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Architectural Scale Models in the Digital Age design, representation and manufacturing

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PREFACE

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In the age of advanced digital technology and parametric architectural design, making physical models characterised by complex geometric forms and structural connections is a real challenge that requires adopting new approaches and applying new techniques. Physical models can be used to test and verify complex geometric forms generated with the help of virtual media, as well as to monitor their practical application. The complexity of modern architectural design requires mastering new modelling techniques, which opens a new dimension in the field of scale modelling, which is what *Architectural Scale Models in the Digital Age* is about. It is aimed at anyone eager to learn the basic and advanced scale modelling techniques based on examples from the field of scale modelling in contemporary architectural design.

This book is intended to fill a gap in the field of contemporary scale modelling. It focuses on connecting the main geometric principles and underlying processes of the generation of architectural forms used today with the fabrication of architectural scale models. It is divided into seven chapters, and in terms of the main topics covered, it gives a brief history of the development of the art of scale modelling, lists some possible uses of scale models in architecture and related disciplines, and presents various digital–technology–based techniques used to build physical models.

The Introduction presents the basic terms and notions used throughout the book and defines the role of the scale model in the process of architectural design development in the digital age. A brief historical overview given in Chapter 2 shows that not only have scale models always had a crucial role in construction, but their use and purpose have also

reflected the cultural and historical circumstances in which they originated. Providing a short historical background is, therefore, highly relevant, as it indicates the emergence of the new, changed circumstances affecting scale modelling in the age of digital technologies.

Chapter 3 identifies a wide range of the uses of scale models in architecture and related disciplines, explaining the goals, purposes and reasons for their building today. Scale models are classified according to a number of criteria, ranging from purpose to structural form, with various cases presented to illustrate the current circumstances in which new fabrication techniques play a key role in their realisation. In connection with this, the introduction of new tools has had a major impact on the technology of physical model building.

Making scale models today requires much more than mere manual skills because the geometric structures built now are far more complex than those built before the introduction of digital technology. However, this has not ruled out the traditional ways of using manual tools, which is why an overview of both digital and traditional modelling kits and materials is given in Chapter 4.

Chapter 5 discusses the methods and processes of manufacturing scale models and scale model components, along with how they are displayed, transported, lit and photographed. It focuses on the geometric analysis of the model structure, more specifically, on the discretisation of complex forms for the purpose of preparing parts for fabrication. Basic instructions are given on how to master the principal cutting and assembly techniques.

As a follow-up, Chapter 6 contains an overview of software tools and digital fabrication techniques. It presents an array of the software most frequently used in architectural scale modelling for generating complex geometry designs. It also briefly introduces different CNC machines and rapid prototyping techniques used for model realisation.

The final chapter of the book, Chapter 7, contains five tutorials illustrating different ways in which digital technologies can be used for investigating the form in architectural design, up to the fabrication stage. Each of the tutorials begins with the theoretical explanation needed to understand the

fundamental geometric principles underlying the applied procedure of generating and manufacturing the scale model.

Each chapter of *Architectural Scale Models in the Digital Age* ends with a reference list which may be used to further explore the discussed topics.

What the readers have before them is the result of the authors' long practical experience of studying, designing and building scale models. Original visual materials have been included to illustrate each chapter. Many of the models presented were also built and photographed exclusively for the needs of this book.

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1 INTRODUCTION

1 INTRODUCTION

Scale modelling is a discipline that covers the construction of physical models of objects, maintaining a particular scale or relative proportions. Scale models are built for many reasons. They are made by professionals, passionate collectors and amateurs who build them as a hobby. From the professional point of view, scale models are used for different purposes. Engineers use scale models to test the performance of a particular object prototype; in the film and theatre industry they are used for scenography, whereas architects use them to prove and evaluate their ideas in different stages of project development. This book is dedicated to scale modelling as a specific field of architecture.

In the age of advanced digital techniques and parametric architectural design, making physical models of complex geometric forms and their complex structural connections is a real challenge that requires a completely new strategy, technology and technique in scale modelling. Only by using physical models can we test and verify complex geometric forms generated with virtual media, as well as control their use value. The complexity of modern architectural design requires mastering new techniques of modelling, which opens a new dimension in the field of scale modelling, which is what we address in this volume.

The word model is derived from the Latin *modus* and *modulus*, which essentially means measure [1]. The Latin terms *modus* and *modulus* have influenced the development of the wider meaning of the word model in different contexts, such as pattern or form. The architectural connotation of the term *modulus* was first used by a Roman architect, Marcus Vitruvius Pollio, in his treatise *The Ten Books on Architecture*. The Italian word *modello* was frequently used

in the Renaissance period and it referred to the making of rough studies and detailed construction architectural models. It was later accepted in other European languages as well.

Different terms relating to scale modelling are found in different languages. The French word for model is *maquette*, whose original meaning was: small, preliminary model whose primary role is to visualise an idea in the architectural and artistic form [2]. The word *maquette* emerged in French in the late nineteenth century, and is derived from the Italian word *macchietta*, which means a sketch.

Scale modelling is an integral part of a broader process of architectural design and requires the ability to comprehend the relation between a designed object (the project) and its materialisation in a particular scale and material (the scale model). Methods and techniques of scale modelling enable us to assess, correct and implement a project from its earliest stages (the initial study of the form) to the conceptualisation and materialisation of the project (the main project). Different phases of design can all be identified through different approaches to building scale models, because they provide a view of each of those phases and offer a three-dimensional and spatial preview. Scale modelling strategies have a broad range of practical applications in architecture and urbanism. The building of scale models requires different techniques and procedures, as well as materials and tools. The primary advantage of using scale models is the ability to preview and identify a tangible form in material space. The material representation of the form enables the architect/designer to interact with it directly. The advantage of a scale model compared to, for example, a computer-generated drawing, or model, is that it is built in the course of the development of a project, it is part of the material construction during a dynamic working process. This process brings all segments of the project into perspective and they may be used to forecast the functioning and behaviour of the structure presented by the scale model or, if necessary, for corrections and improvements. The advantage of a material scale model compared to a computer-generated model is best seen in its tangibility – unobstructed simultaneous viewing by multiple observers from different angles. Since scale models are made of particular material and they have dimensionality that is perceived directly, no additional equipment is needed (a computer) and we can say that a

scale model itself is tactile. This does not mean that digital modelling does not have any advantages compared to scale modelling, nor that its importance should be underestimated.

Computer modelling and scale modelling are in fact inter-related disciplines that use different strategies, techniques and methods to achieve the same goal – the original and quality presentation of an architectural and urbanistic work to a prospective client/audience. In fact, these two disciplines are becoming even more interrelated with the development of digital technologies and related disciplines, so that, eventually, they will become fully integrated. Computer models will be used to accurately define the materialisation of all the elements of a scale model, which is explained in this book. Scale modelling is not only learned from relevant literature, it is here to point out and help avoiding beginner's mistakes, and to choose the right technique or material. Scale modelling is a skill that is mastered through practical work and studying many available implemented examples that successfully represent preceding or derived objects. Before we continue with a more detailed explanation of the basic principles of modern scale modelling, the next chapter gives a short overview of this discipline through its historical development. It also discusses the influence of digital media on the further development of scale modelling in contemporary architectural design.

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- [2] Dictionary and Thesaurus – Merriam–Webster Online (2012) Definition of Maquette. <http://www.merriam-webster.com/dictionary/maquette>. Accessed 12 October 2012

2 SCALE MODELLING IN ARCHITECTURE

2 SCALE MODELLING IN ARCHITECTURE

From their beginnings to the present day, scale models have reflected the cultural and historical contexts in which they were made. Scale models from different time periods can be very similar with regard to construction techniques and used materials, but the development of scale modelling as an architectural representation technique requires the consideration of their specific purpose, type and the temporal context in which they were made. Despite the development of digital techniques, construction of analogue models has not been curbed. On the contrary, digital techniques have led to even greater development and use of analogue models.

In this chapter a brief historical overview of architectural scale modelling is given in order to show to what extent temporal context and the use of existing technology reshape the process of scale modelling and architectural design. Furthermore it is shown that digital technology have shifted and changed process of design representation and thinking through scale models.

2.1 A Brief Overview

The first scale models are believed to be as old as the first drawings and, just like drawings, they have symbolised the relation between the human imagination and its symbolic representation. The purpose and use of the first scale models was different compared to their modern day application. The role of scale models as a method of testing the architectural design ideas in the modern sense is just a little more than half a millennium old.

The oldest surviving examples of scale models from ancient Egypt have been found in ancient tombs and pyramids, dating from the second millennium BC. The most significant of dozens of models found in Egyptian tombs is the one from the tomb of Mehenkwtetre [4],[11] the construction foreman at the mortuary temple of Mentuhotep, dating back to the twentieth century BC. The scale models found in Egyptian tombs were built out of religious belief in the afterlife. Complete sets of figures were made to serve the ruler in the afterlife. The Egyptian models depict everyday life and people's ideas about heaven. Scale models of architectural objects were usually made sectioned or without a roof, so that their interior could be seen. Models were skilfully carved in wood or moulded in clay with a large number of details, such as door frames, window frames and stairs. The structures themselves, as well as figures inside, were painted in vibrant colours. Preserved models from ancient Egyptian tombs were not only built because the architects wanted to render the desired shape of the building for themselves and the ruler¹, but because they also had great spiritual value for their "clients" – they were a door to the serene and everlasting life after death. The cult of death and the religious system enabled the preservation of these ancient models that go back several millennia.

Greek civilization was based on a different cultural and religious system, which affected the architectural profession, the position of architects in society, and their way of thinking, designing and building. The cult of death existed in ancient Greece too, but did not have so many dramatic consequences on Greek culture, philosophy, religion and architecture. Architects did not have as high a position in society as they had in ancient Egypt, and building regulations were strictly defined, especially for public buildings and temples. Proportional relationships between the architectural elements of temples were defined by the building style. Architectural scale models did not have as much significance as the preserved specimens from the Egyptian tombs, which is why very few have been preserved. The preserved scale models were crudely made, without too much attention paid to the scale and detail, but with enough information about the character and type of the object. They were made of clay or limestone, with visible

¹ *It is assumed that the architects made scale models of different objects in order to present their ideas to the Pharaoh, but there is still no physical evidence.*

traces of colour. The ancient Greeks had a special name for scale model: *paradeigma*, hence the word *paradigm* with a similar meaning. The Greek *paradeigma* did not represent a faithfully scaled replica of the original, but more a pattern, a model used to physically present the information about an architectural idea. In a similar context, *paradeigma* represented a model for the study of a specific architectural element, such as a triglyph or a capital [6],[8].

The influence that Greek civilisation had had on Etruscan culture and later Roman civilization was due to its colonial expansion across Southern Italy and Sicily until the seventh century BC. The Etruscan temples that were built of wood have not survived, except the foundations, but the important insight into the influence of the Greek temples on Etruscan construction is evident in the ceramic scale model of an Etruscan temple found in a tomb at Vulci. The model itself was not accurately made, but it reveals the basic features of an Etruscan temple.

Roman architecture largely relied on the Greek and Etruscan heritage while creating an architectural language based on new, alternative aesthetic principles and building technologies. The meaning and use of scale models was reinterpreted and adapted to allow for new engineering achievements. We know that the job of an architect in Roman times did not only imply designing and building houses, but also the construction of various devices, such as hydraulic pumps or siege catapults, as well as the designing of canals, dams, bridges, and seaports.

A book by the Roman architect Marcus Vitruvius Pollio, *De Architectura*, bears witness to the new significance that scale models had for the architects of that time. In the last chapter, describing the making and use of various devices (Latin: *machine*), Vitruvius writes about scale models as a tool for the testing of engineering concepts, but also as one of the methods used to convince the public of the validity and correctness of an idea – object [18]. The engineering spirit that the Roman architects had influenced the birth of a new vision for the use of scale models. At the same time, the Roman architects were aware of the downsides of scale models: the capacity and mechanical properties of materials were not always directly proportional between the scale models and the planned building.

After the division of the Roman Empire, the influence of Christianity began to spread over Eastern and Western Europe. The church had a very strong influence in the Middle Ages, which had a particular impact on architecture. Churches were "houses of God", architects were "God's builders" and scale models of churches had symbolic connotations. Therefore medieval frescoes often portrayed the rulers or founders together with a scale model of the church they were building. The church itself was a symbolic representation – a model of God's house, while the ruler/founder holding a scale model was a representation of the secular rule of the people.

Until the end of the Middle Ages, scale models remained the primary means of expression for architects. Architectural drawings were rarely made in this period, nor were they often made in previous periods². According to certain medieval sources, foundations of large buildings and cathedrals were drawn in actual size on the site, while details such as windows or rosettes were carved or engraved in actual size on the walls of the building [1]. Architects tested their ideas with scale models, which remained a common practice during the Renaissance period.

Although linear, the geometric perspective is one of the most important inventions from the Renaissance period, which had a major impact on the visual arts and the shaping of the European culture in general, but scale models remain the dominant form for the representation of space in architecture.

The Renaissance architects showed great interest in scale models, discovering new goals that could be achieved by using them. It was in the Renaissance period that scale models were first given the modern meaning they have today. In the first theoretical treatise on architecture from the Renaissance period, *De Re Aedificatoria* (1452), Leon Battista Alberti discusses the use and significance of scale models. In this book, Alberti explains that the use of scale models permits the study of the relationship between a building and its surroundings, different parts of the structure, shape

² A very small number of medieval drawings made by architects have been preserved until today. The surviving architectural drawings usually show a portion of a façade or architectural details.