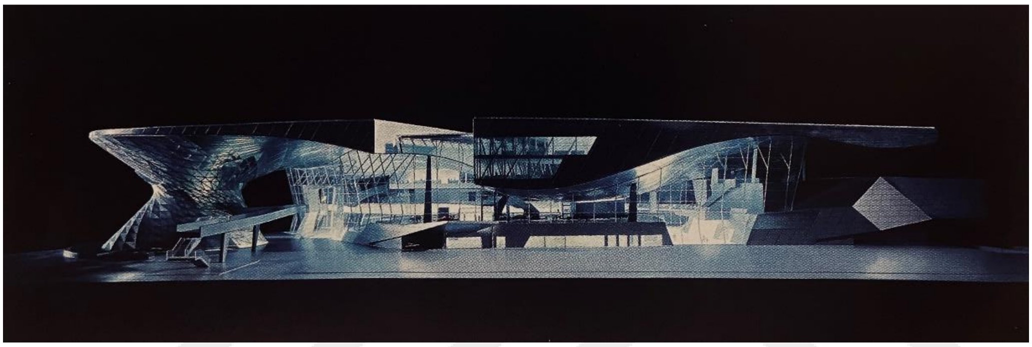

Figure 3.13- Photorealistic vignettes of the BMW Welt, Coop Himmelb(l)au Architects, Munich, 2001.

The project progressed through a phased design process and culminated in an abstract model crafted from polished resin after numerous model studies. In competition projects, there is usually an anticipation for this model to intricately embody all the preceding efforts. However, in this project, the intention behind creating this model was rather than to encapsulate the final outcome. Instead, the aim was to centralize the focus on a specific aspect within the project. Otherwise, attaining such a degree of abstraction in the model would have been unfeasible.

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[142] Morris, *Models: Architecture and the Miniature*, 108-12.

[143] Morris, *Models: Architecture and the Miniature*, 111.

Figure 3.14- Descriptive model of the BMW Welt competition, Munich, Coop Himmelb(l)au Architects, 2001.

The model illustrates the relationship between the ground plane and the topography, offering a sense of scale by representing surrounding structures and incorporating dried grass for trees. Bright metal plates provide support for the undulating roof canopy. The model's focus is on examining the point where the roof shape transforms into a double cone, with thematic clarity from the initial evaluative models and a dominant sculptural quality. [144]

In this example, serving as a descriptive model, the distinctive articulation of the roof structure alters the conveyed perception in the model. The transparent nature of the roof facilitates a dynamic interplay between interior and exterior perceptions. The swirling flow of the hourglass vortex around the spiral ramp, transitioning from outside to inside, and the intermittent divergence and convergence between the ground and the roof structure become evident throughout the model. In this instance,

[144] Morris, *Models: Architecture and the Miniature*, 111.

the model reveals these existing relationships to the observer without direct replication.

3.3 The Explorative Model

Explorative models play a crucial role in experimenting with design ideas, evaluating the design from various viewpoints, and investigating its potential. According to Dunn, explorative models serve the purpose of exploring alternative realities through speculative means.[145] This speculative process involves systematically varying parameters in the descriptive model to identify logically possible alternatives. Parameters, representing various aspects of the design, can be modified to showcase potential variations.

Explorative models serve as a means of refining judgments, making decisions, or conveying information, essential aspects of architectural design. These models are employed to experiment and test various ideas at different levels of scrutiny and are utilized at various stages of the design process. [146] Typically, they find application in the early stages of design development when innovative ideas are at the forefront.[147] Subsequently, they are refined before delving into specific properties of the design through the application of other model types, as discussed earlier.[148] The defining characteristic of an explorative model lies in its focus on testing and probing new ideas.

When experimenting with form and material, designers often employ explorative models to represent their ideas. These models can vary from highly detailed to purely

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145 Dunn, *Architectural Modelmaking*, 196.

146 Dunn, *Architectural Modelmaking*, 196-198.

147 Dunn, *The Ecology of the Architectural Model*, 58.

148 Dunn, *The Ecology of the Architectural Model*, 76.

diagrammatic and effectively communicate the subtle characteristics of a design's underlying principle.[149] Additionally, explorative models may serve as symbolic objects for the project. In contrast to descriptive models, explorative models prioritize quick modification and radical change as a means of testing ideas, rather than being overly precious with the design.[150] While refinement is still possible with evaluative models, their focus is on refining the emergent design concept rather than the quality of the finish. As a result, many explorative models in architecture are quickly produced and may appear unfinished. However, they function as three-dimensional sketches to help develop the design, giving expression to ideas and aiding in the exploration of new design notions. The design development process encompasses a range of models, from basic conceptual forms to detailed component inquiries.[151] In addition, it often triggers creativity by going into more detail and actively participating in the design, manufacturing and representation processes. It challenges structural and functional aspects, questioning feasibility, and serves as the foundation for design, allowing testing of results as it nears reality. Even when a design doesn't lead to physical realization, the model, acting as an explorative tool, influences the design or participates in fabrication and representation.

Antoni Gaudí utilized architectural models for exploration in his design process. In many of his works, he initially creates models to articulate ideas and convey the envisioned system form. These models serve as references for construction methods and how the form takes shape within the envisioned system, emphasizing practical implementation over mere design expression. For instance, the Sagrada Familia Church in Barcelona, under construction since 1883, illustrates this approach. During the design of the Sagrada Familia Church, Gaudí delved into parametric catenary curves and hyperbolic equations, embracing a parametric design approach rooted in

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[149] Dunn, *Architectural Modelmaking,* 197.

[150] Dunn, *The Ecology of the Architectural Model*, 76.

[151] Dunn, *The Ecology of the Architectural Model*, 76-78.

mathematical and computational parameters. [152] The examination of his use of the funicular chain model provides insights into his architectural methodology. This principle was applied in the design of the Colònia Güell chapel, where he developed an inverse model of the chapel. Adhering to "Hooke's law, " the chains were arranged to consistently bear pure pressure.[153] The primary component of the model forms a catenary curve at the chain's end, ensuring an even distribution of static load among the links.[154] Gaudí, thus, introduces various parameters in the model, shaping it according to the established parameter values.

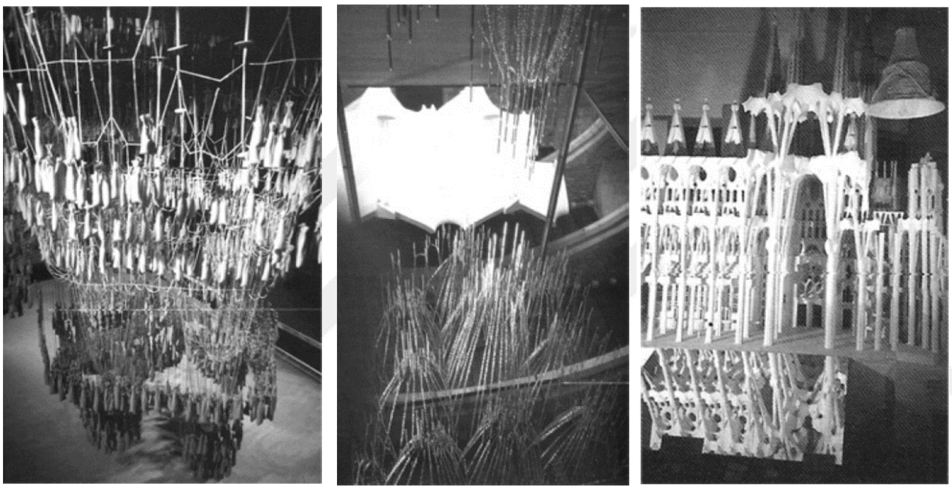

Figure 3.15 - Three types of physical models which made by Antoni Gaudí. and hanging wires and chain model/ catenary arch model(left), and rope model(middle), the white plaster model(right).

[152] Mark Burry, "Between Intuition and Process: Parametric Design and Rapid Prototyping," in *Architecture in the Digital Age: Design and* Manufacturing, edited by Branko Kolarevic. (Taylor & Francis, 2003): 210-229.

[153] Rodrigo Makert and Gilfranco Medeiros Alves, "Between Designer and Design: Parametric Design and Prototyping Considerations on Gaudí's Sagrada Familia," *Periodica Polytechnica* 47, no. 2 (January 1, 2016): 89.

[154] Hooke's law determines the elasticity limits of an object. For instance, it can only stretch so far before excess force causes it to break. In architecture and engineering, Hooke's law has a convenient purpose: to ensure that components can withstand a pre-calculated level of force.

Gaudí 's models for Colonia Güell, developed with a design logic akin to the Sagrada Familia, are geometrically and structurally intricate. Changes in parameters yield infinite iterations in form. By adjusting the parameters in the parametric model, Gaudí had the ability to produce alternative iterations of the Colònia Güell chapel.[155] For instance, altering the end point of a chain can either expand or contract the floor plan, generating a newly optimized catenary geometry. In summary, the models served as tools for exploring the complex structural system, functioning as engineering models to assess not only the form but also the structural system and material knowledge of the design.

The design and construction of the Sagrada Familia have spanned nearly a century since the project's inception. Initiated with Gaudí 's physical models, this protracted process has evolved to incorporate digital design tools and methods while remaining faithful to Gaudí's design philosophy. [156] The primary architects, led by Mark Burry and his team, aim to establish a geometry library by scrutinizing the geometric definitions of the church's already designed sections. This library facilitates the definition and manipulation of complex and curvilinear geometries, enabling swift and straightforward manufacturing during construction or prototyping. Examples of this approach are evident in the design and construction of the rose windows, side windows of the nave, and the adjustment of the nave's roof. All these models rely on the initially established geometry and parametric design, creating a production process with infinite variations and flexibility from the design phase to the manufacturing phase. This strategy allows for swift adaptation to evolving needs and

[155] Makert and Alves, "Between Designer and Design: Parametric Design and Prototyping Considerations on Gaudí’s Sagrada Familia," 89-90.

[156] Makert and Alves, "Between Designer and Design: Parametric Design and Prototyping Considerations on Gaudí’s Sagrada Familia," 91.

design requirements, resulting in a highly versatile and technically remarkable construction of the Sagrada Familia.

> Due to the aspect of digital design, Burry, Grifoll and Serrano highlight in their book some construction and design elements of the Sagrada Família Church (such as columns, windows, domes, the roof of the main nave, sacristies and towers) with a digital design and fabrication approach in collaboration with the handmade design. The simulation and digital manipulation is used in many ways in the construction of the Sagrada Família Church.[157]

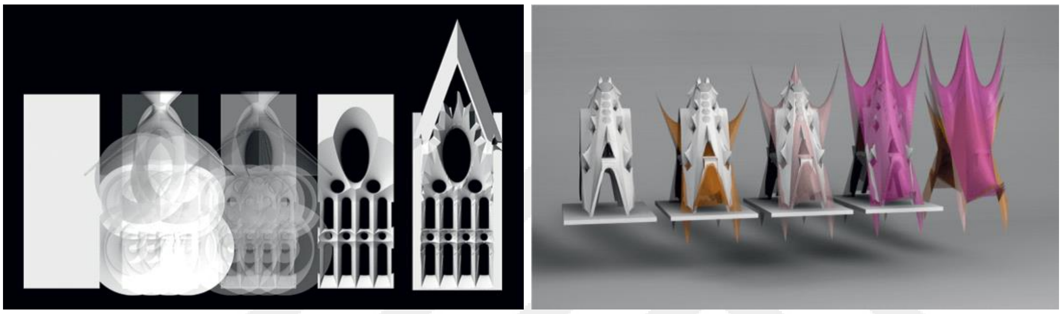

Figure 3.16- Form generation process for the side window in Sagrada Família Church. (left) the nave's roof, finding the values for the virtual cover(right).

Renowned structural engineers, including architects such as Eiffel, Heinz Isler, Felix Candela, Sergio Musmeci, Pier Luigi Nervi, Eduardo Torraja, Eladio Dieste, Maillart, Amman, and Schlaich, embraced an experimental model design process.[158] In their design endeavors, these engineers employed models to anticipate and verify the structural behavior of buildings, yielding distinctive solutions. For instance, Swiss structural engineers Heinz Isler and Heinz Hossdorf effectively utilized measurement models for the construction of numerous shell structures. They

[157] Makert and Alves, "Between Designer and Design: Parametric Design and Prototyping Considerations on Gaudí's Sagrada Familia," 91.

[158] Maria Vrontissi, "The Physical Model as Means of Projective Inquiry in Structural Studies." PhD diss., (ETH Zurich Universtiy, 2018), 24.

amalgamated various form-finding techniques, including suspending and inverting cloth dipped in plaster, with measurement models made from micro-concrete to conduct precise tests.[159]

Frei Otto, another engineer, adeptly employed measurement models to predict and verify the structural behavior of buildings. Additionally, he adopted an alternative design approach, utilizing soap bubble models to generate efficient and aesthetically pleasing structural forms with minimal surfaces. Despite the thin and fragile nature of the foam, he achieved surfaces with remarkable durability.[160] According to his perspective, he identified the ultimate expression of an efficient tensed structural surface in the ephemeral soap bubble models they created. He comprehended that structures with primary stresses limited to axial forces (compression and tension) remained unaffected by scale, allowing for the direct application of precise models of such structures to final building designs.[161]

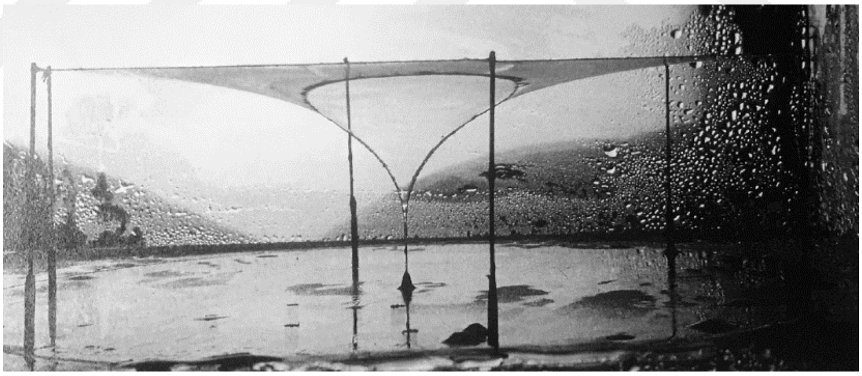

Figure 3.17- Frei Otto's exploration of the soap bubble model for tensile structures.

[159] Bill Addis, "Physical Modelling and Form Finding," in *Shell Structures for Architecture: Form Finding and Optimization*, edited by S. Adriaenssens, P. Block, D. Veenendaal, and C. Williams (London, UK: Routledge, 2014): 33-44.

[160] Siegfried Gaß, "Physical Analog Models in Architectural Design," *International Journal of Space Structures* 31, no. 1 (March 1, 2016): 16–24.

[161] Rob Whitehead, "Model Behavior: The Evolving Use of Physical Prototypes in Structural Shell Design, 1959-1974," in *Architecture Conference Proceedings and Presentations*, 2016, no 114, 528.

Frei Otto consistently integrated models into his design process, employing them to conceptualize innovative spatial shell structures. One of the most renowned examples is the design created for the German Pavilion in Montreal, and subsequent large-scale projects included the Munich Olympic Stadium. In 1972, he and Gunther Benhnisch secured the competition for the Munich Olympic Stadium's design and initiated the project. [162]

Given the project's brief design and construction timeline, the design had to be efficient and straightforward to construct. Consequently, the models crafted needed to be accurate in every detail and error-free throughout the construction process. Any errors could potentially complicate the construction process, especially at a larger scale.[163] Initially, the membrane roof form designed for the competition complex required revision, prompting corresponding adjustments in the design. Analyses and research were conducted, incorporating more detailed and varied parameters into the process.

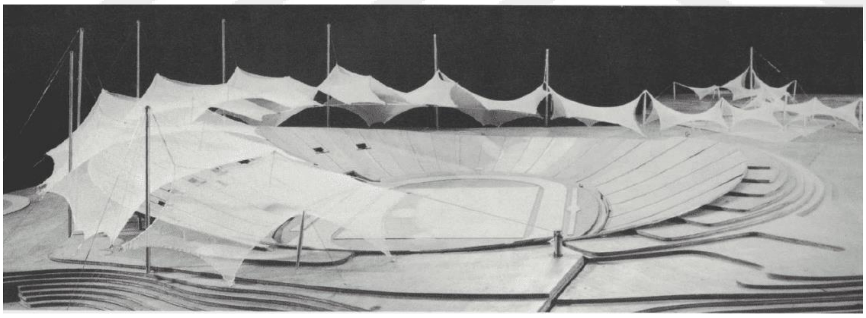

Figure 3.18- Scale model showing the tensile structure of Munich Olympic Stadium.

[162] The tent-like design of the Munich Olympic Stadium represents the beginning of a new era, marking a turning point in rooftop architecture through lightweight materials. Today, engineers and architects collaborated painstakingly to consider it one of the modern symbols of Munich. The roof covers a total area of 74,800 square meters and rises on 58 columns. Translucent Plexiglas connects the striking focal points of the roof. Beneath the Olympic Stadium's light steel roof are facilities such as the Olympic Hall and swimming pool, offering a total capacity of 69,250 people. Although there were plans to remove it in the future, these plans have yet to be realized. - Philip Drew, *Frei Otto: Form and Structure*, 1976.

[163] Whitehead, "Model Behavior: The Evolving Use of Physical Prototypes in Structural Shell Design, 1959-1974," 528.

After the competition, the design of the planned structures commenced with the construction of a 1/125 scale model, geometrically and flexibly proportional to the final product. This model represented a membrane roof operating under compressive forces in accordance with physical laws and effective parameters. The roof's construction involved suspending surfaces from a double-curved steel mesh capable of supporting various loads, creating tension between anchor systems.[164] Support elements utilized included poles, while lightweight membranes, nets, and gratings played crucial roles in the model. Axially extended load-bearing elements minimized material usage in large areas. To ensure equal stress distribution, different configurations were created, resulting in the desired equal surface tension and shaping the membrane forming the roof efficiently.[165]

According to Isler, while physical models facilitated the exploration of complex geometric forms, they had limitations in accurately documenting and creating the final form.[166] The process of transferring three-dimensional models to two dimensions using physical models was time-consuming and prone to errors. Civil engineers on the project suggested that the geometry should be refined in a computer environment during the later stages for more accurate improvements.[167]

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[164] Giulia Boller and Joseph Schwartz, "Modelling the Form: Heinz Isler, Frei Otto and Their Approaches to Form-Finding," paper presented at the *Seventh Conference of the Construction History Society*, Cambridge, UK, April 2020, 573.

[165] Nicholas Goldsmith, "The Physical Modeling Legacy of Frei Otto, " *International Journal of Space Structures*, March 1, 2016, 3.

[166] Whitehead, "Model Behavior: The Evolving Use of Physical Prototypes in Structural Shell Design, 1959-1974," 526.

[167] Whitehead, "Model Behavior: The Evolving Use of Physical Prototypes in Structural Shell Design, 1959-1974," 531.

Professors K. Linkwitz and J. H. Argyris developed a unique computer program for the exact geometry creation.[168] Photogrammetric measurements, captured by cameras imaging the model, provided accurate data. The obtained data were analyzed and integrated into the computer program to generate a digital model. This digital model played a crucial role in the final calculations of the design, encompassing not only geometry but also static and material information. While the physical model served as the primary input for the design, the digital model led to the final product.

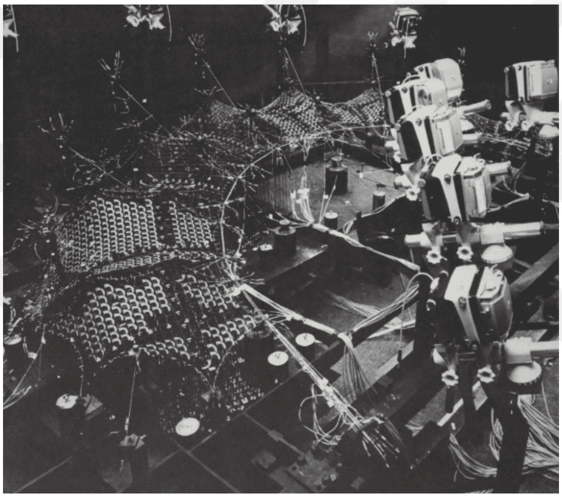

Figure 3.19- Photogrammetry process of the roof model of the Munich Olympic Stadium.

Giuseppe Canestrino emphasizes the need for methods exploring the ideal form, and Gaudí's catenary arch models and Otto's variable support models effectively respond to this requirement.[169] Both examples demonstrate that models serve not only to stimulate creativity and shape form but also to establish the design foundation, bring

[168] Maritz Vandenberg, *Cable Nets: Detail in Building*, 1998.

[169] Giuseppe Canestrino, "Considerations on Optimization as an Architectural Design Tool," *Nexus Network Journal* 23, no. 4 (June 23, 2021): 919–31.

results closer to reality, and scrutinize structural and functional feasibility. Consequently, the developed models adopt a hybrid working approach, incorporating diverse scales and parameters akin to an explorative model.

3.4 The Predictive Model

Dunn defines predictive models as tools for forecasting the future in established situations, assuming conditions are predictable rather than emergent.[170] In established situations, environmental conditions are predictable, while emergent situations may lead to quantitative that can be measured, data generation instead of qualitative data.[171] This distinction is significant because predictive models primarily produce quantitative data, while evaluative models usually provide qualitative data.[172] In architecture, predictive models empower designers to quantitatively measure the impact of changing design variables rather than merely perceiving them, adhering to the principle that there cannot be a "difference which doesn't make a difference."[173] Additionally, a distinction between predictive and evaluative architectural models is evident in their stage of use during the design process. Evaluative models typically come into play after specific design decisions have been made, whereas predictive models find application in the early stages and throughout the design process.[174]

Within the realm of predictive models, performance-based design models are noteworthy. Performance-based design is an architectural methodology evolving

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170 Dunn, *The Ecology of the Architectural Model*, 57-58.

171 Dunn, *The Ecology of the Architectural Model*, 73-74.

172 Dunn, *Architectural Modelmaking,* 182.

173 Dunn, *Architectural Modelmaking,* 182.

174 Dunn, *Architectural Modelmaking,* 183.

through performance analyses.[175] This approach integrates performance criteria into the design process to maximize the physical and functional performance of the designed space. It highlights that design encompasses not only aesthetic or visual factors but also functionality, energy flows, climate conditions, sustainability, comfort, and other critical performance criteria.

Performance-based design is commonly employed in architectural practice through two primary approaches. In the first, designers establish main design decisions and create a digital design subjected to various performance analyses, leading to design revisions based on the outcomes.[176] In the second approach, performance analyses are integrated as design inputs from the early stages, shaping the design effectively.[177] This implies that recent models fuse performance considerations with design representation, generation, and evaluation, highlighting the pivotal role of interactions among various design factors in these emerging digital models.[178]

Predictive models simulate real-world attributes and the structural system, such as the impact of climatic data, structural systems, or technical factors like acoustics on the design, in real-time. Digital models reflect changes concurrently throughout the design process, enabling designers to make informed, data-driven decisions and create complex design narratives by incorporating multiple inputs.[179] Furthermore, the impact of predictive models has increased significantly recently, especially in

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[175] Özsel and İnceoğlu, "Bilgisayar Destekli Tasarım ve Üretim Teknolojilerinin Mimarlıktaki Kullanımları," 247.

[176] Özsel and İnceoğlu, "Bilgisayar Destekli Tasarım ve Üretim Teknolojilerinin Mimarlıktaki Kullanımları," 248.

[177] Özsel and İnceoğlu, "Bilgisayar Destekli Tasarım ve Üretim Teknolojilerinin Mimarlıktaki Kullanımları," 248.

[178] Cem Ataman and İpek Gürsel Dino, "Representations of Performative Architecture in Design Synthesis," in *Materiality as a Process - Art and Science of Materiality in Architectural Design Education* (MATERIART) (Lisbon, 2019): 56.

[179] Ali Rahim, "Designing and Manufacturing Performative Architecture," in *Architecture in the Digital Age: Design and Manufacturing*, ed. Branko Kolarevic (Taylor & Francis, 2003): 280-303.

exploring sustainable design solutions. Beyond guiding the design in terms of particular performance criteria, these models play an influential role in form generation by offering the ability to make discoveries during the design process.[180] These productions involve a simultaneous process of generating design alternatives with specific parameters and evaluating them based on performance, starting from the early stages of the design process.[181]

Coop Himmelb(l)au's incorporation of predictive models in the design of the SEG Apartment Tower stands out as a remarkable example, distinctly showcasing the utilization of simultaneity. Mass additions were made to the tower guided by reference surfaces and a selection process between these models to enhance passive energy performance.[182] Throughout this design process, predictive models played a significant role as essential tools in achieving a balance between energy efficiency and shaping the form of the design, facilitating the interaction of rational criteria for this purpose.

Figure 3.20- Examples of models made by Coop Himmelb(l)au Architecture Company for SEG Apartment.

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[180] Michela Turrin, "Performance Assessment Strategies: A Computational Framework for Conceptual Design of Large Roofs" (PhD diss., TU Delft, 2013): 153-155.

[181] Michela Turrin et al., "Performative Skins for Passive Climatic Comfort," *Automation in Construction* 22 (March 1, 2012): 36–50.

[182] Dunn, *Architectural Modelmaking,* 11.

A predictive model is a tool for predicting and evaluating the future performance of a design, closely integrated with performance-based design, an approach that focuses on integrating performance into the design process.[183] Addressing performance design is a fundamental step in understanding predictive models. Performative design aims to improve design performance by encouraging objective and rational decision-making processes in architectural practice. Yehuda Kalay, an academic and architect, proposed a more objective and rational decision-making process for evaluating performance-based design. Kalay's method involves an iterative exploration of alternatives to meet specific conditions within a given context.[184] However, even within this iterative process, the designer's ability to represent and reflect upon the desirability of form, function, and context remains crucial to making informed design decisions.[185]

The National Bank of Kuwait (NBK) Tower, designed by Foster + Partners, successfully exemplifies an iterative process involving performance criteria in the design process, considering climatic conditions. To enable the analysis of climatic conditions, predictive models were produced in various alternatives.[186] These models have been instrumental in the conversion of digital software analysis to physical models. These analyses and models produced to determine the most appropriate

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[183] In the literature, the term "Performance-based design" generally refers to a focus on specific performance criteria in the design process, while "Performance-based building design" generally represents a design approach used to ensure that a building or structure achieves specific performance targets. Both usages are common in studies. In this study, the term "performance-based design" will be preferred as it describes a broader framework, emphasizing focusing on specific performance criteria in the design process and making design decisions following these criteria.

[184] Yehuda E. Kalay, "Performance-Based Design, " *Automation in Construction* 8, no. 4 (April 1, 1999): 395–409.

[185] Steffen Petersen and Svend Svendsen, "Method and Simulation Program Informed Decisions in the Early Stages of Building Design," Energy and Buildings 42, no. 7 (July 1, 2010): 1113–19.

[186] Dunn, *Architectural Modelmaking*, 183.

solution in the design process have enabled an iterative process to find the ideal form of the building and to continuously improve the performance of the design.

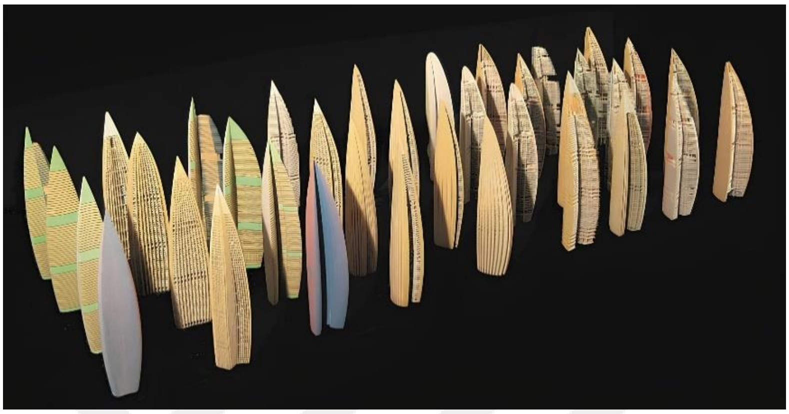

Figure 3.21- Predictive models for the National Bank of Kuwait Tower, Foster + Partners.

Beyond the mass models, additional predictive models for the National Bank of Kuwait (NBK) Tower showcase the diverse use of various model analyses in the design process. The small red and blue model positioned at the bottom left in Figure 3.22 represents the sun's path in the designed area. This model serves to comprehend the interaction between the building's location and the sun, informing decisions related to shading, daylighting, and energy efficiency.

Adjacent to this model, three environmental models analyze the impact of wind and solar gain. These predictive models play a crucial role in understanding the effects of environmental factors on the building. Below these models, there is a detailed model illustrating the solar impact on the facade floor. This specific model was created to demonstrate the interaction of sunlight with the material of the facade, providing insights into the building's visual and thermal aspects. The incorporation of these various predictive models highlights NBK Tower's multifaceted approach to the design process. This approach considers not only aesthetics but also addresses environmental impact and functionality, emphasizing a comprehensive and integrated design strategy. [187]

Figure 3.22- Predictive models for National Bank of Kuwait Tower, Foster+Partners.

Predictive models aim to maximize the functionality of designed spaces by integrating performance criteria such as shadow analysis, energy simulation, acoustic performance analysis, wind analysis, and thermal analysis into the design process. When integrated into the design, these criteria allow for more optimal and healthy designs by focusing on functionality.[188] However, sometimes these criteria may not only contribute to the development of the design but also be the elements that give birth to the design.

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[187] Dunn, *Architectural Modelmaking*, 183.

[188] Rachel Becker, "Fundamentals of Performance-Based Building Design," *Building Simulation* 1, no. 4 (November 13, 2008): 356–71.

Sarah Shuttleworth's design proposal, Swarm Theory Pavilion, is based on a swarm of birds following the sun. The flight of the birds creates different shadows at different times of the day, and depending on the position of the sun, this movement forms the main tectonics of the design. Also, it represents the continuous movement of the birds.[189] Since the design is shaped around the sun's position, the potential for light is designed accordingly. In Figure 3.23, the top left image shows the tectonic model made using cards and wood, the top right image shows the top cover model made using cotton thread. The bottom image shows the analysis of the model created using Ecotect software.[190] This software determines which areas of the model need shade and shapes the cover accordingly.

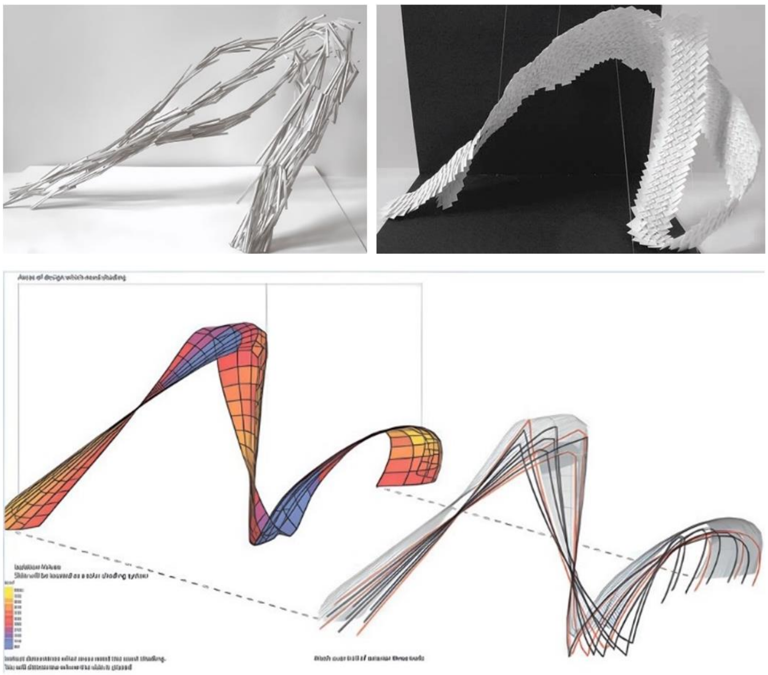

Figure 3.23- Sarah Shuttleworth's models for design proposal, Swarm Theory Pavilion.

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[189] Dunn, *Architectural Modelmaking*, 186.

[190] Dunn, *Architectural Modelmaking*, 186.

As evidenced by the illustrative instances, integrating predictive models into the architectural design process has become a crucial measure of how designs are conceived and developed. With the performance criteria they incorporate into the design, the models enable the design to evolve not only in the later stages but also from the moment of the first decision. Using the model significantly improves the precision and sustainability of designs.

3.5 The Integrative Model

The integration of CAD/CAM technologies into architectural design has significantly transformed the tools and methods employed in architectural production. These changes have also played a role in the traansformation of the generic model, adaptable through alterations in the architectural model within the production method. According to Dunn's classification, no existing category fully encompasses models created through CAD/CAM, computational design methods, and digital fabrication tools. Within this context, this thesis introduces the concept of an "integrative model" as the fifth category. [191] This category advocates for a more cohesive approach to architectural model creation, intertwining the processes of design, production, and digital fabrication.

The advent of CAD/CAM technologies has reshaped the relationship between design and production, establishing a cyclical structure and influenced the production processes and methods of architectural models.[192] Within this production framework, physical and digital models can seamlessly transition between each other, facilitated

[191] In this framework, the categories that can be suggested to Nick Dunn's classification can be increased and this subject can be studied in the future. However, this thesis will be limited to the integrative model.

[192] Kolarevic, "Digital Production," 46-51.

by digital fabrication tools, creating an iterative process. Consequently, a tightly integrated dialogue between physical and digital realms emerges, challenging the digital's role as a mere representation of the future and the physical as a realization of digital creativity. The digital-physical design dialogue becomes more complex and bidirectional.[193] The physical model digitizes, the digital model embodies, and vice versa, establishing a generative and iterative method. This iterative process involves a series of repetitive steps, moving back and forth to maintain control over the entire process.

Branko Kolarevic contends that the digital age transforms the connection between thought and production, establishing a direct link between conceptualization and realization. [194] In his perspective, the focus shifts from whether a specific form is constructible to identifying new implementation methods that leverage the opportunities presented by digital design in architecture. Within this context, the architectural model of Frank Gehry for the Lewis House project in 1989 can be assessed through the lens of the integrative model. Unlike the disciplined and gradual development seen in the Walt Disney Concert Hall, this residence undergoes a more liberated and spontaneous design process.[195] As per Marianna Charitonidou, Gehry used this residence as a testing ground to explore novel architectural forms, evident in the experimental approaches observed in the design process.[196]

Gehry conceived various areas with distinct purposes within the Lewis Residence. He initiated the design process with sketches, serving as references for both physical

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[193] Andrzej. "Integrating Physical and Digital Assemblies." *International Journal of Architectural Computing,* 249.

[194] Kolarevic, "Digital Production," 84.

[195] Lynn, *Archaeology of the Digital,* 32.

[196] Marianna Charitonidou, "Frank Gehry’s Self-Twisting Uninterrupted Line: Gesture-Drawings as Indexes," *Arts* 10, no. 16 (February 22, 2021): 8.

and digital models.[197] At times, digital models were employed to create physical models as needed. Gehry explained that the extensive use of models was instrumental in bringing the design ideas to life in his mind.[198]

Figure 3.24- Evaluative models for different parts of the Lewis Residence, Frank Gehry.

Gehry crafted a model to illustrate the Sauna section of the project, choosing red velvet to convey movement and emotion through folded fabrics.[199] The decision drew inspiration from Sluter's tomb for Philip the Bold.[200] The model's practical utility in the design process sparks debate, with varying opinions on its usefulness. However, its preference lies in its capacity to achieve fluid and easily moldable

[197] Lynn, *Archaeology of the Digital*: 149.

[198] Sketches of Frank Gehry, directed by Sydney Pollack (2009), https://vimeo.com/252370825.

[199] *Frank Gehry from A to Z 1996 2003: El Croquis*, 2003, 43.

[200] *Frank Gehry from A to Z 1996 2003: El Croquis*, 37.

forms. After shaping the velvet, Gehry coated it with wax, allowing it to set for several hours until attaining the final form.[201]

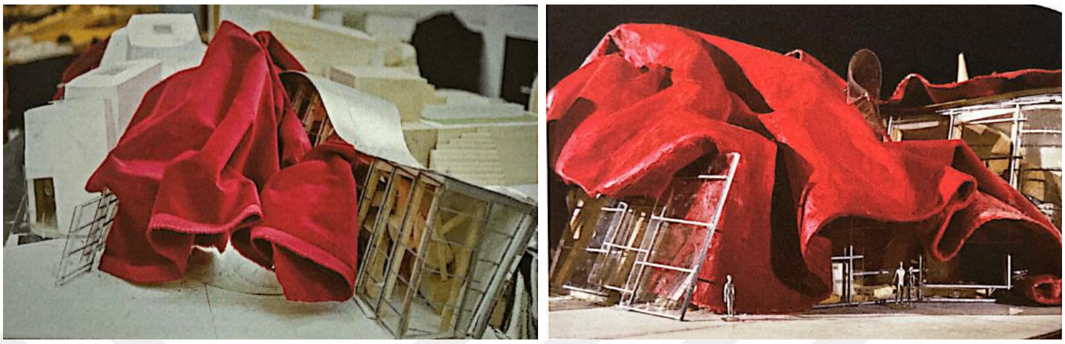

Figure 3.25- Red velvet entrance hall and gallery of Lewis Residence, Frank Gehry, Cleveland, 1989-1995.

The team proceeded by using a digital arm to scan the model's hardened fabric and convert it to a computerized point cloud. They then employed CATIA to sketch spline curves and generate surfaces.[202] Contrary to common belief, the shift from the physical model to the digital realm wasn't a straightforward one-to-one transfer, and the entire physical model wasn't instantly available on the computer. According to Tensho Takemori, the design closely resembled the scanned model in the versions that entered the project as point clouds.[203] However, the spline curves formed by the points and the surfaces they created could yield different results.[204] Consequently, the team aimed to create a digital model that faithfully replicated the physical model

[201] Lynn, *Archaeology of the Digital*, 188.

[202] Lynn, *Archaeology of the Digital*, 15.

[203] Lynn, *Archaeology of the Digital*, 33.

[204] Lynn, *Archaeology of the Digital*, 33.

and frequently referenced the physical model throughout the creation process, emphasizing an iterative approach.

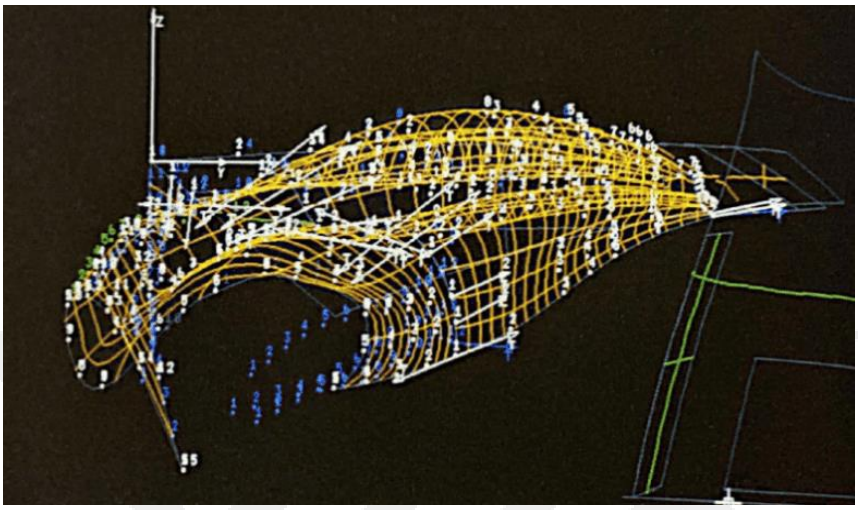

Figure 3.26- Lofting points geometry study from CATIA 3D model, Lewis House, Frank Gehry, 1995.

This iterative process served as an effective control mechanism in the design process, facilitating a bidirectional flow. The designers in the Lewis Residence project guided the design progression more effectively by transferring surfaces and structural decisions from digital models to the physical model and observing the outcomes. Similarly, they incorporated design decisions from the physical model into the digital model for testing. This dynamic approach significantly contributed to the design process by fostering continuous interaction between physical and digital models. Over time, this interaction resulted in a blending of physical and digital models, leading to a novel conceptualization of architectural models. The distinction between physical and digital models is no longer clear-cut, as a digital model can yield physical results, and a physical model can serve as a tangible representation enabling digitization.

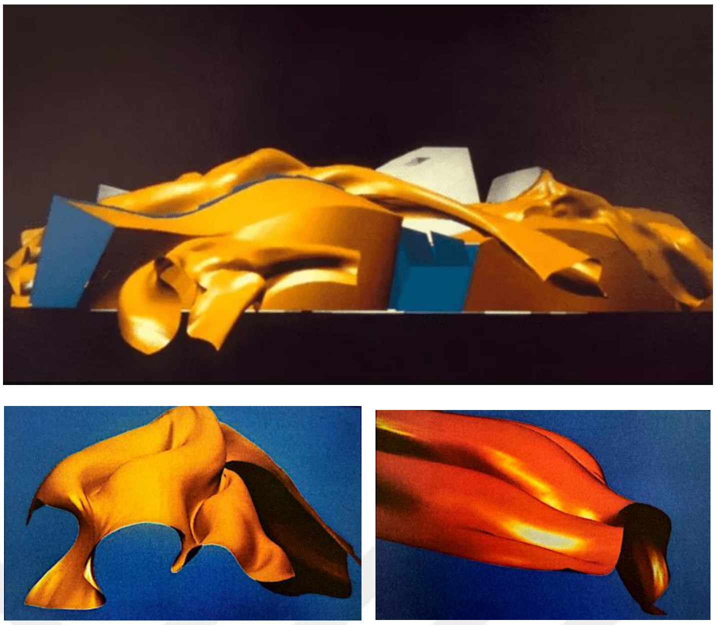

Figure 3.27- Model of entrance hall and gallery, Lewis Residence, Frank Gehry, 1995.

Frank Gehry's 1988 Marques de Riscal Winery and Hotel provides an ideal example to observe the influence of digital fabrication tools on the design process. The primary goal of this project was to reconstruct the Vinos Heredos del Marques de Riscal Winery in Spain's Rioja region, one of the oldest wineries in the area.[205] While Gehry's architecture is renowned for its uniqueness and sculptural quality, the client aimed to create a memorable and inviting structure. In terms of the design process, Gehry extensively utilized physical models at various scales, translating them into the digital realm through three-dimensional scanners. This allowed his design to evolve simultaneously in both physical and digital environments. Furthermore, the

[205] The shell of the building consists of a series of linear elements made of Spanish limestone, along with curved elements covered with gold or pale pink titanium panels and mirror-finished stainless steel panels. The choice and utilization of materials, particularly in the physical model, are expressed in great detail and form the fundamental source of inspiration for the project. For instance, the exterior shell of the building reflects its themes through the selection of colors. Pink titanium panels symbolize the red wine, while silver panels represent the foil covering the wine cork, and gold-colored materials denote the zigzag pattern on wine bottles. The selection and use of these materials help us understand the design language through physical models, drawing associations through simile. *Frank Gehry from A to Z 1996 2003: El Croquis*, 245.

departure from familiar or conventional geometries in the design became evident through experimentation in three-dimensional spaces and at different scales.

Figure 3.28- Models of the Marques de Riscal Winery and Hotel, Frank Gehry, 1988.

These examples illustrate the substantial advantages that architects gain from digital fabrication tools in their thinking and design processes. These tools not only shape the boundaries of design but also expedite the transition between physical and digital realms, providing designers with a comprehensive analysis of their creations. The prevalent use and easy accessibility of digital fabrication tools have profoundly influenced design ideas and processes. Neil Gershenfeld views personal fabrication and digital fabrication tools as a revolutionary means to design and produce concrete objects, independent of constraints like time and space.[206] In the realm of design practice, digital fabrication tools have expanded creativity by integrating design and production stages, enabling novel possibilities.[207]

In summary, existing classifications primarily prioritize the distinction between analog and digital. The integration of CAD/CAM technologies and computational design methods into architectural practice has led to a gradual blurring of the distinction between the physical and digital model and has reshaped the production methods and processes of architectural models, contributing to the development of the generic model. However, these changes expose inadequacies in current classifications. The proposed classification in this chapter reinterprets the architectural model, aligning with Dunn's categorization found in *The Ecology of Architectural Model*, which includes evaluative, predictive, exploratory, and descriptive models for the physical model. Additionally, it introduces the integrative model as a new category.

For the purpose of providing a clearer classification and facilitating the examination of model usage in the context of a specific project, the ACC (Atatürk Cultural Center) Presidential Symphony Orchestra Concert Hall in Ankara, with its unique characteristics, has been chosen as a case study. This project holds a distinct status as the first concert hall in Turkey specifically designed for symphonic performances.

Digital fabrication is about producing three-dimensional mass structures and combining mechanical and electronic mechanisms to produce a product in a single step. Gershenfeld gave the example of uncrewed aerial vehicles being Digital fabrication is about producing three-dimensional mass structures and combining mechanical and electronic mechanisms to produce a product in a single step. Gershenfeld gave the example of uncrewed aerial vehicles being able to fly directly after the printer prints them out with electronic and mechanical parts instead of having to manufacture the parts, and added: "Personal (digital) fabrication tools are just like the printers we now have in our homes; they print 'things,' not just 'pictures' on paper." Neil Gershenfeld, *FAB:The Coming Revolution on Your Desktop--from Personal Computers to Personal Fabrication*, 2005.

[206] Gershenfeld, *FAB: The Coming Revolution on Your Desktop--from Personal Computers to Personal Fabrication*, 19-22.

[207] Lucia Corsini and James Moultrie, "A Review of Making in the Context of Digital Fabrication Tools," *Proceedings of the DESIGN 2018 15th International Design Conference* (January 1, 2018): 1021.

Notably, it is also remarkable for being the pioneer in using the pneumatic formworks method in the construction of concert halls in Turkey, marking the first instance of its kind in the country, despite its limited global use. Another noteworthy feature is its prolonged duration, spanning an impressive 29 years since the initial competition.

In addition to these reasons, the primary motivation for selecting this case lies in the diverse and comprehensive utilization of architectural models throughout all stages of the project, from the competition phase to design development and construction. All models collaboratively created by the architectural project team and relevant technical teams have a rich diversity and serve different purposes. These models, reinterpreted and developed within the framework of Dunn's classification, not only offer diverse applications but also significantly contribute to a nuanced understanding of architectural models in an academic context.

CHAPTER 4

THE CASE STUDY: THE ACC PRESIDENTIAL SYMPHONY CONCERT HALL

This study aims to investigate the architectural models used from the competition stage to the construction stage of the ACC Presidential Symphony Orchestra Concert Hall, within the model classification reinterpreted and developed with reference to Dunn. The project, spanning over 29 years, represents a complex construction overseen by a comprehensive team, including architectural offices, acoustic experts, and construction teams. Different architectural models were employed at each stage, and the definition of the architectural model transformed from the project's initiation to completion. With the integration of digital technologies into architectural practice, the use and potential of the model expanded. The study meticulously examines the various architectural models used in the CSO Concert Hall construction process and explores how other disciplines utilize these models.

The selected case is the ACC (Atatürk Cultural Center) Presidential Symphony Orchestra Concert Hall, situated between Ulus and Kızılay in Ankara, within the "Atatürk Cultural Center" Zone 4.[208] It occupies a prominent urban location near

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[208] Gülce Halıcı, ed., "Atatürk Kültür Merkezi Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu," *Yapı Dergisi* 470 (October 2021): 67.

The AKM Area, as defined by the law, includes places that are instrumental in promoting the history of the National Struggle and Turkish Folk Culture and Arts, museums, various stages, meeting halls and exhibition areas, workshops, libraries, and archives. The AKM Area consists of five different zones. The First Zone is the Culture and Arts Zone, which includes the Old Hippodrome Area and essential spaces such as the Atatürk Cultural Center, the State Opera and Theater Building, and the Congress Complex. The Second Zone is the Sports and Recreation Zone, which hosts sports events and recreational areas and includes facilities such as the 19 Mayıs Stadium and Atatürk Indoor Sports Hall. The Youth Park Zone, which serves recreational purposes, constitutes the Third Zone. The Fourth Zone is the Arts and Culture Zone. It includes important venues such as the CSO and the Museum of Contemporary Arts. The Fifth Zone is the Museum Area, located between Ulus Square and Gençlik Park, and includes museums such as the Republic Museum and the War of Independence landmarks such as Anıtkabir, Courthouse, Nervi Bridge (the current Opera Bridge, so called because Luis Nervi designed it), Gençlik Park, and Historic Ankara Castle.[209] The CSO Complex, surrounded by Cer Modern and the Historic Presidential Symphony Orchestra Concert Hall, establishes itself as a central hub for cultural and artistic events.

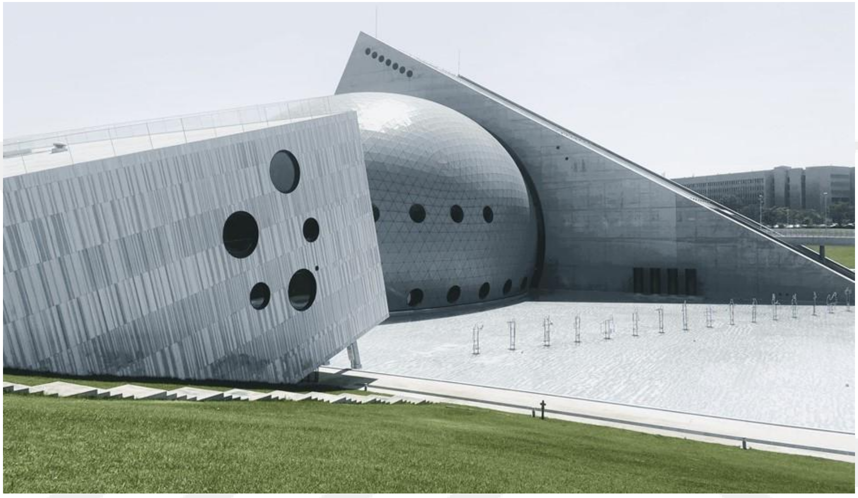

Figure 4.1- ACC (Atatürk Cultural Center) Presidential Symphony Orchestra Concert Hall, photography by the author.

In 1992, the Ministry of Public Works and Settlement of the Republic of Turkey initiated an architectural project competition in this area with the objective of "designing a cultural complex that withstands the test of time. "[210] The Uygur

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Museum. - "Atatürk Kültür Merkezi Alanı Kentsel ve Mimari Programı" (Mimarlar Odası Ankara Şubesi - AKM Alanı, 2006).

[209] Gamze Köküm, ed., "Atatürk Kültür Merkezi CSO Konser Salonu ve Koro Binaları," Serbest Mimar 40–41 (June 2021): 2.

[210] T.C. Bayındırlık ve İskân Bakanlığı - Ankara, "Atatürk Kültür Merkezi Cumhurbaşkanlığı Senfoni Orkestrası ve Koro Çalışmaları Binaları - Mimari Proje Yarışması Şartnamesi," 1.

Architecture Office emerged victorious in the national architectural project competition, prevailing over 46 competing projects.[211] The winning design exhibits a notable social-urban relationship and stands out for its distinctive spatial characteristics.[212] Situated in the sole undeveloped space between Anıtkabir and the historic Ankara Castle, the site seamlessly integrates into the surrounding urban landscape. Moreover, the design's foundational principle underscores its role as a timeless symbolic artifact rather than a structure bound to a specific era. [213]

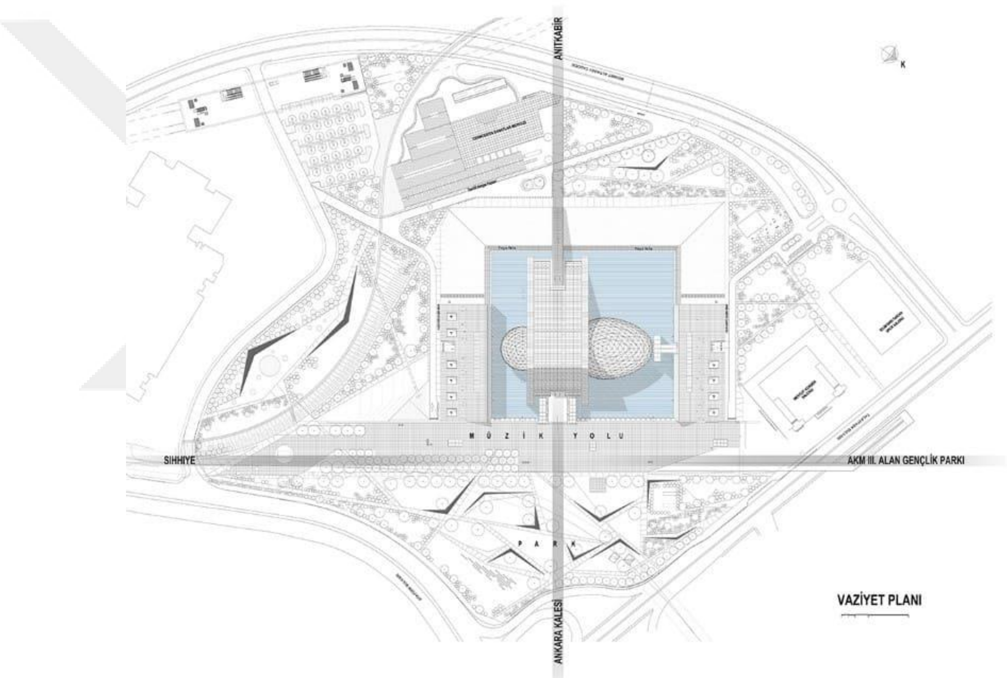

Figure 4.2- CSO Concert Hall layout plan and main axis representation, Arkitera, 2021.

[211] Köküm, ed., "Atatürk Kültür Merkezi CSO Konser Salonu ve Koro Binaları," 24.

[212] "Uygur Architects | Ataturk Cultural Center Presidential Symphony Orchestra Concert Hall," n.d., https://www.uygurarchitects.com/site/en/projects/cso.html.

[213] T.C. Bayındırlık ve İskân Bakanlığı, "Atatürk Kültür Merkezi Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu ve Koro Çalışma Binaları Mimari Proje Yarışması Jüri Değerlendirme Çalışmaları – Jüri Raporu," 1992, 7.

After winning the competition, a lengthy process unfolded. The ministry initiated the project tender in 1995, and construction commenced in 1997. However, delays, insufficient funding, and bureaucratic obstacles led to the project's completion and commissioning being postponed until 2020.[214] The construction of the ellipsoid and spherical concert halls within the CSO Concert Hall Complex marked the inaugural use of pneumatic formwork and shotcrete techniques in Turkey. This pioneering approach exemplifies creative and contemporary curvilinear structures.[215] The innovative system, coupled with a construction process showcasing high-level technical skills, material selection, and craftsmanship, earned the CSO Concert Hall Complex the Building Award at the XVIIIth National Architecture Series and Awards in 2022.[216] Spanning a 62,547m^2 construction area, this music complex comprises five main sections. The Main Concert Hall, an elliptical symphonic concert hall, and the Blue Hall, a spherical chamber music concert hall, constitute the first two sections. The third is the main foyer, a triangular prism-shaped space serving both concert halls. The Choir buildings, encompassing side blocks housing artists' rehearsal spaces, professional studios and administrative offices, constitutes the fourth section. Additionally, there's a parking garage for 703 cars, and a power center was later added to meet the building's energy needs.[217]

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[214] Köküm, ed., "Atatürk Kültür Merkezi CSO Konser Salonu ve Koro Binaları," 27-32.

[215] Lale Özgenel, "Katmanlararası Müzakere: AKM Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu," *Mimarlık 429*, 2023, 49.,

[216] Çağda Türkmen, ed., "2022 Ulusal Mimarlık Ödülleri," *Mimarlık 425*, 2022, 48–51.

[217] "Ankara Atatürk Kültür Merkezi Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu Açıldı," Yapı Dergisi.

Figure 4.3- Presidential Symphony Orchestra Concert Hall, Arkitera, 2021.

One key decision in the project is the triangular prism shape adopted for the foyer, with singular structures designed for the adjacent concert halls. The intention is for these elements to be perceived as a unified whole from the upper floors, avoiding any separation between the roof and facade. The project revolves around an original main idea that derives its strength from simplicity.[218] The concert halls and the main foyer, characterized as symbolic and simple, occupy the lowest level of the building. The rectangular water element surrounding them simulates a crater lake in the city's heart.[219] This design principle successfully maintains the autonomy of private spaces while opening up public areas to the surrounding topography instead of enclosing them.[220] The public spaces, including the foyer, main concert hall, and chamber music concert hall, are integrated into the design in a well-balanced manner.

218 T.C. Bayındırlık ve İskân Bakanlığı, "Atatürk Kültür Merkezi Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu ve Koro Çalışma Binaları Mimari Proje Yarışması Jüri Değerlendirme Çalışmaları – Jüri Raporu," 6.

219 Semra Uygur and Özcan Uygur, "Ankara'yı Değiştiren Projeler 7 - TSMD" (Ankara, 2013).

220 Özüm İtez, ed., "Atatürk Kültür Merkezi Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu ve Koro Çalışma Binaları," Arkitera.com, September 2021

Figure 4.4- Concert Hall Complex Pool, photography by Cemal Emden.

The 1500-seat foyer, a pivotal component of the complex, is conceptualized as a transparent "city room," offering a welcoming space for everyone.[221] The foyer entrance is bi-directional, with access from Atatürk Boulevard leading to the third floor and access from Talat Pasha Street leading to the second floor. These floors have a fictional connection with each other. Upon entering the foyer, the glass line on the floor aligns with the axis of Ankara Castle and Anıtkabir. According to the project's architects, this establishes a music center and a cultural stop between the past and the future, signifying its importance.[222] Spatially analyzing the foyer reveals its design, characterized by a diagonal triangular prism shape, intertwining with the ellipsoid symphony orchestra concert hall and the spherical chamber music concert hall. This intertwining is visible from both inside the foyer and outside the complex. Glass bands enclose the areas between the foyer and concert halls, deliberately leaving openings between the foyer floors to facilitate an uninterrupted view of the concert halls.

[221] "Uygur Architects | Ataturk Cultural Center Presidential Symphony Orchestra Concert Hall. "

[222] T.C. Bayındırlık ve İskân Bakanlığı, "Atatürk Kültür Merkezi Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu ve Koro Çalışma Binaları Mimari Proje Yarışması Jüri Değerlendirme Çalışmaları – Jüri Raporu," 6.

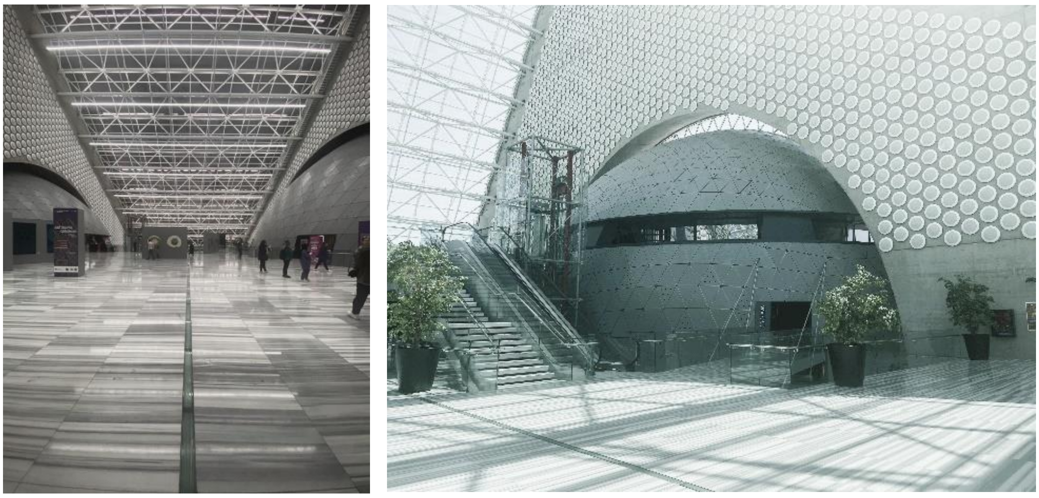

Figure 4.5- CSO Concert Hall Foyer (opposite angles), photography by the author.

The project's seamless design approach extends to its structure. Using the "space truss steel" method, the structure supports the walls rising with glass components, defining the foyer area. This steel system establishes a spacious and open ambiance in the foyer, allowing for broad openings without the need for columns and beams. Furthermore, the system operates seamlessly, with floors resting on internal columns and beams, and individual reinforced concrete walls shaping the concert halls serving as load-bearing elements. From a technical standpoint, the careful selection of glass panels enveloping the entire foyer ensures optimal light transmission and minimal heat absorption.[223] Consequently, the foyer maintains a comfortable "climate control" within its space. Simultaneously, the foyer accommodates various cultural

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[223] Köküm, ed., "Atatürk Kültür Merkezi CSO Konser Salonu ve Koro Binaları," 33.

In the report prepared by the Fraunhofer Institute for Building Physics, concert halls are classified as rooms with high acoustic requirements. The unique acoustic conditions selected and placed the structural materials used in these halls, such as wood cladding, glass panels, and textured plasters. Sound control was not limited to the halls alone but also in all areas of the complex. The foyer interior facades have circular disks with decorative patterns contributing to sound control. In addition, the practice halls inside the choir buildings are equipped with suspended ceilings with holes of different diameters and wooden panels on the wall surfaces due to their high acoustic requirements. - Mehmet Çalışkan, Zühre Sü Gül, Zeynep Bora Özyurt, and Özgün Sinal, "Acoustical Design of Music Practice Rooms: CSO Concert Hall" October 2019, 3-7. Özgenel, "Katmanlararası Müzakere: AKM Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu."

activities, including exhibitions and events, and offers amenities such as a restaurant, gift shop, technical areas, and wet floors.

Figure 4.6- CSO Concert Hall Restaurant and gift shop, photography by the author.

Moving from the foyer to the Main Symphony Concert Hall involves traversing three distinct levels. Shaped like an ellipsoid (often referred to as an egg), the hall accommodates 2000 people with a vineyard seating arrangement. This arrangement situates performers on the lower hall level and relatively in the middle. The seating around the stage ensures an optimal view for the audience, with appropriately designed slopes. Notably, this hall marks the first symphonic concert hall in Turkey.[224] The halls constructed in Turkey so far have typically been versatile,

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"The Mızıka-i Humayun," established by the Ottoman Empire in 1826, was brought to Ankara under the command of Mustafa Kemal Atatürk. Subsequently, its name was changed to the "Riyaset-i Cumhur Senfoni Orkestrası" and, in the present day, it has become the Presidential Symphony Orchestra. Zekeriya Türkmen, "Riyaset-i Cumhur Filarmoni Orkestrası," *Atatürk Ansiklopedisi, March 30*, 2021.

[224] Özlem Ak, "Geçmiş İle Gelecek Arasında Bir Kültür Durağı: Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu ve Koro Çalışma Binası," *TÜBİTAK Bilim ve Teknik Dergisi*, January 2021, 61.

serving various functions like theater, opera, conferences, ballet, and congresses. Designing a Symphony Orchestra hall differs from creating a multi-purpose hall. In multi-purpose halls, the volume per person averages 6-8 m³, whereas in symphony halls, it increases to around 10-12 m³. This distinction arises from the focus in multi-purpose halls on accommodating human sound with lower ceiling designs. Conversely, symphony orchestra halls prioritize instrument sound, necessitating higher ceilings to ensure a homogeneous transmission of sound to the audience. [225]

Figure 4.7- CSO Main Concert Hall (opposite angles), photography by the author.

[225] Ak, "Geçmiş İle Gelecek Arasında Bir Kültür Durağı: Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu ve Koro Çalışma Binası," 64.

Architects and acoustic consultants collaborated at different project stages to meet the concert halls' design, audience capacities, plan type, hall volume, size, and acoustic requirements. In addition, Professor Wolfgang Fasold, from the Department of Building Physics at the Fraunhofer Institute, served as the acoustic consultant for the project for many years and developed the project in collaboration with different acoustic consultants in the project's final phase. The project focused on two acoustic phases. First, it aimed to identify the noise generated within and around the building and to implement suitable insulation. Due to the project's location in a busy area, it effectively applied sound insulation from the foundation to the top of the project, ensuring sound reduction from the inside to the outside. In terms of volume acoustics, it is necessary to transmit sound homogeneously to the audience following the functions of the interior spaces. In this context, acoustic consultants and the architectural design team conducted the acoustic arrangement of the halls by utilizing models and tests. Ak, "Geçmiş İle Gelecek Arasında Bir Kültür Durağı: Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu ve Koro Çalışma Binası," 61- 67.- Semra Uygur and Özcan Uygur, "Ankara'yı Değiştiren Projeler 7 – TSMD." - Özgenel, "Katmanlararası Müzakere: AKM Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu," 48-53.

The Chamber Music Concert Hall, positioned opposite the main hall with a single-level entrance, consists of three distinct sections within the project—a spherical mass housing the bistro-cafe on the 3rd floor, the CSO 1826 Exhibition Area on the 2nd floor, and the 1st floor, named the Blue Salon, hosting a 512-seat chamber music concert hall accessible from the lowest level.[226] The chamber music concert hall features a seating arrangement in a three-quarter circle around the stage, with terraces rising around the stage and utilizing structural materials identical to those in the main concert hall to meet acoustic requirements. Similar to the main hall, this chamber music concert hall incorporates window openings, allowing controlled entry of natural light and enabling users to customize the atmosphere based on lighting preferences.

Figure 4.8- CSO Chamber Music Concert Hall, CSO Ada Ankara Website.

The CSO Concert Hall, marked by an extended design development and project design process, presents a complex scenario with diverse spatial requirements, making it an ideal case for scrutinizing the role of architectural models in the design process. Moreover, it serves as a tangible example of how the definition and function

[226] "Mavi Salon - CSO Ada Ankara," CSO Ada Ankara.

of architectural models evolve towards the project's conclusion. Each project phase incorporates numerous architectural models varying in styles, scales, abstractness, construction techniques, and purposes. Subsequently, the upcoming sections of the chapter will delve into a detailed discussion and analysis of the models created within the project, guided by the proposed alternative classification.

Figure 4.9- Semra Uygur and Özcan Uygur analyzing the 1:50 scale sectional model of a Chamber Music Concert Hall, Uygur Architecture.

4.1 Architectural Models Utilized Throughout the Entire Process of the Presidential Symphony Concert Hall

The CSO project extensively employs architectural models across various stages, spanning from the competition phase to design development and construction. These models, created collaboratively by the architectural project team and associated technical teams, serve distinct purposes, employing specific techniques and methods. The models have been carefully designed in accordance with the requirements of the period in which they were created and thus meet various needs specific to the project process.

When these models are considered through the lens of Dunn's classification, it is observed that they sometimes function as descriptive models representing the final product and at other times as evaluative models to enhance the project. Additionally, some of these models take part in the design process as predictive models to test technical aspects, exploratory models to evaluate design ideas, or integrative models supporting hybrid usage. These models may have been produced with different purposes at the beginning of the process, they actively contribute to shaping the versatile use of the model and the design process by integrating into other classifications. Moreover, when considering the close relationship of the design process of the CSO Concert Hall Complex with manufacturing and structural system elements, it can be regarded as a model itself. This situation illustrates that different models are used in various ways at each stage, including the CSO Concert Hall Complex.

In this section, the objective is to assess the utilization of models throughout the design and production processes and to comprehend the potentials they bring in accordance with the proposed classification. Within this context, approximately 14 physical models and 2 digital models produced for the CSO Concert Hall Complex were examined. The architectural team created all physical models during both the competition and design development phases, and subsequently utilized some of these models throughout the construction phase. Additionally, the architectural team and other technical teams exclusively produced digital models only during the construction phase for refining more detailed design solutions. The reason for this is that the use of computers was not yet widespread in architectural practice at the beginning of the project. Subsequently, many changes have been experienced in architectural practice during a long period of stagnation of the project during a very long construction phase. This situation also had an impact on the architectural model, and the use of CAD/CAM technologies, computational design methods and digital models were observed during the construction phase.

As per the insights gained from interviews with the project architects, they informed that a number of models of different purposes and scales were produced in order to find solutions to the design problems, but not all of them could be preserved. It is noteworthy that, despite some models being unavailable, the overall count exceeds the average seen in numerous projects, providing evidence for the efficacy of model utilization in shaping the project. In this context, the models produced by the architectural office and other teams will be analyzed under the headings of project competition phase, design development process and construction phase respectively, with reference to Dunn's reinterpreted and extended classification, which is examined in detail in preceding chapter.

Figure 4.10- Examination of 1:20 Scale model of the main concert hall built for acoustic tests in Germany, Uygur Architecture archive.

4.2 Competition Phase Model

Within this context, the model prepared for the competition can be classified under the proposed title of "descriptive model." As explained in previous chapter, the descriptive model, in general, is not exerting a guiding influence on design decisions and not serving as an exploratory tool for generating new ideas. However, as discussed earlier, the use of descriptive models does not imply that they encapsulate the final design rather, they serve as a representation of its concluding stage. In this regard, it is crucial to underscore that the use of descriptive models does not imply a comprehensive representation of the final design. This assertion becomes evident when considering the significant alterations implemented in the subsequent stages of the project. The competition guidelines mandated a 1:200 scale model, leading to uniformity in language and construction technique among all entries, including the winning design. These models encapsulated not only the design but also a significant portion of the surrounding topography. The intricate and complex environment in the competition area introduced uncertainties regarding building language, scale, and orientation.[227] This ambiguity provided additional freedom to the projects, prompting a quest for an urban-scale reference or an attempt to establish a unique reference point.

The competition projects shared similarities, with many adopting axis systems inspired by the environment or creatively devised. To highlight these similarities in architectural models, various approaches were taken, involving materials, colors, or textures. Sharp forms were often eschewed in favor of more original and symbolic structures, employing different colors or materials to accentuate distinct elements.

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[227] Abdi Celal Güzer, "C.S.O Konser Salonu Yarışma Ardından : Mimarlıkta Pluralism Üzerine," *Mimarlık 250* (1992): 60.

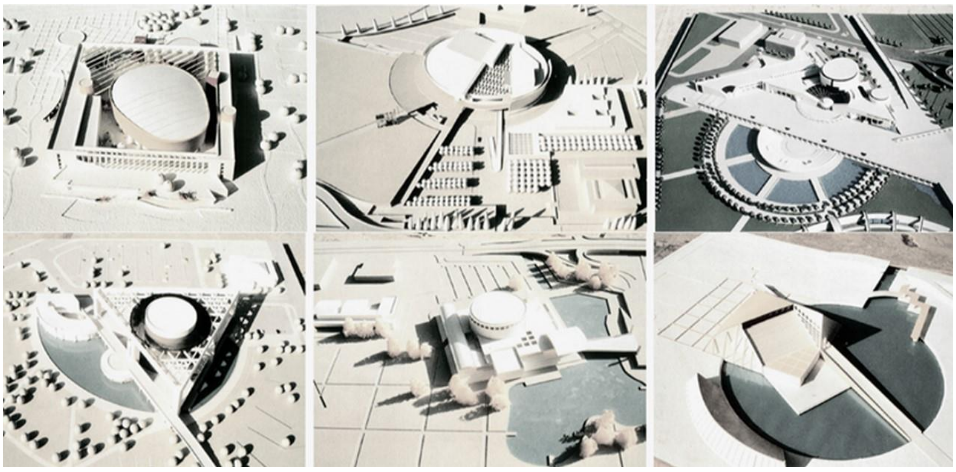

Figure 4.11- Models from participants in the CSO Competition project.

Semra and Özcan Uygur's winning competition model features two simple disk forms and a triangular prism at a 1:200 scale. Red materials emphasize these forms for easy viewer perception. The masses are highlighted in red, except where blocks in subsequent model segments rise on the topography without attaching to it. The yellow section acts as a substantial platform, connecting the area above the triangular prism with the open-air amphitheater in the front and the block on top in the back. An artificial water element, encompassing the main halls and the foyer, is depicted in blue. The prevalent white color in the model's design serves the purpose of accentuating the topography, enhancing the model's readability.

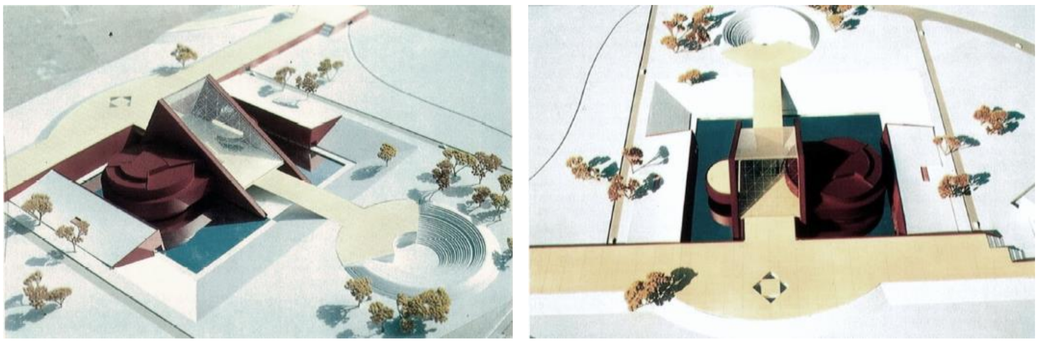

Figure 4.12- 1:200 Scaled model of the CSO Competition by Uygur Architecture.

The model predominantly employs an abstract language, focusing on conveying the project through colors, excluding forms and plants designated for landscaping. Simultaneously, the main halls and foyer detach from direct references, while surrounding blocks rise more modestly from the topography. This illustrates an effort to spotlight the halls and foyer by immersing them in a subsequently added artificial water element. Such an approach accentuates these elements as distinctive components of the overall design.[228] The descriptive model underscores its function as a symbol conveying crucial design decisions, even though it was employed in the concluding stage. It should be noted that it is not a finished product, despite its use in the final stage.

4.3 Design Development Phase Model

The models became more actively utilized in the design development phase, gaining prominence after the completion of the competition process. The shift occurred as the project team adopted a city-oriented perspective, broadening their approach beyond a model-centric one.[229] Post-competition, the team dedicated efforts to enhance perceived deficiencies, leading to significant alterations in the project. Notably, the original disk-shaped concert halls evolved into ellipsoid and spherical structures. Additionally, concerns about Ankara's climate prompted the removal of the open-air amphitheater, replaced by landscaping arrangements.[230] The jury report contained a note that recommended ensuring that "working spaces in the side blocks

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[228] Semra Uygur. "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process," Interview by Şevval Gökkılıç. 3 August 2023.

[229] Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

[230] Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

make use of natural light."[231] Responding to this suggestion, the project team elevated the extremities of the side blocks and created openings in the roof, allowing them to integrate with the landscaping. However, it's crucial to acknowledge that certain planned sections were never executed.

> …The connections to the music path have not been established, which is a crucial element of the site. Serving as the primary access point for the public, the music path links Atatürk Boulevard to Gençlik Park. Unfortunately, it lacks a connection to the courthouse, leaving a significant gap in the project. Additionally, the planned bridge, intended to span Talat Pasha Boulevard and link the music path to Youth Park in the northern direction, remains unbuilt since the competition. This omission contributes to an incomplete project that lacks sufficient integration with the city. Furthermore, the designated Republic Park, part of the CSO area, was not incorporated as planned. Its intended extension to the base of the Opera Bridge has not been realized.[232]

The mentioned changes occurred gradually throughout the project's extended timeline, with continuous model production. Before the alteration to the main concert hall's shape, a model depicting its disc-shaped form was produced by Selahattin Yazıcı, a professional model maker, as shown in Figure 4.13. This model, similar to the competition model, can be categorized as a descriptive model. It has been created to visualize the latest decisions taken in the design development stage in three dimensions, yet it is still not the final product. The model, made of four parts held together by small notches and poured in plaster, is designed to represent the main configuration of the concert hall. It showcased the stage, surrounding levels, circulation between levels, and external floor access—highlighting the concert hall's primary features. In later project stages, considering acoustic requirements and

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[231] T.C. Bayındırlık ve İskân Bakanlığı, "Atatürk Kültür Merkezi Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu ve Koro Çalışma Binaları Mimari Proje Yarışması Jüri Değerlendirme Çalışmaları – Jüri Raporu," 10.

[232] Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

spatial needs, the main concert hall transitioned to an ellipsoid form, and the small hall to a spherical form.

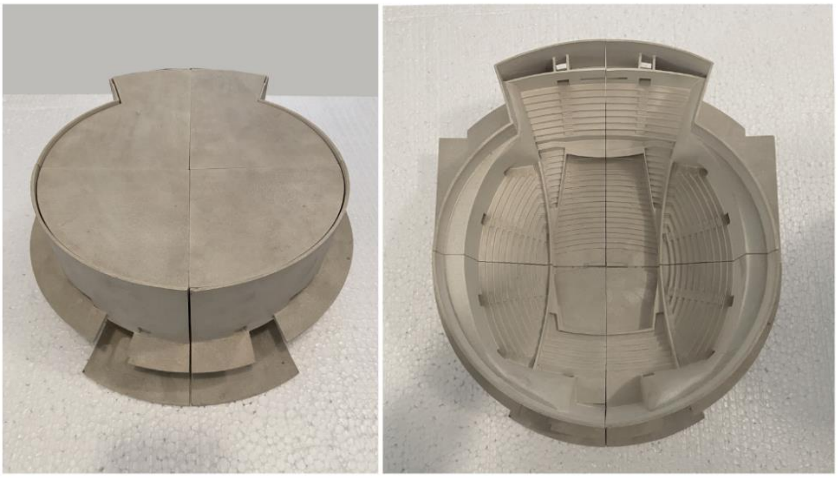

Figure 4.13- Scale model of the main concert hall in disc-shaped form by Selahattin Yazıcı, photography by the author.

Upon observing the Berlin Philharmonic building, Semra Uygur identified shortcomings in their concert hall's spatial design.[233] Subsequently, collaborating with the project team, they generated models that can be produced quickly and easily to redesign the main hall's seating arrangement.[234] The models developed during this phase can be serve within the framework of the evaluative model discussed in preceding chapter. In a broader context, these models assume a multifaceted role, involving the articulation of the designer's thoughts, the generation of new ideas, the facilitation of design decisions, and the shaping of the overall design process. A model chosen from this set was employed to refine the terracing, leveling, and

233 Semra Uygur and Özcan Uygur, "Ankara'yı Değiştiren Projeler 7 – TSMD."

234 Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

transitions around the stage. Subsequent models in the process focused on evolving these elevations and seating arrangements. The variety and abundance of these models, falling within the category of evaluative models significantly contributed to design development. As the design progressed, modifications were applied to the new models concerning detail level, scale, mode of expression, and abstraction level, aligning with design decisions. The project team seamlessly integrated finalized decisions and alterations into the evaluative model.

Figure 4.14- 1:100 Scale CSO Foyer and Concert Halls Model, photography by the author.

Another evaluative model, the 1:100 scale model illustrating the concert halls and foyer of the project highlights this concern. According to the project architects, "1:100 model to show the integrity of the model of the halls and foyer, the dimensions of the glass, the position of the steel to see their interrelationships and also see how similar the visuals we received as a project and the built version are to each other."[235] Various comparisons with the competition model, encompassing all masses, can be made. This more detailed model, addressing specific decisions, transforms the main and small concert halls near the triangular foyer from disc forms to ellipsoid and sphere forms. Both forms are openable and can operate independently of the larger model, facilitating easy adjustments. Cardboard elements delineate the stage and seating arrangements within these plaster models. Annotations and height variations on the cardboard unveil ongoing refinements, such as the elevation design of terraces and the relationship between stairs and terraces. Beyond the halls, the remaining part of the model distinctly portrays the layers within the triangular foyer, inter-floor relationships, circulation, and the structural system throughout. The model's language is explicit and easily understandable, with fine wooden sticks representing the steel structural system of the foyer.

Exclusively categorizing this model under the evaluative model heading would be an oversimplification. After a comprehensive evaluation throughout the entire project stage, the model not only served as an evaluative tool but also functioned as a descriptive model to illustrate the project's final decisions. Furthermore, during the creation of triangular cladding patterns for the concert hall, it was employed as an evaluative model which will be detailed further in subsequent sections. This highlights the versatile utility of the architectural model and serves as substantive evidence for the inclusiveness of the considered classification in the evaluation.

[235] Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

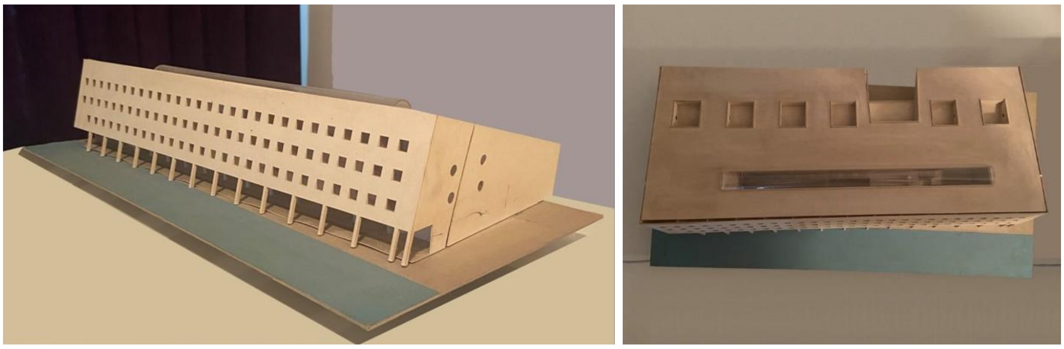

Figure 4.15- 1:100 Scale CSO Choir Building Model, photography by the author.

In the 1:100 scale model of the CSO Choir building, a similar approach to the one mentioned above is observed. Initially serving as an evaluative model influencing the design decisions of the project, it transforms into a descriptive model in the later stages, solidifying and detailing the project team's key decisions. Made of balsa wood, this model expresses in simple language the character of the façade, the relationship between the floors through its openable façade, the interaction of the building with water and the structural system of the building.

Figure 4.16- 1:50 Scale model where level relationships are studied, photography by the author.

After finalizing the seating arrangement in the main concert hall project, evaluative models were generated at various scales to clarify the relationships between different levels. Figure 4.16 displays an evaluative model showcasing a portion of the terracing in the main concert hall, illustrating their adjacency and height relationships. This small-scale evaluative model, aligned with the plans, simplifies the relationship between elevated parts. Similar scale models were employed in different project phases, with design development occurring by transitioning between models at different scales based on distinct design challenges. Another evaluative model scaled at 1:1000 and shown in Figure 4.17, aimed to encompass the vast area of the CSO Concert Hall, understanding its relationship with the environment and regulating the land's connectivity with other areas. Similar to the other model, materials were chosen for easy modeling, devoid of presentation purposes, and the level of detail was tailored for the model's requirements.

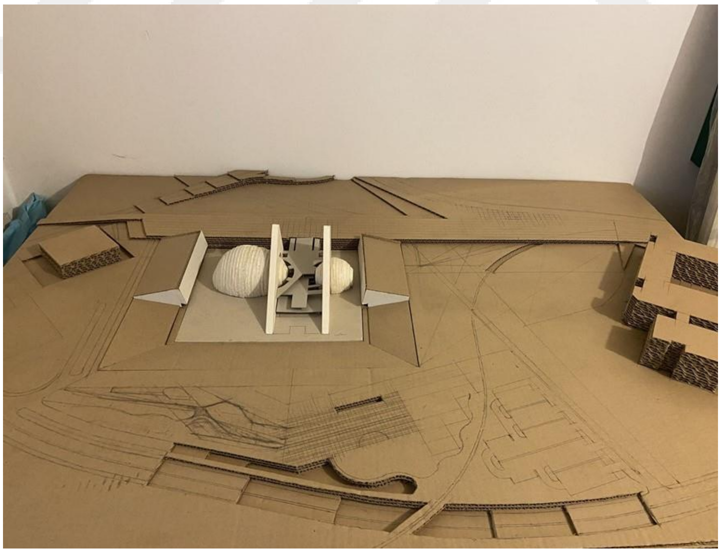

Figure 4.17- 1:1000 Scale model of the land and the mass of the concert halls and foyer, photography by the author.

Another evaluative model, scaled at 1:50, followed a series of experiments with the 1:100 scale model to assess the effect of the elliptical mass ceiling on the space, as shown in Figure 4.18.[236] Similar to other models, its distinct form from the current structure and ease of production indicate that it is not a final element in the design process but rather a model crafted for design improvement. The model is abstract, easily interpretable, and quickly reproducible, utilizing the "sectioning" method without incorporating material differences, colors, or textures. This method involves forming sections perpendicular to each other at equal intervals on the plan, resembling the process of slicing a defined mass or area. This approach facilitates the creation of a curved ceiling, and by increasing the frequency of sections, a volume similar to the existing space can be achieved in models produced using this this method.

Figure 4.18- 1:50 Scale Model of the Main Concert Hall’s ceiling made by sectioning method, photography by the author.

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[236] Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

In the subsequent phases, the design team concentrated intensely on addressing the acoustic requirements, a critical aspect of the design process. Before this project, Turkey had not witnessed the design of concert halls at this scale with such specific requirements. From 1996 to 1999, the team collaborated regularly with Prof. Fasold from the Fraunhofer Institute for Building Physics to refine the acoustic designs of the concert halls.[237] Professor Fasold applied his proprietary techniques and tests to optimize the 1:20 and 1:50 architectural models. Following this, the team digitally tested the design using software from the institute and calculated the expected acoustic features for further refinement. This process unfolded in three stages, with the team applying the method and providing feedback to the project team in each stage, leading to subsequent revision requests.[238]

Figure 4.19- 1:20 Scale model of the main concert hall built for acoustic tests in Germany, Uygur Architecture archive.

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[237] Fraunhofer Institute for Building Physics. "Ankara Konser Salonu Projesinin Maketi Üzerinden Yapılan Akustik Testin Sonuçları," 1999, 1.

[238] Fraunhofer Institute for Building Physics. "Ankara Konser Salonu Projesinin Maketi Üzerinden Yapılan Akustik Testin Sonuçları," 1-3.

In the initial phase of acoustic experiments conducted by the acoustic team in 1996 to determine fundamental acoustic parameters, they produced explorative models of the main and chamber music concert halls based on the architectural plans and sections. Explorative models, which we discussed in detail in previous chapter, are employed at various stages of the design process to experimentally test and scrutinize different ideas, as well as to make informed decisions. Simultaneously, they provide designers with the flexibility to dynamically adjust design parameters and explore potential variations, allowing for a more comprehensive evaluation of the design. In this context, the tests focused on three key parameters.

The first parameter, related to "resonance frequency," concerns the time it takes for sound to travel back and forth within a volume.[239] For symphonic music, the ideal target is within the mid-frequency range of 500-1000 Hz.[240] They calculated and tested resonance frequencies for various sound frequencies to achieve this goal, while also ensuring a balance of volume per person in the hall using structural elements that dampen or reflect sound. The second parameter, "direct sound," focuses on the sound emanating from the stage, distinct from the resonance frequency in a well-executed acoustic design.[241] The aim is to ensure that this sound directly reaches all seats in the hall without grazing past the audience during propagation. The third parameter, "reflection time," represents the initial reflected sound that reaches the ear immediately after the direct and resonance sounds. This

[239] Ak, "Geçmiş İle Gelecek Arasında Bir Kültür Durağı: Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu ve Koro Çalışma Binası," 62.

[240] T.C. Bayındırlık ve İskân Bakanlığı - Ankara, "Atatürk Kültür Merkezi Cumhurbaşkanlığı Senfoni Orkestrası ve Koro Çalışmaları Binaları - İhale Projesi Şartnamesi," 3.

[241] T.C. Bayındırlık ve İskân Bakanlığı - Ankara, "Atatürk Kültür Merkezi Cumhurbaşkanlığı Senfoni Orkestrası ve Koro Çalışmaları Binaları - İhale Projesi Şartnamesi," 4-5.

aspect significantly affects the smoothness of the musical performance.[242] Comprehending the smoothness between the initial and subsequent reflected sounds requires the combined execution of modeling and computer experiments. The acoustic team analyzed the models they created according to these parameters and conducted tests, developing a method to detect a room's impact or acoustic responses.

> These are time histories of the sound pressure at representative seats in the entire hall after impulse sound has been emitted from sources on the podiums (in the main hall also from the organ). The impulse response in a room helps to detect desirable and interfering reflections and contains information applicable for the calculation of room acoustical parameters.[243]

Figure 4.20- Interior of the 1:20 main and chamber music concert hall models built in Germany for acoustic tests, Uygur Architecture archive.

The tests conducted in this process and the explorative models created accordingly helped identify existing problems, as shown in Figure 4.20. Simultaneously, they functioned as a predictive model, optimizing the design by simulating acoustic

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[242] T.C. Bayındırlık ve İskân Bakanlığı - Ankara, "Atatürk Kültür Merkezi Cumhurbaşkanlığı Senfoni Orkestrası ve Koro Çalışmaları Binaları - İhale Projesi Şartnamesi," 5-6.

[243] Fraunhofer Institute for Building Physics, "Preliminary Design Documentation Room Acoustics of Atatürk Cultural Centre Ankara," March 1996, 14.

performance, and as an explorative model, discovering and solving design problems by considering existing parameters. As briefly addressed in the preceding chapter, predictive models are crafted with the assumption that future conditions are foreseeable rather than emergent. While these models typically generate quantitative data, evaluative models often provide qualitative data. These models generally aim to integrate performance criteria into the design process, aiming to optimize both the physical and functional performance of the design. In subsequent stages, the use of models continued in this direction. The acoustic design team conveyed information to the architectural team, highlighting the need for adjustments in the concert halls' design based on issues such as concave sloping surfaces causing sound convergence at specific points due to sound wave reflections.[244]

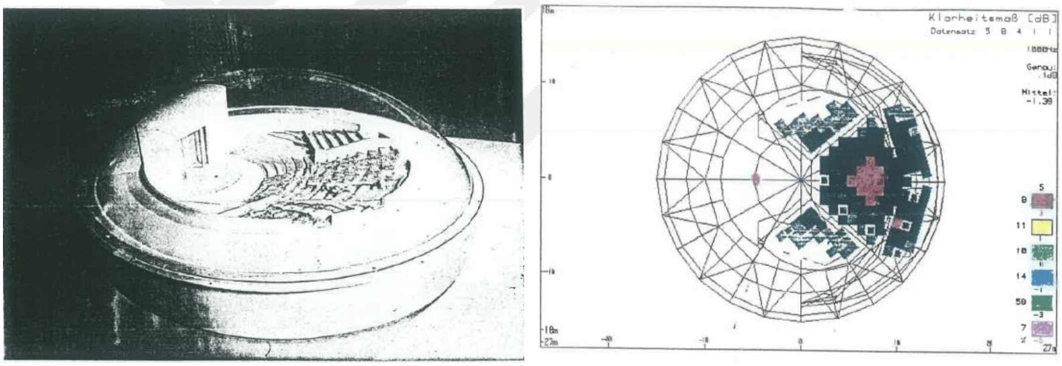

Figure 4.21- Chamber Music Concert hall model made in 1:20 scale and computer test results.

During the second phase of model experiments, the architectural team sent revisions to the acoustic team, who then conducted additional work through model and computer experiments. The acoustic team provided recommendations to the project

[244] Fraunhofer Institute for Building Physics, "Minutes of Meeting," 1996, 2.

team for addressing problematic areas in the main hall, focusing on correcting reflector and diffuser placements.[245] They concluded that the 1:20 scale model of the chamber music concert hall and the acoustic tests conducted on the computer were sufficient. In the next stage for the chamber music concert hall, the acoustic team conducted final tests on the 1:20 scale model of the room and finalized the design decisions.

The test model featured six wooden supporting structures, with plastic sheets representing the main hall's ceiling and the projection zones in the audience section. Removable curved areas of the walls and ceiling facilitated easy modification of the inner hall. Sound was generated by a spark emitter, creating waves to simulate the acoustic conditions.[246] This approach establishes a realistic testing framework for the diffuse, all-directional sound diffusion of an orchestra on a podium. The accompanying computer tests further validated the acoustic adequacy of the chamber music concert hall, ultimately solidifying the design of the concert hall.

After the second stage, the project team incorporated revisions into their design based on recommendations from the acoustic team for the main concert hall. Semra Uygur mentioned in an interview that a visit to Alvar Aalto's converted office building to a museum in Finland highlighted the importance of 1:50 scale section models in truly understanding, making decisions, and advancing the design.[247] Following this insight, the project team created 1:50 scale models for the Main and the Chamber Music Concert Hall, enhancing the design's legibility, precision, and understanding. In this context, these models can initially be described as descriptive

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[245] Fraunhofer Institute for Building Physics, "Minutes of Meeting," 1.

[246] Fraunhofer Institute for Building Physics, "Preliminary Design Documentation Room Acoustics of Atatürk Cultural Centre Ankara," 14.

[247] Köküm, ed., "Atatürk Kültür Merkezi CSO Konser Salonu ve Koro Binaları," 29.

models; however, due to their subsequent use in simulating acoustic tests and shaping the design of the hall, they can also be considered as predictive models.

Figure 4.22- Section Model of the Main Concert Hall and Chamber Music Concert Hall made in 1:50 scale, photography by the author.

When evaluated from descriptive model perspective, the two 1:50 scale section models showcase crucial design elements, such as the stage, stage-floor relationship, terraces around the stage, stair locations within the hall, hall entrances, dressing rooms, structural systems, ceiling designs of the halls, and window openings. Various wood materials in the main model, along with similarly colored cardboard used for the terraces, serve as references to the current wood usage in the hall. In the chamber music concert hall, similar materials were employed, but this time, the stage and seating layout, highlighted in white paint, stand out against the rest of the model painted in gray. While these models initially served as presentation tools, they later played a pivotal role in shaping decisions about the acoustic design in the project, according to Semra Uygur.

> In the acoustic model, particularly within the sections, you can perceive what you desire. However, it is not very easy to get the cross-sections in periods when you cannot enter the cross-sections in three dimensions from anywhere at any time. It is essential to understand the sound movements there, especially about these angles and orientations; we experimented with the late Fasold. He taught us too. He contributed to the detailing.[248]

Professor Fasold, part of the acoustic team, visited Ankara to work on the section models. During this phase, he experimented with the 1:50 scale section models to assess sound propagation within the space. At this point, the model used to simulate the acoustic tests can be characterized as a predictive model. Using a laser pointer, he projected a laser beam from a point assumed to be the sound source on the stage area and placed an aluminum plate at the projected point.[249] These tests helped determine where the sound would be reflected, dampened, and prevented from returning after hitting surfaces.[250]

Figure 4.23- 1:50 Scale organ model for acoustic tests, Uygur Architecture archive.

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248 Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

249 Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

250 Ak, "Geçmiş İle Gelecek Arasında Bir Kültür Durağı: Cumhurbaşkanlığı Senfoni Orkestrası Konser Salonu ve Koro Çalışma Binası," 64.

Additionally, the organ model, crucial in designing symphony orchestra halls, was employed in these tests, as shown in Figure 4.23. Based on the test outcomes, decisions were made regarding the selection and placement of surface materials in the hall, leading to terracing, positioning of reflective panels, and the arrangement of diffusers and reflectors. Transporting the model to the construction site during the building phase enhanced comprehension of the project for those involved. The model served as both a predictive model during the design process and had the potential to be an explanatory model that emphasized the comprehensive nature of architectural models.

In the project's last phase, the architectural team communicated the model-based revisions to the acoustic team. The acoustic team then adjusted the 1:50 scale model according to the changes and conducted tests. Once they confirmed that the acoustic requirements were met, the architectural team proceeded to craft a 1:20 scale model of the main concert hall, following the same approach used for the chamber music concert hall. This step marked the completion of the acoustic design, as shown in Figure 4.24.

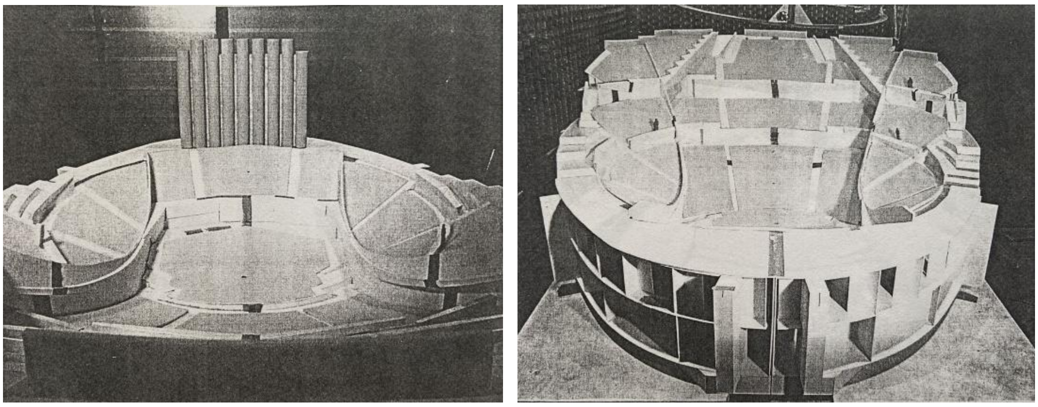

Figure 4.24- Front and back view of the Main Concert Hall model made in 1:20 scale.

4.4 Construction Phase Model

In the years when the project was designed and developed, digital design tools and methods were not widely used in architectural offices. Usually designs were developed using existing methods and tools. Therefore, digital models did not contribute to the process of making the main design decisions for the CSO Concert Hall.[251] They were more influential in making design decisions on a smaller scale and in detail and, for example, adjusting the triangular cladding material, which was placed on the concrete structure of the concert halls, in sizes and configurations suitable for the form of the concert halls.[252] The project's architects used a football as a reference point while creating the triangular coatings in the concert halls.[253] They stated that the regular geometries on the ball provided a reference point that would form the basis of the design and that this geometry laid the foundation of the methodology created for the claddings.[254] After this stage, they tried different variations of this method on plaster models designed for concert halls, as shown in Figure 4.25. Then, to obtain this triangular coating in the main concert hall, they divided the form into eight equal slices and tried to create the curved structure of the form by dividing the divided pieces into triangles of equal size with ropes. However, since they thought this division was insufficient, they increased the number of divisions and continued experimenting with ropes. Based on these experiments, they tried to capture the triangle pattern that would create the closest form to the form of concert halls. In doing so, they tried not to reduce the triangles to very small

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[251] Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

[252] Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

[253] Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

[254] Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

dimensions, to create a pattern, and to remain faithful to the geometry of ellipsoids and spheres.

Figure 4.25- Explorative models made with rope for triangular cladding, Uygur Architecture archive.

The models, which were used to optimize the form of the design to be covered with triangles, can be considered as explorative models in the process. In the manufacturing phase, the construction team modeled these triangular surfaces using parametric methods to match the original. The architectural design team stated that the surfaces created and the models they made by creating a primary parameter during the design process matched to a great extent.[255] In other words, the first model created constituted the primary inputs and the digital model allowed to reach the final product at this point.

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[255] Uygur "Design of CSO Concert Halls and the Effect of the Architectural Model on the Process." Interview by Şevval Gökkılıç.

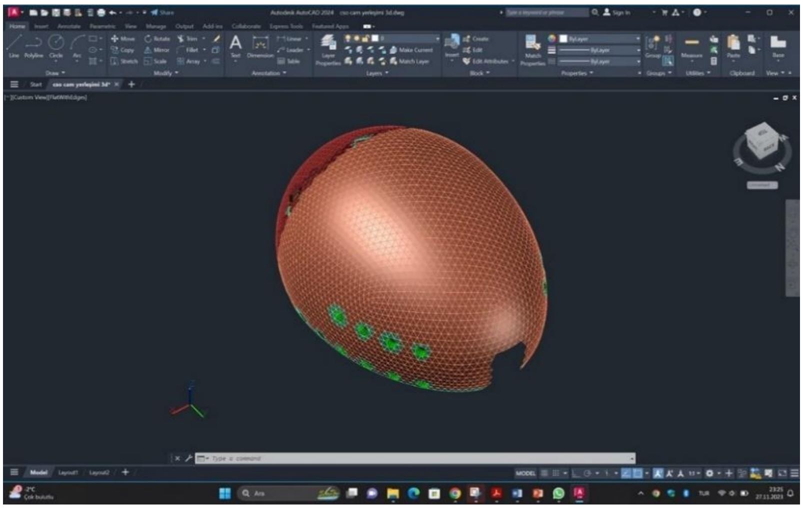

Figure 4.26- Model made to show the frequency of triangular panel cladding of halls.

The last model to be analyzed in this section is the project's point cloud model. The point cloud model created using sound waves is based on the principle of reflection of sound waves to provide a three-dimensional model of the surface or surroundings of an object and is referred to as 3D Scanning or laser scanning.[256] The basis of this process is that a sensor, such as a laser scanner device or an ultrasound sensor, sends laser or sound waves to the surface of the surrounding object, and the sent waves interact with the surface and return back to the sensor.[257] The sensor detects these returning waves. It generates a point cloud (necessary to create the model) containing the surface information of the project depending on the round trip time of the sent wave.

In this project, the technical teams created the point cloud model, including the foyer and concert halls, during the construction phase, as shown in Figure 4.27. The model

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[256] Yuting Li, "Design of 3D Image Visual Communication System for Automatic Reconstruction of Digital Images," *Advances in Multimedia* 2022 (July 30, 2022): 1.

[257] Edward Zhang, Jan Laufer, and Paul C. Beard, "Backward-Mode Multiwavelength Photoacoustic Scanner Using a Planar Fabry-Perot Polymer Film Ultrasound Sensor for High-Resolution Three-Dimensional Imaging of Biological Tissues," *Applied Optics* 47, no. 4 (January 25, 2008): 563.

created can be assessed within the scope of the integrative model, as detailed in the previous section. In architectural practice, the integrative model establishes a tight integration between the physical and digital realms by incorporating CAD/CAM technologies, computational design, and digital fabrication tools. This integrative model created by 3D Scanning provides the opportunity to compare the models created during the project phase with the project created as a result of construction. This way, the point cloud model can act as a control mechanism during the project's progress.

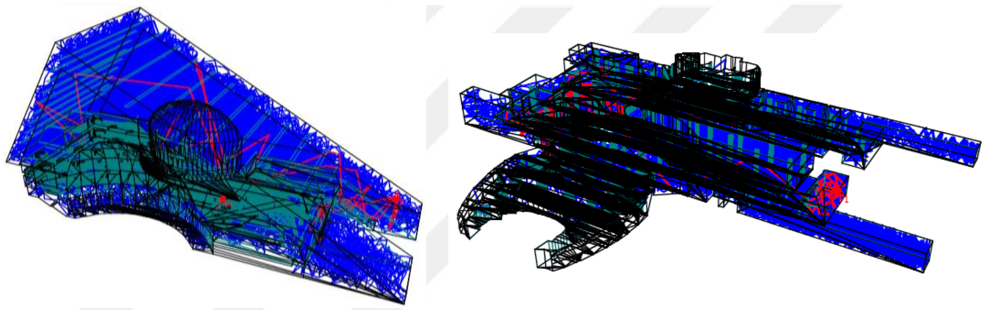

Figure 4.27- Point cloud model of the foyer and concert halls created by sound waves.

In summary, the architectural model is used effectively in a number of phases of the CSO's project, from the competition stage to the development of the design and construction. During this process, the architectural office and other teams have continued to use the model and its variations at different stages, adapting it to their principles. This thesis aims to evaluate the use of the models created during the project in all phases and the purpose behind it. At the same time, how the use of models and methods of model production can differ in a 29-year project process, taking into account the CAD/CAM technologies and computational design methods that have been introduced into architectural practice in this process, is explained through models. The analyzed models are briefly mentioned in which category they can be included in the model classification developed by Dunn, and the models are examined in detail.

CHAPTER 5

CONCLUSION

The second half of the twentieth century witnessed critical transformative changes in architectural practice with the advances in CAD/CAM technologies and the adoption of computational design methods and tools. These changes have redefined the strategy, process, and understanding of architectural models and significantly impacted the design discipline. By examining the new contexts and possibilities that have emerged as a result of these transformations, this thesis aims to show how to re-evaluate the role of the architectural model and how it shapes its potential in the design process. From the examples of architectural models analyzed in the thesis, it can be concluded that the developments in the model have also profoundly influenced the design process and the thinking and creation processes of designers.

The fundamental shift in architectural modeling commenced with the integration of CAD/CAM technologies in the 1980s. CAD technology significantly streamlined the creation and manipulation of intricate structures and design forms in the architectural design process, notably through the use of NURBS curves embedded in computer modeling programs. These advancements have resulted in alterations to the existing structure of architectural models, the production process, and methodologies.

CAM technologies, addressing the complexities introduced by changes in architectural models, encompass manufacturing methods. The introduction of digital fabrication tools, currently making their mark, enables the production of physical models using data extracted from the digital environment. Additionally, digitalization technology facilitates a reversible cycle, allowing a seamless transition from physical to digital. This iterative process intertwines physical and digital models.

The diverse purposes, production methods, and tools in architectural modeling have given rise to various model types. Advances in CAD/CAM technologies, the transformation of computational design tools and methods, and the development of modeling programs have resulted in a progressively indistinct boundary between the physical and digital realms. However, existing model classifications still maintain the distinction between physical and digital models, which may be inadequate in some respects. The thesis aims to reevaluate and broaden the scope of architectural models using Nick Dunn's classification, originally designed for physical models. This classification includes evaluative, predictive, exploratory, and descriptive models, providing a more inclusive and comprehensive framework compared to other architectural model classifications. Additionally, the integrative model will be integrated into this framework.

This thesis focuses on reevaluate the architectural model, scrutinizing its role in the design process and comprehending the impact of CAD/CAM technologies and emerging computational design tools and methods on architectural modeling. The CSO Concert Hall Complex, chosen for its unique characteristics, offers a great opportunity to observe the extensive use of models in the project and track the transformation of the architectural model over time. The initial model of the CSO project, created at the competition's end, serves as a descriptive model representing the final project version in this context.

In the design development phase, various models serve specific purposes. Alongside a descriptive model illustrating the main hall layout, a series of evaluative models at different scales (ranging from 1:1000 to 1:50) were crafted to propel the project and guide decisions. The 1:1000 scale land model emphasizes overall mass and design integrity typical of large-scale models. In contrast, the 1:100 model delves into design details, determining concert hall seating and conveying the general ambiance of the terraces. For the 1:50 scale main hall layout, the detail model and ceiling model offer a specific and detailed perspective. The detail model illustrates terrace leveling, while the ceiling model reveals the acoustic-driven ceiling staggering.

Professor Fasold and his German team developed explorative models for the main hall and chamber music concert hall at 1:50 and 1:20 scales. They assessed acoustic design effects using resonance frequency, direct sound, and reflection time parameters as references. Through tests and digital simulations, these models were refined to optimize acoustic designs. In essence, they were instrumental in enhancing the acoustic design of concert halls. Collaborating with the acoustics team, the architectural design team in Ankara created 1:50 scale section models for the main concert hall and chamber music concert hall. Evaluating these models to concretize decisions made in the project classifies them within the descriptive model category. At the same time, considering their use in simulating acoustic tests by employing aluminum plates and a laser pointer to assess sound transmission and propagation allows them to be regarded as predictive models.

Until the construction phase, physical models served various purposes, with limited use of digital design tools and methods. Typically, digital models come into play when decisions solidify and design details emerge. Following the explorative model using rope for triangular claddings, the technical team employed a parametric design method to create a digital model. They organized positions and configurations of triangular claddings on the ellipsoidal hall, determining assembly details. Additionally, the point cloud model, derived from digitizing the project with 3D scanners and part of the integrative model, intertwines the existing project with the digital production process. This model acts as a control mechanism, facilitating comparisons among different project stages and monitoring project progress.

In summarizing the use of the model in the CSO project, the architectural design team and technical teams employed it in varied processes and for diverse purposes. Each team tailored the model to align with their unique objectives and principles. Thus, the thesis elucidates the transformation of the model's configuration and production methods over the 29-year project, considering the integration of CAD/CAM technologies and computational design tools into architectural practice., taking into account Dunn's reinterpreted and developed classification.

The models generated for the CSO project collectively illustrate the architectural model's inherent flexibility. Influenced by its structure and the transformative impact of digital advancements, the model is adaptable, allowing easy modifications in response to evolving needs and developments throughout the design process. This project underscores that all design teams can utilize the architectural model effectively, fostering increased collaboration and productivity. The model's adaptability aligns with the dynamics of these teams and the overall design process.

Considering the influence of digital developments on the architectural model, it can be anticipated that the model will play a pivotal role in shaping an even more flexible and experimental design process in the future. Subsequent studies can enhance their analysis by incorporating Dunn's classification into the architectural model, comprehensively evaluating changes and potentials from various perspectives. This forward-looking approach ensures a clearer understanding of how the architectural model will continue to evolve and contribute to the future landscape of design practices.

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APPENDICES

A. Interview Questions

Questions Specific to Architectural Model

1- How do you start the design process and how does model making progress in this process? How do you maintain a balance between the physical and digital model and do you go back and forth between the two in this process?

2- When we analyze the projects of your office, we observe that architectural models are used. At what stage and for what purposes do you start making models? Do you see the model as an element that manages the design process? Do you prefer to make specialized models such as scale models, prototypes, detail models?

3- How do you go about digital modelling? At what stage do you start digital modelling and which programs do you usually use for modelling?

4- Do you use digital fabrication tools and methods (laser cutting machines, 3D printers, CNC machining machines, 3D scanners, etc.) in your office to produce architectural models? Considering that these digital fabrication tools usually use a digital model, can we say that this architectural model functions as a control mechanism in the design process in your office?

5- Could you describe how you organize the different teams and departments to understand the internal structure of your office? For example, do you have a team specialized in model making, or do you have departments dedicated to other disciplines such as digital modeling?

Questions Specific to the CSO Concert Hall Complex

6- You mentioned in a panel that you participated in many different competitions before entering the CSO Concert Hall competition and that you could not achieve the results you wanted. Mr. Özcan mentioned that you realized your progress in this process and even went through a process of making a lot of models. Can you tell us more about this process and your relationship with models?

7- In the CSO competition, can we say that the model is at the forefront in describing the project? If so, can you explain how this model-oriented approach affects the design process of the project?

8- One of the unique and prominent aspects of the CSO Concert Hall competition project is that the building creates its own fiction within a collapsed volume and creates a reference system. We clearly observe this in the competition model. Did the model have an impact on the design of this architectural expression?

9- When looking at the competition model of the project, there are many design decisions that were changed in the original project. Changes such as changing the halls from circular disk-like forms to simpler Euclidean forms such as eggs and cubes, canceling the open-air amphitheater and replacing it with landscaping and removing the music path were made at which stage of the project and on what basis?

10- Within the scope of this project, architectural model making seems to follow a dynamic and repetitive process. How do you evaluate the interaction between the physical and digital model throughout your design process?

Questions Specific in the Project Design Process

11- After seeing the Berlin Philharmonic Concert Hall, how did your decision to redesign the CSO halls affect your design process? Can you explain your decision to choose one of the seventeen different designs and seating plans and the evolution of the masses in the form of circular disks into egg and sphere forms during this selection process?

12- The 1:50 scale sectional models that will form the final version of the main hall were tested with a laser pointer by the acoustic team from Germany. Could you explain how the feedback obtained during this process influenced your design process and how these models contributed to the digital model? Also, what kind of progress was made during this process and whether the focus was on changing the form of the project or the material to be used? In this context, how do you assess the role of the architectural model in shaping your design?

13- Can you explain the purpose of the sectional model in 1:50 scale and at which stage of the project this model is used?

14- Could you give information about Professor Fasold's 1:50 scale model, the acoustic tests performed on it and the methods used?

15- When transferring the egg and sphere-shaped form you made to the digital environment, did you encounter the difficulties of modeling in the computer environment? Did you use a 3D scanner or other digital design tools in such cases? How did the use of these tools affect your design process? Did it facilitate the conversion of the form into a digital model?

16- You have successfully tested an inflatable balloon mold system that has not been tried before in Turkey. We observe the same method in a few other places around the world. How did you describe the process and was the production based on the digital models you sent to the manufacturer?

17- In which stage of the project and for what purposes did you prepare the 1:100 scale models including the entire CSO Concert Hall? Could you also give information about the different material choices in these models, especially the use of materials such as plaster?

18- Could you tell us about the triangulation method you used to create the ellipsoid and spherical shapes of the concert halls? How did your process of transitioning this to digital progress?

19- Could you give information about the parametric design method used to create the ceiling model of the spherical Chamber Music Concert Hall and why you preferred this method? Also, at what stage of the project process was this ceiling model created and for what purpose?

B. Approval of Human Research Ethics Committee

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13 EKİM 2023

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Doç. Dr. Esin Kömez Dağlıoğlu

Danışmanlığını yürüttüğünüz Şevval Gökkılıç'ın **"*Mimari Modelin Araç Olarak Yeniden Değerlendirilmesi: Ankara Cumhurbaşkanlığı Senfoni Konser Salonu Örneği*"** başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek **0441-ODTUİAEK-2023** protokol numarası ile onaylanmıştır

Bilgilerinize saygılarımla sunarım.

Başkan

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