Architectural Modelmaking

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SECOND EDITION

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Introduction

Why we make models

The representation of creative ideas is of primary importance within any design-based discipline, and is particularly relevant in architecture where we often do not get to see the finished results, i.e. the building, until the very end of the design process. Initial concepts are developed through a process that enables the designer to investigate, revise and further refine ideas in increasing detail until such a point that the project's design is sufficiently consolidated to be constructed. Models can be extraordinarily versatile objects within this process, enabling designers to express thoughts creatively. Architects make models as a means of exploring and presenting the conception and development of ideas in three dimensions. One of the significant advantages of physical models is their immediacy, as they can communicate ideas about material, shape, size and colour in a highly accessible manner. The size of a model is often partially determined by the scale required at various stages of the design process, since models can illustrate a design project in relation to a city context, a landscape, as a remodelling or addition to an existing building, or can even be constructed as full-size versions, typically referred to as ‘prototypes’.

Throughout history, different types of models have been used extensively to explain deficiencies in knowledge. This is because models can be very provocative and evoke easy understanding as a method of communication. Our perception provides instant access to any part of a model, and to detailed as well as overall views. Familiar features can be quickly recognized, and this provides several ways for designers to draw attention to specific parts of a model. A significant advantage of using models is that they are a potentially rich source of information – providing three dimensions within which to present information, and the opportunity to use a host of properties borrowed from the ‘real’ world, for example: size, shape, colour and texture. Therefore, since the ‘language’ of the model is so dense the ‘encoding’ of each piece of information can be more compact, with a resulting decrease in the decoding time in our understanding of it.

Members of the Office for Metropolitan Architecture (OMA), with a design development model for the Universal Headquarters, Los Angeles.

In order to understand architecture, it is critical to engage in a direct experience of space. As Tom Porter explains in The Architect’s Eye, this is ‘because architecture is concerned with the physical articulation of space; the amount and shape of the void contained and generated by buildings being as material a part of its existence as the substance of its fabric’.1 The organization and representation of space is not the sole domain of architecture – other visually orientated disciplines such as painting and sculpture are equally engaged with these tasks, but on different terms. The principal difference between these disciplines lies in a concern with the function of the final ‘product’. In the case of painting or sculpture, such purposes are typically visual alone. By contrast, the creative process in architectural design often results in a building that has a responsibility to address additional concerns such as inhabitation, climatic considerations and maintenance. The considerable amounts of expense, resources and time invested in building architecture at its full-size scale demands that we need to be able to repeatedly describe, explore, predict and evaluate different properties of the design at various stages prior to construction. This raises an important issue concerning modelmaking since, as with other modes of representation in architecture, it is not a ‘neutral’ means for the conveyance of ideas but is in fact the medium and mechanism through which concepts and designs are developed. This point is reinforced by Stan Allen writing about architectural drawing, as he suggests it is 'in some basic way impure, and unclassifiable. Its link to the reality it designates is complex and changeable. Like traditional painting and sculpture, it carries a mimetic trace, a representational shadow, which is transposed (spatially, across scale), into the built artefact. Drawings are, to some degree, scaled-down pictures of buildings. But to think of drawings as pictures cannot account either for the instrumentality of architectural representation nor for its capacity to render abstract ideas concrete.'2 Considered in this manner, the discrimination on behalf of the modelmaker to decide which information to include, and therefore which to deliberately omit, to best represent design ideas becomes crucial.

As practitioners, architects are expected to have a highly evolved set of design skills, a core element of which is their ability to communicate their ideas using a variety of media. For the student learning architecture, the problem of communicating effectively so that the tutor may understand his or her design is central to the nature of design education; spatial ideas can become so elaborate that they have to be represented in some tangible form so that they can be described, explored and evaluated. This situation becomes complicated since 'crosstalk occurs between different methods of communication so that they form a coherent presentation' but they may also contradict one another.3 However, this delivery of ideas is not simply for the benefit of a tutor or review audience. The modelling of an architectural design has important advantages for a student during the design process as he attempts to express his ideas and translate them, allowing the designer to develop the initial concept. However, it is important to emphasize the performative nature of models at this point since they, as with other media and types of representation, are highly generative in terms of designing and are not simply used to transpose ideas. This establishes a continuous dialogue between design ideas and the method of representation, which flows until the process reaches a point of consolidation. This latter point is important and something we shall return to again and again throughout the course of this book.

The team at the in-house modelmaking facility at Rogers Stirk Harbour + Partners works on a 1:200 model of The Leadenhall Building, London.

Antoine Predock working on a clay model for Ohio State University's Recreation and Physical Activity Center, en route to a project presentation, 2001. On his website, Predock refers to the importance his clay models have within his design process: 'compared to a drawing on paper, the models are very real; they are the building'.

Fundamentally, the physical architectural model allows us to perceive the three-dimensional experience rather than having to try to imagine it. This not only enables a more effective method of communication to the receiver – such as the tutor, the client or the public – but also allows the transmitter – such as a student or architect – to develop and further revise the design. As Rolf Janke writes in the classic Architectural Models, 'the significance of a model lies not only in enabling [the architect] to depict in plastic terms the endproduct of his deliberations, but in giving him the means – during the design process – of actually seeing and therefore controlling spatial problems'4; while Criss Mills asserts that 'models are capable of generating information in an amount of time comparable to that needed for drawing, and they offer one of the strongest exploration methods available'.5

At this stage it is worth expanding further upon the use of a model by a student of architecture, since it is a common assumption that an architect has sufficient experience and skills to employ a variety of design processes and methods of communication as required by the task in hand. When developing design ideas as a response to studio-project briefs, the employment of various methods of communication is a prerequisite for the thinking process necessary for a student to deal with the complexity of architectural design. Unlike the final presentation type frequently found in architectural practice and exhibited to the public, in educational environments models and drawings are not seen as end products in order to 'sell' the solution, but as vehicles for thought or tools with which ideas can be developed and expressed. More specifically, the use of different communication methods encourages greater exploration of a student's ideas. This is because different visualization methods and techniques provoke different thought processes, and inspire greater insight during the design process. Every model has a specific purpose and user, as it is not possible to embody all potential design ideas within a single one. In the first instance it may function purely as a design tool, allowing the designer to explore a particular idea or analyze successive developments. Secondly, it may be used to present or demonstrate design ideas to an audience – allowing others to share the designer's vision. Whilst it is tempting to rigidly classify different types of model, and indeed this book will look at the full spectrum available, it is apparent that most models are dynamic in nature and have at least a dual function depending on who is using them and why and when they are employed throughout the design process. Marcial Echenique first described the difficulty of architectural model classification in his essay of 1970, 'Models: a discussion', wherein he defined a model as 'a representation of reality, where representation is the expression of certain relevant characteristics of he observed reality, and where the reality consists of the objects or systems that exist, have existed, or may exist.'6 This short introduction seeks to demonstrate the significance of models not only as aids in the decision-making process, but also as a means of generating, searching and investigating creative impulses. Before moving onto the main part of the book there follows a brief overview of the role of the model in history, an explanation of the format of the book, and some basic information on the type of equipment necessary to begin making models.

1:20 model of a temporary pavilion by 6a architects in the process of being made. The intricate pattern directly replicates that of the final intervention and uses the same process of manufacture, albeit on a smaller scale.

A variety of explorative models by Grafton Architects for their Università Luigi Bocconi scheme in Milan. Note the range of materials used and their resultant differing effects on the spaces within the models.

Presentation model for UNStudio's design for the Columbia Business School, New York, under construction (left) and the finished result (right).

A modelmaker at Alsop Architects in the process of assembling a presentation model for the CPlex project, West Bromwich (the completed building is known as The Public).

A quickly produced design-development model made by UNStudio during their process of composing the geometry for the Mercedes-Benz Museum in Stuttgart. Models such as these provide architects with flexible tools, through which they can explore ideas in a fast and effective manner.

The number of models made to investigate design ideas obviously varies from project to project, but a series of models that clearly communicate the process through which a concept has evolved are not uncommon, as shown here.

Series of design-development models for Coop Himmelb(l) au's SEG Apartment Tower, Vienna, illustrating the increasing articulation of the tower's form in order to maximize its passive-energy performance.

Explorative model for Daniel Libeskind's design for the Jewish Museum, Berlin. This model was made to examine the relationships between the voids of the building and its powerful generative geometry.

The effect of lighting upon a model and how it communicates its ideas is beautifully illustrated by this design for a new urban vision, FREE city, by the practice FR-EE (Fernando Romero), which uses different colours to indicate the various zones and networks. The master plan synthesizes three existing urban typologies: the radial city, the hexagonal connection and the urban grid. The scheme organizes the city in a radial manner, creating a hierarchical zoning strategy and allows for continuous growth in all directions. A rectangular grid is superimposed in each sector and hexagonal rings optimize the proximity between the various axes.

Competition model for the Fourth Grace, Liverpool, by Rogers Stirk Harbour + Partners, 1:500, illustrating the urban scale of the scheme.

Sectional model for CPlex project by Alsop Architects, investigating internal characteristics of the design.

Coop Himmelb(l)au's presentation model for Museum of Knowledge, Lyon, France, 2010-14. Note the careful use of lighting within the model to enhance the effect of the project's sculptural forms and their interplay with space.

Series of design development models for the Burj Al Maydan Tower, Dubai by Morphosis which sought to integrate an iconic design with public space. The top two images show a card model used to refine the initial form. The bottom left image illustrates various iterations of the design as 3D powder prints, some with acrylic blocks for contrast. The final image demonstrates the evolved design placed into a massing model of the context. All these are tools for the design team to think about the building's geometry and form.

The larger final model of the proposed scheme enables more detailed elements such as the translucent façade and intricate structural lattice of the curved wall to be appreciated.

The presentation model of the Absolute Towers, Mississauga, Canada, designed by MAD Architects. Standing at 170m (558 ft) and 150m (492 ft) tall respectively, the towers consist of oval-shaped floors but with each storey incrementally rotated to give both buildings a curved and twisted outline and aims to provide each residential unit with 360 degree views. The design also features a continuous balcony that wraps around the whole building, eliminating the vertical barriers traditionally used in high-rise architecture. Far right: the completed building.

A brief history

The first recorded use of architectural models dates back to the fifth century BC, when Herodotus, in Book V, Terpsichore, makes reference to a model of a temple. Whilst it may be inspiring to believe that scale models were used in the design of buildings from ancient civilizations, this appears highly unlikely. This is because the inaccuracies in translating scales at this time would have resulted in significant errors, but also because designs in antiquity were in fact developed with respect to cosmic measurements and proportions. Despite this, however, the production of repetitive architectural elements in large quantities was common, and the use of a full-size physical prototype as a three-dimensional template for the accurate replication of components such as column capitals was typical.

Architectural design continued in a similar manner through to the Middle Ages. Medieval architects travelled frequently to study and record vital proportions of Classical examples that would then be adapted in relation to a client's desires. Although models were not prevalent at this time, they would occasionally be constructed to scale from wood in order to enable detailed description to the client as well as to estimate materials and the cost of construction. This was largely because two-dimensional techniques of representation were comparatively under-developed. Therefore, despite the very early recording of an architectural model, there is no substantial evidence to suggest that such models were used again until this point: 'only since the fourteenth century has this form of representation become relevant to the practice of building; we know that a model of the Cathedral of Florence was made towards the end of the fourteenth century.'7

There appears to be an explanation for this emergence of the scale model as a method of design and communication. Unlike his predecessor and Gothic counterparts, the Renaissance architect had no equivalent frame of reference as he derived his style from fragments of Graeco-Roman architecture. The only method of checking the feasibility of these new architectural concepts was to build exploratory models. These models were even, when necessary, made using the actual materials proposed for the building itself. Therefore, from the early Renaissance on, an increasing number of architectural scale models exist, illustrating not only buildings but also urban districts and fortifications. Welldocumented architectural models included those of the church of St Maclou in Rouen from the fifteenth century, the church of ‘Schöne Maria’ in Regensburg of 1520 and the pilgrimage church of Vierzehnheiligen by Balthasar Neumann, circa 1744. Such scale models were large prefabrications constructed in wood, plaster and clay. In contrast to the primitive structural models of the Middle Ages, these new models were expensive and extravagant – frequently including pull-away sections and detachable roofs and floors, both to allow internal viewing and to aid the development of the design.

During this period, the proliferation and status of the architectural scale model grew significantly. It not only complemented drawings, but also frequently became the primary method for the communication of design ideas in architecture. In particular, specialized models were made as part of the design process for major building commissions. Two such important examples were the domes of the Florence Cathedral by Filippo Brunelleschi and St Peter’s in Rome by Michelangelo. Brunelleschi primarily designed in three dimensions and used models extensively – whether as elaborate 112-scale wooden constructions for the benefit of the client, or quickly carved in wax or even turnips to explain structural ideas to the builders. Domenico Cresti di Passignano’s Michelangelo Shows Pope Paul IV the Model of the Dome of St Peter’s, 1620, perhaps best illustrates the importance of the model within this period. This painting depicts the architect using a large wooden model of St Peter’s Basilica to explain and sell his ideas to his papal client. The significance of the model as a method of communication is evident in the way the model is represented in the painting. The high quality of workmanship apparent shows how the proposed building could exist at full size. The model is the focal point of a conversation between the architect and the client, who will evaluate the design from it. This painting also signals a change in the function of the model during this period, from a vehicle for exploration to a descriptive tool used to explain a design.

Inspired by Antonio da Sangallo’s huge wooden model of St Peter’s in Rome – started in 1539 and, at 124 of the full size, taking several years to construct – Sir Christopher Wren commissioned the Great Model for his design for St Paul’s in London. Built between 1673 and 1674 by a team of craftsmen, the Great Model was accurately made at a scale of 1 inch to 18 inches, enabling the client and prospective builders to walk inside the model's 18-foot-high interior. However, it is evident that Wren considered the model to be for the benefit of the client and builders rather than for his own design-development purposes as he wrote: 'a good and careful large model [should be constructed for] the encouragement and satisfaction of the benefactors who comprehend not designs and drafts on paper.'8

Domenico Cresti di Passignano's painting Michelangelo Shows Pope Paul IV the Model of the Dome of St Peter's, 1620.

Wooden model from around 1717 of the Church of Saint Mary-le-Strand, London, designed by James Gibbs. This type of model is typical of those made in the period between the sixteenth and nineteenth centuries.

Sir Christopher Wren, model for dome of Royal Naval Hospital, Greenwich, London. This model, from circa 1699, is one of the earliest examples of a sectional study in British architecture.

Prior to the eighteenth century, architectural models were primarily produced as either descriptive or evaluative devices, or occasionally as full-scale prefabrications used to predict structural behaviour. However, during the mideighteenth century, and coincident with the newly founded technical colleges, the use of physical models for teaching purposes became more widespread. Such models represented the more complex structural and constructional conditions that this period ushered in, and they were used in the education of technical students and building tradesmen. Parallel to this development, architectural and scientific models quickly populated the displays of museums and collections in different countries around the world. This dissemination also began to have considerable impact on a wider culture as Nick Hopwood and Soraya de Chadarevian have explained, 'models were demonstrated in popular lectures and above all at the international age shows of the capital and empire that followed the Great Exhibition of 1851. Many of the exhibits representing manufactures, the sciences, and the arts were models, which here came together most prominently as a class.'9 A major resurgence in the use of the model as a design tool in architecture can also be traced to the start of the twentieth century – for example in the work of Walter Gropius, who, in founding the Bauhaus in 1919, was keen to resist the prevailing preoccupation with paper designs in favour of physical models to explore and test ideas quickly, an impetus reflected in the extensive use of models in the De Stijl period and elsewhere.

From this point on, the scale model was re-established as a vital design tool for architecture. The design-development model was to have an important role in the conception and refinement of countless built and unbuilt projects of the Modernist era. For example, there was Gerrit Rietveld's attempt to give architectural form to the ideas about space that he had previously explored in his furniture designs. From the sequences of models for his design of the

Schröder House, it is clear that Rietveld's starting point was a block form, whose coloured surfaces combined with receding and projecting parts to break up the massiveness of its volume. A similar intent is discernible in Vladimir Tatlin's search for a monument to represent a new social order in Soviet Russia, described in the great model of his leaning, twin helicoidal tower, the Monument to the Third International. The actual building of the model took just less than eight months and was undertaken without preliminary sketches, enabling Tatlin to explore design possibilities as the model was constructed. The progression of architecture throughout the twentieth century bore witness to the increasingly common use of models as explorative tools in an architect's design process.

Delmaet and Durandelle's plaster model from 1864 of the capital for the columns on the façade of the Opéra Garnier, Paris, designed by Charles Garnier.

Vladimir Tatlin's assistants building the first model of his Monument to the Third International from wood connected by metal plates, 1920. This was one of several models made for this project that tested various iterations of the design. A simplified version was paraded through the streets of St Petersburg (then known as Leningrad) in 1926.

Sir Edwin Lutyens' proposed design for the Metropolitan Cathedral of Christ the King, Liverpool, 1929–58. The model was constructed from yellow pine and cork, and made by John B. Thorp in 1933.

Model for the Concrete City of the Future, designed by F. R. S. Yorke and Marcel Breuer, 1936.

Sir Denys Lasdun and Philip Wood looking at the model of the library extension for the School of Oriental and African Studies, London, 1972.

It was this direct handling of materials and space through the use of models that heralded the key early twentieth-century architects as creative designers who visualized and articulated their concepts in a provocative and unconventional manner. A study of their formative experience and design processes reveals an explorative nature, which, being founded upon an understanding of spatial possibilities, transcends a singular reliance upon drawing. In fact, as the twentieth century progressed, physical models sometimes became the fundamental means and resonating echo of radical ideas and projects. As Holtrop et al. have observed, 'the revolutionary 1960s will always be associated with the models and images of Constant's utopian New Babylon or Frederick Kiesler's Endless House.'10 Whilst the architectural model continued to offer a dynamic tool for design conception, development and communication, during the 1970s it also began to be perceived as having value as an art object in its own right. Beyond this point in history, the physical model was established as a powerful method of communication in the description, exploration and evaluation of architecture. The model has been an important method of communication in the understanding of architecture for over five hundred years. Whilst the increase and developments of new technology have enabled Computer-Aided Design (CAD) to become a powerful design tool in architecture, the use of physical models remains a key aspect of education within the discipline and for many practices around the world. This position is further supported and explained by Juhani Pallasmaa in his book The Thinking Hand, ‘Even in the age of computer-aided design and virtual modelling, physical models are incomparable aids in the process of the architect and the designer. The three-dimensional material model speaks to the hand and the body as powerfully as to the eye, and the very process of constructing a model simulates the process of construction.’ 11 Therefore, let us turn our attention to modelmaking in the twenty-first century.

Wooden concept model showing the geometrical solution for the pre-cast concrete shells, Sydney Opera House, Sydney. Designed by Jørn Utzon, this landmark project initiated an era of complex geometry in modern architecture.

1:20 model of the design for the new additions to the Reichstag, Berlin, by Foster + Partners. Made by Atelier 36, using MDF (medium-density fibreboard), acrylics, steel and brass, this model of the plenary chamber, dome and light cone was hoisted onto the roof of the Reichstag to test the lighting in 1996.

The widespread adoption of digital fabrication technologies in architecture schools and practices has contributed to a major resurgence in the production of models such as this 3D powder print of a sculptural staircase as part of UNStudio’s design for Le Toison d’Or, Brussels.

This beautiful concept model by Ken Grix, Feilden Clegg Bradley, skillfully combines concrete, acrylic and dichroic film to illustrate the proposed extension to the Festival Wing of the Southbank Centre, London. The model won the Grand Award for Architecture at the Royal Academy Summer Exhibition in 2013.

Modelmaking now

Why use physical models to describe and explore the qualities of architecture? This question seems even more pertinent given the significant rise of computers engaged in the architectural design process. The most obvious answer lies, of course, in the actual tangibility of such models that, unlike their cropped and flat counterparts, offer substance and completeness. Physical models enable designs to be explored and communicated in both a more experimental and more rigorous manner than other media, as various components of the project may not appear to make much sense until visualized in three dimensions. Akiko Busch suggests that part of our attraction to models lies in the fact that ‘the world in miniature grants us a sense of authority; it is more easily manoeuvred and manipulated, more easily observed and understood. Moreover, when we fabricate, touch, or simply observe the miniature, we have entered a private affair; the sense of closeness, of intimacy is implicit.’12

The integration of digital technology with traditional modelmaking techniques has resulted in important and exciting shifts in the manner in which we engage with the design process of architecture. The proliferation of computers and advanced modelling software has enabled architects and students alike to conceive designs that would be very difficult to develop using more traditional methods – yet despite this, the physical model appears to be experiencing something of a renaissance. This return to ‘analogue’ models seems to confirm that, as Peter Cook suggests, ‘as we become cleverer at predicting colour, weight, performance or materiality, we are often in danger of slithering past the question of just what the composition of space may be … [since] … the tactile and visual nature of stuff may get you further into the understanding and composition of architecture’13 Furthermore, the application of CAD technologies as part of the production of physical models is increasingly widespread through processes such as laser cutting, CNC (Computer Numerical Control) milling and rapid prototyping. The translation of computer-generated data to physical artefact is reversed with equipment such as a digitizer, which is used to trace contours of physical objects directly into the computer.

Computational modelmaking offers a different set of techniques and tools for the designer compared to traditional methods, thereby increasing the development of design innovation and the production of architectural knowledge. The tactile qualities of constructing and handling a physical model afford the maker contact with the real world and so any overlap between different techniques and media, both digital and physical, can only enrich the discourse within the discipline even further. Indeed, as Karen Moon writes, ‘Even as architecture moves beyond the realm of the material, the physical model – contrary to expectation – may not lose its purpose. Models produced at the push of a button cannot offer the individuality and range of expression requisite for the task, nor can the imagination of architects be satisfied in this manner.’14 The potential for computer technologies to run parallel to, or combine with, hand techniques as part of the design process is an exciting evolution that suggests the days of physical models are far from over. From the current situation, the future of architectural design looks set not only to retain physical models as essential tools, which enable design development and communication at the very core of its practice and education, but also to increase their production as the connection between design data and construction information becomes ever closer through digital fabrication techniques.

CAD model of a design proposal in context.

This physical model was made using CAD/CAM processes.

About this book

Already, we have touched upon a number of different ways in which models are used in architecture. Models are important objects for the communication of architectural designs, but perhaps of more significance is their application as adaptable tools as part of the design process of architecture. In this sense physical models are dynamic, as their role can change depending on the stage of the design process, who is using them and why. This approach will be reiterated throughout across the various sections of this book, as it is essential to developing a coherent and deep understanding of such design tools. The purpose of this book is to provide an essential basis for readers of all levels, from students to professionals and any other aspiring modelmakers. The content of the book aims to give interesting and provocative examples and practical explanations for those approaching the subject for the very first time, whilst offering an important source of information for those with more experience to return to again and again.

In format, the book will introduce key principles and techniques, with useful step-by-step examples, case studies and handy tips in each section. The making of physical architectural models has become both a profession in its own right and an independent art form replete with its own materials, tools and methods. Architecture students are typically required to learn and develop the techniques and principles of modelmaking on their own, and therefore this book presents background knowledge alongside different types of models and their appropriate application during the design process. Furthermore, the book will introduce a variety of materials and discuss their properties in addition to advice on the tools and machines with which to work with them. It is therefore intended that whilst this book may not be an exhaustive account of every potential variation of model, it is expansive and comprehensive enough to enable readers to benefit from the diverse opportunities of modelling and to transform their design ideas creatively and instinctively. Indeed, part of the book's intention is for it to also provide a resourceful springboard for inspiration through a wide range of exemplars.

This book therefore is divided into three main parts concerning various media, types and application of models. In the first section we will introduce a variety of physical modelmaking materials and media, and discuss their properties in addition to advice on the tools and machines with which to work with them. We will also introduce the workshop environment, where many models are conceived and developed, as well as discuss the various methods for finishing models once they are constructed. The second part explains the different types of models that designers make as they develop and communicate their ideas during the design process. The third part of the book examines the ways in which models are used or applied by architects and students. This is a key aspect of this publication since although each section may be referred to in isolation, the accumulation of knowledge regarding models throughout the book is reflected in its structure. By first describing what models may be made from, then elaborating on why different types of models are produced, the final part of the book explains how models are used and by whom to broaden and deepen the reader's understanding of their role in the discipline. To best illustrate these themes, each part of the book contains an extensive range of examples from leading practitioners, both established and cutting-edge, alongside innovative work carried out by students of architecture and urban design. In summary, it is intended that, by reading and subsequently referring to these three sections, the reader will develop a clear understanding of the wide spectrum of possibilities in physical architectural modelmaking to inform their own practice and knowledge. Whilst no contemporary book on modelmaking would be complete without explaining the role of various handheld tools, machines and CAD/CAM processes, it should be noted that the latter of these is included within the wider context of assisting the process of making models rather than for their conception. For readers who wish to engage with a more holistic understanding of digital design and fabrication techniques, I kindly direct them to my companion title, Digital Fabrication in Architecture (2012) which covers such subjects much more comprehensively than is possible here.

Getting started

There is a set of basic tools that a modelmaker needs in order to make models out of commonly used materials including paper, cardboard, and wood. Clearly, the more elaborate the model under construction, the greater the need for additional tools with which to work the materials. Therefore, it is worth mentioning at this stage some both primary and secondary pieces of kit that will aid modelmaking on a regular basis (left to right in the picture):

1. A cutting mat (image background) – provides a surface on which to cut materials. This is usually made of rubber as it reduces the chances of slipping when using knives on it, but a piece of hardboard or other similar material can be used as a suitable alternative. Rubber cutting mats have several advantages. They typically have a grid printed onto them that provides a guide for lines to be cut quickly, they accept cuts easily yet are very hardwearing, and they also protect the surface upon which the model is being made.

2. A metal ruler – is essential as it not only guides the knife in a straight line when cutting but will also prevent the knife from slicing into the rule – or the modeller's fingers! By contrast, a plastic ruler will not provide this safety and in no circumstances should a scale ruler be used to cut against, because the knife will damage its edge.

3. Caliper – is a useful device to measure the distance between two opposite sides of an object. The tips of the caliper are adjusted to fit across the points to be measured, the caliper is then removed and the distance between the tips measured against a ruler. In the context of modelmaking this is especially helpful in situations where measurement using a ruler would be difficult such as spherical and other non-linear components.

4. Tape measure – is a flexible type of ruler, typically with either a metal, plastic or cloth strip with linearmeasurement markings. Its lack of rigidity enables curved components and model bases to be easily measured and provides a convenient way of measuring a large vari-

ety of lengths quickly and effectively.

5. Protractor – is a tool for accurate measurement of angles and when combined with a rotating lever as shown here can be a valuable tool for setting up templates for angled model components. They are usually made of stainless steel for use in a workshop environment. The lever pivots to enable any angle to be accommodated and can be locked in position for precision.

6. Set square – is a tool which enables the modelmaker to ensure rectilinear components are accurate and for marks to be set out prior to cutting. In contrast to the plastic triangular versions used for drawing, this type is often made from metal or wood and is in an 'L' shape. Set squares are also very helpful when building models as they enable components to be set perpendicular to each other prior to bonding.

7. Pencil – is an essential part of any modelmaker's toolkit. It should be relatively soft but sharp as this allows for accurate marking out of components but also for the pencil lines to be erased afterwards if required.

8. Scalpel – is perhaps the most frequently used type of knife as it is very sharp and can be employed to make fine cuts and small apertures such as windows. As a result it needs to be used with great care since if too much pressure is applied the blade with snap. Careful storage is essential if kept with pens and pencils so a protective cap as shown here is useful and a packet of spare blades should be at hand since scalpel blades get blunt quite quickly. Different blade types are available for different tasks ranging from very fine points to curved blades depending on the intended application.

9. Craft knife – also known as a utility knife, this is a more robust version of a scalpel and be used to cut a variety of materials in their original form. Its advantages are that it is simple and inexpensive, and that many different versions are available for different cutting tasks. Knives are important for cutting materials accurately and should always be sharp to ensure a clean cut. Care should be taken when cutting materials, as rough edges will be obvious when pieces are joined together. When selecting a knife, it is important to make sure that it fits comfortably in the hand and that the blade is rigidly attached so that it can be used effectively and safely. Please remember that any cutting with knives should be done carefully in a well-lit environment.

10. Tweezers – a pair of these will increase the precision of the modelmaker and enable very small components to be easily manipulated. For models with parts that are only a few millimetres in size, this is an essential tool as handling with fingers may be very difficult.

11. Pliers – are a tool used to hold model components firmly and can also be employed to bend and compress a wide range of materials. Pliers give the hand a mechanical advantage by enabling the force of grip to be amplified and concentrated on a specific part with preci-

sion. Pliers come in different types but ones such as the needle-nose pair illustrated are helpful when making a model with components too small or unwieldy to be manipulated with the fingers.

12. Scissors – have a fairly limited application when making models and are only really used with paper and thin card, but are quick and easy to use. For cutting materials of greater thickness and density, they are usually handled in a workshop environment using tools such as a bench saw, table saw or jigsaw.

13. Files – similar to sandpaper, these can be used with a range of materials to finish edges and corners. Different files are available for different materials, such as metal and wood. A file typically allows for more specific and intensive work to be carried out, whereas sandpaper provides a general finish.

14. Plane – a hand plane is a tool for shaping wood and used to flatten, reduce the thickness of, and develop a smooth surface to a rough piece of timber. Hand planes generally have a cutting edge, often a sharpened metal plate, held within a firm casing so that when moved over a wood surface it takes up relatively uniform shavings. A cutter extends below the bottom surface, also known as the sole, of the plane slices off shavings of wood. A large, flat sole on a plane guides the cutter to ensure only the highest parts of an imperfect surface are removed.

15. Hacksaw – is a fine-tooth saw with a blade held under tension in a frame. Hand-held hacksaws are typically used for cutting materials such as plastics or metal. The blade can be mounted with either the teeth facing toward or away from the handle, resulting in cutting action on either the push or pull stroke. On the push stroke, the arch will flex slightly, decreasing the tension on the blade, often resulting in an increased tendency of the blade to buckle and crack. Cutting on the pull stroke increases the blade tension and will result in greater control of the cut and longer blade life.

16. Coping saw – is a type of handsaw used to cut intricate shapes and interior cut-outs in model components. A coping saw consists of a thin, hardened steel blade, stretched between the ends of a square, c-shaped, springyiron frame to which a handle is attached. The blade is easily removed from the frame so that the blade can be passed through a drilled hole in the middle of a piece of wood. The frame is then re-attached to the blade and the cut starts from the middle of the piece. Long cuts perpendicular to the edge of the material are possible but the shallow depth of the frame limits how far from the edge it can cut. The coping saw blade is removable by partially unscrewing the handle. The blade is prevented from rotating by means of the short, steady bar provided where the blade is attached. Loosening the handle also allows the blade to be rotated relative to the frame as desired so that curves may be achieved.

17. Backsaw – is any type of hand saw which has a stiffening rib on the edge opposite the cutting edge. This allows for better control and more precise cutting than with other types of saws. Backsaws, such as the tenon saw pictured, are normally used when working with wood. The stiffening rib, whilst offering greater precision, does limit the extent to which such saws can cut due to their depth.

18. Claw hammer – is a tool primarily used for hitting nails into, or extracting nails from, another object. It is typically associated with woodworking in a workshop environment but is not limited to use with this material.

19. Wooden mallet – is a type of hammer with a relatively large head. It is usually used to knock wooden components together, or to drive chisels or dowels since it will not deform the striking end of the metal tool.

20. Clamp – is a fastening device used to hold or secure components tightly together to prevent movement or separation through the application of inward pressure. There are many different types and size of clamps available for a range of purposes. The most commonly used in workshops are (from left to right):

a. Quick grip clamps – general purpose. Mechanism can be reversed to work in both compression and expansion.

b. Spring clamps – used for smaller lightweight component assembly.

c. Bessey kliklamps – high pressure clamps particularly useful for materials under tension and for heavy duty clamping.

d. Steel corner clamp – used for holding right angle joints in place

e. G-clamps – wide spread use in all assembly

f. Crab Clamp – wide jaw means pressure can be applied to the centre of an object. Available in different sizes.

g. Stanley corner clamp – used for holding right angle joints in place, ideal for making frames.

All-purpose glue is usually a transparent, solvent-based adhesive and can be used with a wide range of materials including paper, cardboard, wood, plastics and metal. Carefully test a small area first as it may react with some materials – such as polystyrene, which it melts!

Polyvinyl acetate (PVA) glue is a white, general-purpose adhesive and will be appropriate for working with a variety of materials such as paper, cardboard and wood. It is more effective if applied to both the components to be connected, which are then pressed together. This type of glue only works with porous materials and is not appropriate for metals and plastics.

Adhesive sprays are aerosol glues that are useful for fixing lightweight card and paper. Their key benefit is that they allow components to be stuck together and then repositioned if required.

Specialist glues are available for particular materials, such as balsa, cement and plastic. Always follow the instructions carefully when using glues such as these, as they may need to be applied in a different manner to more general-purpose adhesives.

Superglue is a transparent, very fast-drying adhesive, which should be used carefully as it is difficult to undo connections without causing damage to model components.

Masking tape is particularly useful for holding model components together whilst a glue bonds, as it will not leave any marks or residue on the materials. Double-sided tape, meanwhile, can be used to attach elements together in a swift manner, but is generally suited to large surfaces rather than for connecting small components.

Machines

These basic and affordable tools will serve the modelmaker time and time again although more specific machinery and tools may be required to enable a wider variety for materials to be handled effectively. Indeed, the majority of professional architectural modelmakers have the same workshop tools as carpenters including: handsaws, files, planes, chisels and mallets which all extend the methods by which materials can be worked, especially wood. Most universities have extensive workshop facilities in which a range of useful processes can be conducted. Remember that it is very important that any necessary training and supervision is obtained prior to working with such facilities. Whilst the range of resources may vary between different workshops the most commonly found machines and their applications are described below.

Hot-wire cutter – this is used to precisely slice through thick polystyrene foam and leave a clean edge. It works by electrically heating a fine wire which can then have blocks of material pushed against it to cut it. The wire's malleability facilitates complex shapes and curves to be drawn onto the foam and then cut. This machine is particularly useful for massing, urban and city models as blocks can be cut quickly and easily.

Power saw – this is often used when a knife is no longer practical due the thickness or density of a mate-rial. A table saw is a type of saw that comes with a variety of blades which make it ideal for cutting straight components from plastics and wood and even profiling the latter. The band saw is able to provide freeform and curved cuts of materials. Electric jigsaws can also be used to provide similar results but there is greater reliance on the user's ability as these are usually handheld.

Drill – this is typically used to make holes for connecting components such as dowelling rods. Care should be taken to mark out holes properly prior to drilling and a drill should preferably be used within a drill stand to ensure precision of depth and angle of the apertures created.