清华大学主办
清华大学美术学院承办
艺术设计月刊
1958年创刊
总第297期

装飾
ZHUANGSHI

1
2018 戊戌

海外汉学
SINOLOGY

中文社会科学引文索引 CSSCI来源期刊

装飾 ZHUANGSHI 2018.01 ● 总第297期 中国装饰杂志社

本期导读 Introductory reading

信息时空　栏目主持：张　明　News and Events　Column Host: Zhang Ming

特别策划：海外汉学　栏目主持：赵毅平　Special Feature: Sinology　Column Host: Zhao Yiping

纸上展览　栏目主持：刘晶晶　Exhibition on Paper　Column Host: Liu Jingjing

第一线　栏目主持：萧　冯　Front Line　Column Host: Xiao Feng

海外动向　栏目主持：刘晶晶

International Scholars　Column Host: Liu Jingjing

史论空间　栏目主持：周　志

History of Art and Design　Column Host: Zhou Zhi

民俗民艺　栏目主持：赵毅平

Folk Art and Culture　Column Host: Zhao Yiping

设计实践　栏目主持：田　君

Practice　Column Host: Tian Jun

个案点击　栏目主持：李　云　徐　璐

Case Study　Column Host: Li Yun　Xu Lu

教学档案　栏目主持：王小茉

Teaching Archives　Column Host: Wang Xiaomo

院校风采　栏目主持：毓　勤

Colleges　Column Host: Yu Qin

作为“中间物”的三维模型
——早期现代建筑实践中中间知识的创造

Three-dimensional Models as 'In-between-objects' - The creation of In-between Knowledge in Early Modern Architectural Practice

[意] 西蒙娜・瓦莱里亚尼博士　翻译：汪　芸
Dr. Simona Valeriani Translated by Wang Yun

导言

理论与经验这两种知识的综合，是新文化出现的一个重要因素。在早期现代欧洲，这种新文化强调新经验科学的发展，旨在探索自然。同时，具备观念与应用技能的人群之间对工作场所和实践经验的分享，使得他们彼此之间交流实质性的以及方法论方面的专业知识，使他们的知识创造实践成为可能，有助于发展出探索自然的新手段，并创造出有关自然现象的知识。近年来，该主题分别被贴上了不同的标签进行阐释。这些标签包括“有意识的手”[1]和“启蒙经济”[2]，以及最近由帕梅拉・隆开发出来的“商圈”概念[3]。

本文提出的论证是，一系列“中间物”在整合理论 / 实践、知识分子 / 工匠、抽象知识 / 技能等类别的过程中发挥了重要作用，而这些类别在中世纪原被视为是彼此相异的。我们可以给地图、科学仪器、技术图纸、三维模型等诸如此类的物品贴上“中间物”的标签，并论证它们是重要的节点。有实际经验的知识分子、深思熟虑的匠人、导航员、地理学家等，可以通过它来相遇并分享彼此不同的“知识”。[4] 为此，他们创造出了任何单独的群体无法独立产生的新事物。[5] 不过，显而易见的是，这些物品早已存在，并在现代早期就投入了使用，其重要性——无论是从一般意义上而言，还是特别作为知识生产工具的角度看来——在不断增强。

分析这些对象所起的作用，可以帮助我们了解知识创造和认证方式在现代欧洲早期的变化。在这一时期，通过学习所获取的知识与通过实践获得的知识之间的相互关系似乎在不断变化。同时，这种变化是以矛盾的方式呈现的：虽然从业者所拥有的知识种类的有用程度在上升，但与此同时，一种知识编码和“科学化”的过程正有意将这种技能边缘化。反之，理论知识的重要性却得到了强化（因此，掌握理论知识的人也被赋予了重要性）。尤其在建筑领域——若干世纪以来，其知识的信度都与通过几代人经过反复实验而获取的实践专长休戚相关——在 17 世纪见证了解释科学（例如：理论）术语中的稳定性与强度的尝试。不过，这些尝试直到 18 世纪才结出成果，更早一些时候，它们开始影响对知识的信度进行判断的方式，导致了依靠理论知识（及其持有者）解决技术问题的转变。[6]

在上述中间对象的范畴内，本文的重点在于三维模型的使用[7]，展示了它们如何斡旋于不同类别的专业知识之间以产生出新的知识，这些知识介于“中间的”社会群体、认知传统、抽象概念与物质性——以及它们如何居于已知与未知之间。近几十年来，科学模式的作用已经成为了科学史与科学哲学讨论中更加重要的一个话题。例如，由摩根和莫里森[8]编辑的文集清晰地阐释了模型是如何充当斡旋于理论与实践之间的工具。虽然这部文集针对这些问题提供了有趣的理论见解，但是其主要关注点在于模型是如何应用于现

Introduction

The coming together of two kinds of knowledge - the theoretical and the experiential - was an important factor in the emergence of a new culture for investigating nature that underpinned the development of the new empirical sciences in early modern Europe. The sharing of both working locations and practices by people with conceptual and applied skill sets allowed for the exchange of their factual and methodological expertise and their knowledge creation practices, facilitating the development of new ways of investigating nature and creating knowledge about natural phenomena. This theme has been elaborated in recent years under different labels such as the 'Mindful Hand'[1] and the 'Enlightened Economy'[2] as well as, more latterly, in Pamela Long's development of the concept of 'Trading Zones'.[3]

The argument put forward in this essay is that a range of 'in-between objects' played an important role in the coming together of such categories as theory/praxis, intellectuals/artisans, speculative knowledge/skill which had been seen as distinct in the Middle Ages. We can give such artefacts as maps, scientific instruments, technical drawings, three dimensional models etc. the label 'in between objects' - and argue that they were important loci where practically minded intellectuals and speculating artisans, navigators, geographers etc. could meet and shared their different 'knowledges'.[4] In so doing they created something new that no one group could have produced independently[5]. While, obviously, these objects already existed and were in use before the Early Modern times, their importance - in both general terms, and specifically their significance as instruments for knowledge production - increased in the period under consideration.

Analysing the role(s) played by such objects can help us understand how the ways in which knowledge was created and accredited changed in early modern Europe. The relationship between learned knowledge and knowledge acquired by doing appears to have varied constantly during this period, and in a somewhat contradictory fashion: while the degree of usefulness attributed to the kind of knowledge held by practitioners was rising, at the same time a process of codification and 'scientification' of knowledge was tending to marginalize such skills, and underline instead the importance of theoretical knowledge (and so also of those who held it). In the field of architecture in particular - where for centuries reliability had been connected with the practical expertise developed via trial and error over generations - the 17th century sees attempts to explain, for example, stability and strength in scientific (i.e., theoretical) terms. While these efforts did not bear fruit until the late 18th century, they had begun to influence the ways in which reliability of knowledge was judged much earlier, causing a shift towards relying on theoretical knowledge (and its holders) for solutions to technical problems.[6]

Among the range of in-between objects mentioned above, this paper focuses

与知识的关系	实用功能			
修辞手段	演示模型	用于沟通技术想法的模型	用于教学的模型	
体现不同类别的知识 / 技能	作为合同的基础的模型			作为计算材料与人工工具的模型
创造新的（中间）知识	工作模型			

表 1. 三维模型：它们在建筑实践中的功能及其与知识的关系

Relationship to knowledge	Practical functions			
Rhetoric device	Presentation models	Models for communicating technical ideas	Teaching models	
Embodying different kinds of knowledge/skill	Models as contractual basis			Models as devices for calculating materials and labour
Creating new (in-between) knowledge	Working Models			

Table 1. Three–dimensional models: their functions in architectural practice and their relationship to knowledge

代科学——尤其是物理、数学以及经济学的，而且三维模型并不是重点。同时，还存在着一些专门关注三维模型的尝试与探索，尤其以 18 世纪以后的时间段为重点。[9] 该著作所关注的大多是作为教具以及示范对象的模型。这些模型介于教师与学生、科学家与公众、艺术家与赞助人，等等之间。在这种情况下，我们可以说，模型扮演着“修辞手段”的角色。在这里，主旨在于阐明三维模型（以及其他没有在这里讨论的中间材料）是如何促进产生于早期现代欧洲探索未来的新方式的出现。我们将更详尽地研究三维立体模型是如何在某些时间段充当中间物质——以体现来自不同“根源”的现有知识。不过，我们还将进一步说明，在其他情况下，三维立体模型又是如何成为产生由综合不同类别的技法与知识所产生的新知识的手段的。

为了实现这一目标，我们将重点放在建筑领域，以及早期现代三维模型在该语境中所扮演的角色。建筑——一个介于科学、艺术与技能之间的交叉学科——似乎是一个值得关注的领域。在这个领域中，三维模型不仅有着悠久的历史，而且似乎在所考量的时间段之内向着新的方向发展。与上述的科学史一样，和建筑模型相关的现存的文献同样主要关注具有展示功能的模型，旨在以三维立体的方式将拟建建筑物视觉化，帮助建筑师获得客户的委任，或者是在探讨项目细节的时候起到辅助性作用；抑或是出于教学或公共关系的目的就现有建筑进行复制。尽管该文献有着诸多优点，但就制造三维模型的过程是如何有助于斡旋在不同的“知识”之间并引发新知识的产生这些问题，还有许多有待探究和了解的地方。（表 1）

在对建筑实践中模型的不同功能进行概述之后，本文介绍了建筑三维模型应用的历史发展。重点首先在于文艺复兴时期重要的意大利建筑师所撰写的经典文本及其对于这些文本的阐释，两者在国际范围内对几代人都产生了极大的影响力。由于（从许多方面来看）英国被视为早期现代阶段探究自然和知识形成这一新文化发展的重要场所之一，所以调研继而转向了三维模型是如何在英国得以应用的。为了使讨论更加具体且聚焦，特此提供了相关克里斯托弗·温伦爵士的活动的个案研究，该个案研究被置入当代“科学”以及建筑的语境中。[10] 本文以作为“中间”知识的模型为例而存在的一般性注释作结。

建筑中的三维模型

建筑模型最突出的变体是前面提到过的经多次研究的“演示模型”，其丰富性和艺术价值意味着在相关建筑完成之后，它们通常仍然会被保留下来，且在许多情况下传给后人。不过，认识到模型同时还具备许多其他功能也是重要的。（表 1）工作模型被用于开发针对搭建过程中有关风格与技术问题

on the uses of three dimensional models,[7] showing how they mediated between different kinds of expertise to produce new knowledge which was ‘in-between’ social groups, epistemic traditions, abstraction and materiality - and between what was already known and what was still to be found out. The role played by models in science has become a more prominent topic of discussion in the history and philosophy of science over recent decades. The collection of essays edited by Morgan and Morrison,[8] for example, explicitly addresses how models act as instruments that mediate between theories and the world of practice. While the collection offers interesting theoretical insights into these issues, its main focus is on how models are used in modern science - particularly physics, mathematics and economics - and three-dimensional models are not prominent. Other attempts have been made to look specifically into three dimensional models, with particular attention to the period from the 18th century onwards.[9] The emphasis in such literature has been mostly on models as teaching instruments and as demonstration objects, for mediating between teachers and students, scientists and the public, artists and patrons etc. – in such cases we could say models function as ‘rhetorical devices’. The aim here is instead to elucidate how three dimensional models (together with other in-between objects not discussed here) were instrumental in fostering a new way of investigating nature that emerged in Early Modern Europe. We examine in more detail how three dimensional models sometimes functioned as in-between objects - in embodying existing knowledge coming from different ‘sources’ - but in other cases went further, to become instruments for the production of new knowledge, achieved by merging different kinds of skills and knowledge.

To achieve this aim, we focus on the field of architecture and the role three dimensional models played in that context in the Early Modern period. Architecture - a discipline at the intersection between science, art and skill - seems a good field to focus on, and is one in which three dimensional models not only have a long tradition but also seem to develop in new ways in the period under consideration. As in the case of the history of science noted above, the extant literature on architectural models also concentrates mainly on presentation models, intended to visualise a proposed building in three dimensions to assist the architect in securing a commission from a patron, or in discussing project details; or to reproduce an extant building for teaching or public relations purposes. Despite the merits of this literature, there is more to investigate and understand about how the process of producing three dimensional models helped mediate between different ‘knowledges’ and led to the production of new knowledge (Table 1).

After giving an overview of the different functions of models in architectural practice, the paper describes the historical development of the use of three

的解决方案。或许，在历史文献中最常引用的有关模型的功能在于计算搭建所需的材料的数量和工匠的类别与数量，以及其在法律意义上的重要性——作为合同规定的一部分记录下将要搭建的结构的所有细节，以此作为参照来审核完工后的建筑。因此，模型被用于在建筑师和客户之间，以及建筑师和工匠之间沟通与技术相关的想法；开发技术解决方案；协助规划、监测并测量实际作品；以具体形式记录成功的解决方案，其无论作为建筑师创造性的展示，还是教学辅助工具都同样雄辩有力。

许多早期文明都使用了建筑的三维微缩模型——可以追溯到古埃及——不过，从这些时期流传至今的物品通常应该被理解为以宗教为目的的建筑表征（例如献祭的物品以及墓葬家具），而鲜有用于建筑过程的辅助工具。[11] 在一些希腊文献[12]，以及古典时期流传下来的唯一一部建筑专著——维特鲁威的《建筑十书》（公元前 1 世纪）里提到了欧洲建筑项目中三维模型的使用情况。不过，在描述设计过程的时候他并没有涉及模型，只有在探讨机械构件的时候明确提到了它们。[13] 所以，古代世界似乎已经开始使用模型，但是并没有赋予它们显著的作用——至少从方法论和理论的角度看来是这样的。

用于设计和建造的模型案例可以追溯到中世纪，不过，关于它们在建筑实践中使用的广泛程度的讨论并没有达成共识。[14] 在文艺复兴时期，模型的重要性得到了显著的提升，这个阶段自 14 世纪 50 年代从托斯卡纳开始，并迅速蔓延了整个欧洲。[15] 关于模型的使用，我们掌握了充分资料的第一座建筑是佛罗伦萨的圣母百花大教堂。在这里，砖木的模型被用作施工过程中的辅助材料。[16] 同样，在 1390 年开始搭建的博洛尼亚圣白托略大殿的施工过程中也使用了模型。反之，就位于米兰的晚期哥特式大教堂而言，在北部专家负责的阶段，其搭建并没有使用模型，不过 20 年之后，该项目由意大利的大师接手（1468），总共建了 11 个模型。[17]

一直存在这样一种争议，即 15 世纪意大利的模型是建筑设计师展示自己的想法并为这些想法寻求知识产权保护的一种方式。同时，建筑师们希望这种方式可以被广泛理解，其中包括不识字的人。这些建筑“设计师”——该行业与“建筑师”这个称号尚未真正发展起来——也在使用一些通常是比较粗略的模型（有时候由秘密协议提供支持[18]），以便有效掩饰他们的“发明”的一些重要细节：持有这种观点的最典型代表是菲利波·布鲁内莱斯基（1377–1446），他经常自己搭建模型。[19]

在 15、16 世纪，随着意大利建筑师逐渐脱离工地，并且与贵族和宫廷之间的关系变得更加紧密，模型就演化成为更加精准且有力地将建筑师的指令传达给施工人员的工具。这种在模型的使用以及理解方面的进步在文艺复兴时期的建筑写作领域产生了反响：因此，虽然莱昂·巴蒂斯塔·阿尔贝蒂（1404–1472）的著作《建筑论》中有若干页是特别有关于模型的（该书对后来几个世纪的几代建筑师都产生了影响），但是在关于构思新建筑这一章节中他并没有提到它们。[20] 在这里（和维特鲁威一脉相承），与建筑设计过程紧密相连的是通过图纸“固化”的思维活动（第一书《特性》）。

> 将整个形式投射在头脑中，而无需由于要给各种线以及角度指定并确定一个固定的方向与关系求助于材料是可能的。因为这就是案例，即让线性结构成为精准且正确的外轮廓，孕育于思想中……在通过学习而获得的智慧与想象中完善。[21]

阿尔贝蒂认为，相对物质世界，观念属于创造过程中更加重要的一个部

dimensional models in architecture. The focus will be first on the classic literature and its interpretation by the leading Italian architects of the Renaissance, which was hugely influential, both internationally and for generations to come. As (in many respects) England is seen as one of the key locations for the development of the new culture of natural enquiry and knowledge formation in Early Modern times, the investigation then shifts towards how three dimensional models were used in the English context. To make the discussion more concrete and focused, a case study considers the activities of Sir Christopher Wren, as situated in the contemporary ‘scientific’ and architectural context.[10] The paper closes with some general notes on models as examples of ‘in-between’ knowledge.

Three-dimensional models in architecture

The most prominent variant of architectural models are the much studied ‘presentation models’ described earlier, whose richness and artistic value mean they were often retained after the associated architectural works have been completed and so, in many cases, remain for posterity. However, it is important to realise that models also had a number of other functions (Table 1). Working models were used to develop solutions for stylistic and technical problems that arose during construction. Perhaps the use of models cited most often in the historical literature was to calculate the quantities of materials needed for construction and the kinds and numbers of craftsmen required, and a similar important function saw them used in a legal sense, as part of contractual stipulations, documenting all the details of the structure to be built against which the finished building could be checked. Thus models could be made to communicate technical ideas between architects and patrons or between architects and craftsmen; to develop technical solutions; to help plan, monitor and measure actual works; to document successful solutions in concrete form, which could function equally eloquently as demonstrations of architects’ creativity or as teaching aids.

Three dimensional miniatures of buildings were used in many early civilisations - and can be traced back to ancient Egypt - but it seems the objects that have come down to us from such periods should generally be understood as architectural representations designed for religious purposes (such as votive objects and grave furniture), and only unusually as aids to building processes.[11] The use of three dimensional models in architectural projects in the European context is mentioned in some Greek sources,[12] as well as in the only architectural treatise that remains from antiquity - Vitruvius’ De architectura (1st century BC). However he does not include models in his descriptions of the design process, and only mentions them explicitly when discussing the construction of machines.[13] So the ancient world seems to have used models but not to have assigned them prominent roles – at least from a methodological and theoretical point of view.

Examples of models used for design and construction can be dated to the Middle Ages, but how widely they were used in architectural practice is open to discussion.[14] A significant increase in the importance of models can be observed during the Renaissance period, starting in Tuscany in the 1350s and spreading quickly throughout Europe.[15] The first building for which we have abundant evidence of their use is S. Maria del Fiore in Florence, where wood and brick models were produced as aids to the construction process,[16] as they were for the construction of S. Petronio at Bologna, which started in 1390. In contrast, the design and construction process of Milan’s late gothic cathedral was conducted without the use of models while Northern experts were in charge, but in the twenty years after the project was taken over by Italian masters (in 1468) as many as eleven models were constructed.[17]

It has been argued that Italian models from the 15th century represent a way

分，而模型正是属于物质世界范畴的——不过，他并没有贬低它们的作用，在其著作第二册（专门关于材料）开始的这一部分，他用了好几页的篇幅探讨模型，并清楚认识到模型在更加实用的语境中的效用：

> 我会一如继往推崇这个历史悠久的习俗……即配备由木材及其他材料搭建的模型。这将使我们能够在参照专家意见的同时反复权衡作为整体的作品，以及所有局部单独的尺度，而避免潜在的麻烦和费用方面的损失。[22]

正如沃纳·奥克斯林详细探讨的那样，阿尔贝蒂用双重术语“模数与样本”（指的是它们与理论／精神领域以及物质领域之间的关系）描述模型，这与本文的论证一致，即模型在理论与实践“之间”发生作用的重要地位。[23]

就阿尔贝蒂而言，创造性过程主要发生在意识当中，模型只不过是头脑中所构思的内容的外化而已。除此之外，还存在着另一种以米开朗基罗（1475–1564）为代表的传统。依循这种观念，创造者的发明是藉由模型本身的物质属性而产生的：在设计过程中，米开朗基罗广泛运用了一系列模型，通过黏土模型产生大概的想法，运用木制模型向客户展示设计，而真正的模型（大尺度的模型——有时候甚至是 1:1 的比例）则用于在建筑工地与施工人员沟通。[24]

从 15 世纪后期开始，意大利就越来越频繁地将模型作为实验性的工具进行使用，由此便可探究在绘图与小型模型当中不易被发现的建筑搭建的细节与潜在问题。模型作为设计工具的重要性在威尼托（威尼斯周围的地区）变得尤为明显。在这里，它们成为了建筑师、王公贵族、将军，以及军事工程师之间不可或缺的调停与沟通的工具。这些人越来越多地开始制作有关防御工事的模型，既包含了相关建筑方面的考虑，也照顾到周边地区，以便针对距离和设计轨迹等进行实验。在此，由不同人所掌握的各种各样的知识便融合在一起了。[25] 因此，模型（与鹅毛笔和墨水一起）首次明确地作为建筑师的工具出现在《建筑普遍理念》（1615）中便不足为奇了。《建筑普遍理念》是由威尼斯人文森佐·斯卡莫齐（1552–1616）撰写的有关建筑的专著。在该论著中，三维模型成为理论与实践混合物中的“中间对象”。[26]

我们现在要思考的是颇具影响力的意大利建筑传统（既包括文字也包含建筑实践）是如何在 17 世纪被英国所采纳的，以及在这样的文化语境中，三维模型究竟占有什么样的位置。自 16 世纪后期起，模型的使用在英国的建筑实践领域日益盛行。J·威尔顿 – 伊利指出，在英国，有关建筑模型的最早记录之一是关于法国细木工阿德里安·冈特的。他 1567 年制作了一个模型，用于位于朗利特的伊丽莎白乡村别墅的搭建施工。[27] 同样，在早期英国的建筑类著作中也提到了模型，例如沃顿的《建筑元素》（1624）[28]、罗杰·普拉特爵士关于建筑的笔记 [29]，以及巴尔萨扎·格比尔爵士撰写的广受欢迎的《致所有建筑者的忠告与建议》（1664）。这些作者都遵循阿尔贝蒂的建议，在施工开始之前制作模型，以避免错误和后期昂贵的改动；同时，他们也明确指出模型旨在帮助解决比例和总体的设计问题，并揭示出潜在的技术难题。《钱伯斯百科全书》（编纂于 1680 至 1740 年之间）是一本总结当时的知识的著作，在该书中同样列举了“模型”这个概念，并首先将其与三维建筑模型相联系：

> 模型特别适用于建筑……旨在更好地传达并执行一些重大的项目，并根据想法给出大概的效果。在所有大型建筑中，制作具有浮雕效果的模型是最可靠的方式，而不应该依赖纯粹的设计，或者是草图。[30]

威尔顿 – 伊利进一步提出了将模型引入英国的建筑实践与采纳一种新

for building designers to present their ideas and claim intellectual property rights over them in a form that could be widely understood, even by illiterate people. These building ‘designers’ – the profession and thus the label ‘architect’ had not yet really been developed – also used models which were often rather sketchy (and were sometimes backed up by secrecy agreements[18]) effectively to conceal some important details of their ‘invention’: the individual who most obviously represented this attitude was Filippo Brunelleschi (1377 – 1446), who often built his own models.[19]

Over the 15th and 16th centuries, as Italian architects gradually detached themselves from construction sites and became more closely connected with princes and courts, models evolved into instruments to communicate the architect’s instructions to the workforce more precisely and more robustly. This progress in the use and understanding of models reverberates through Renaissance architectural writings: thus, while Leon Battista Alberti (1404–1472) devotes several pages of his De Re Aedificatoria (which influenced future generations of architects over some centuries to come) to models, he makes no mention of them in the section dedicated to conceiving new buildings,[20] where (following Vitruvius) the building design process is associated instead with mental activities that are ‘fixed’ in drawings (book I, De Lineamentis).

> It is possible to project whole forms in the mind without recourse to the material by designating and determining a fixed orientation and conjunction for the various lines and angles. Since that is the case let lineaments be the precise and correct outline, conceived in the mind… and perfected in the learned intellect and imagination.[21]

Alberti considered ideas as being a superior part of the invention process to the realm of materiality, where models belonged - but he did not denigrate their use, which he discusses over several pages at the start of book II (devoted to materials) and which he clearly recognises as useful for more practical purposes:

> I would always commend the time-honoured custom … of preparing models of wood or any other material. These will enable us to weigh up repeatedly and examine, with the advice of experts, the work as a whole and the individual dimensions of all the parts and, before continuing any further, the likely trouble and expense.[22]

As Werner Oechslin has discussed in detail, Alberti described models with the double term ‘modulis atque exemplaribus’ (referring to their relevance to both the theoretical/mental and material spheres), which aligns with this paper’s arguments of their important status as functioning ‘in-between’ theory and praxis.[23]

An alternative tradition to that of Alberti – for whom the creative process happens essentially in the mind, and the model is little more than a mere representation of what the mind has already conceived – is embodied by such figures as Michelangelo Buonarroti (1475 –1564). In this conception, the creator’s invention happens via the materiality of the model itself: Michelangelo made extensive use of a range of models throughout his design processes, from clay models to work out general ideas, to wooden models to present designs to his patrons, to modelli al vero (large scale models – sometimes even 1:1) used on building sites to communicate with his workforce.[24]

From the late 15th century, Italy saw the increasing use of models as experimental instruments through which building construction details and potential problems that were not revealed by drawings or small models could be investigated. The importance of models as designing tools became very evident in the Veneto (the region around Venice), where, in particular, they became indispensable mediation and communication tools between architects, princes, generals and military engineers who increasingly made models of fortifications that included both the building concerned as well as the surrounding area, enabling experiments about distances, shooting trajectories etc. in which the various kinds

的、更为精巧复杂的建筑风格之间的相互关联。[31] 很明显，这是一个重要的方面，原因在于，一方面，新的风格要求更多的“阐释”；另一方面，它（至少从部分看来）和对于建筑师的角色，以及如何整合设计与建筑过程的新理解是一致的。

案例研究：克里斯托弗·雷恩对模型的使用

圣保罗大教堂的建筑模型

伦敦圣保罗大教堂当前的结构是克里斯托弗·雷恩爵士（1632–1723）及其合作者的设计成果。[32] 在圣保罗大教堂的原址上曾经矗立着一座中世纪的教堂。即便是在伦敦大火（1666 年）之前，这座教堂就经判定需要修缮和更新。[33] 火灾发生后不久，就做出了拆除中世纪教堂残垣并开始建造一座新教堂的决定。1668 年，克里斯托弗·雷恩（雷恩于 1666 年被委任作为重建伦敦的专员 [34]，并于 1669 年成为皇室著作的主检查员）被委托进行设计：教堂于 1710 年完成，而雷恩的高寿则使得他得以跟进整个搭建的过程。

圣保罗大教堂或许是那个时期英国最重要的建筑成就，大量的学术研究都是围绕着这座教堂展开的，从各个不同的角度分析其建造的过程，这些资料都非常完好地保存在现存的建筑报告中。[35] 本文所集中关注的是（到目前为止一直被忽视的）在教堂搭建过程中使用的三维模型，而不是其知名的展示模型（请见图 1、2）[36]。现存的报告记录了至少 70 件模型的使用：确切的数据很难确定——有一些条目是非常具体的（不过没有一件模型的记录既包含了模型的目的，又包含了其所使用的材料），而其他的一些条目则相对模糊，仅有关于某个时间段支付给工匠的费用的一些细则。（另外一个困难是，在 17 世纪，“模型”这个词有时候还用于指称绘图以及其他建筑辅助工具，例如模具。）

雷恩和他的合作者显然使用了大量的“工作模式”来探索并发展自己的

of knowledge held by the different actors could be merged.[25] So it is no surprise that models figure explicitly for the first time (alongside quills and ink) as architect's tools in L'Idea dell'Architettura Universale (1615), an architectural treatise by the Venetian Vincenzo Scamozzi (1552 –1616), where the three dimensional model becomes (even more explicit than in Alberti's work) a 'in-between object', where theory and praxis are mixed.[26]

We now consider how the influential Italian architectural tradition (both in writings and in building practice) was taken up in England in the 17th c., and what place three dimensional models occupied in this cultural context. Models were used increasingly in English architectural practice from the late 16th c. onwards. J. Wilton-Ely notes that one of the earliest references to architectural models in England concerns the French joiner Adrian Gaunt, who (in 1567) produced a model for the construction of the Elizabethan Country house at Longleat.[27] Models are also mentioned in such early English architectural writings as Wotton's Elements of architecture (1624),[28] Sir Roger Pratt's notes on architecture[29] and in Sir Balthazar Gerbier's very popular publication Counsel and Advice to all Builders (1664). These authors all follow Alberti in recommending making models before construction starts, to avoid mistakes and costly alterations later on; they also make it clear that models are meant to help solve problems of proportions and general design, as well as to expose potential technical difficulties. A work summarising the knowledge of the time – Chamber's Cyclopædia (compiled between ca. 1680 and 1740) – also lists the term 'model', relating it in primis to three dimensional architectural models:

> MODEL is particularly used in Building … in order for the better Conducing and Executing of some great Work, and to give an Idea of the Effect it will have in Large. In all large buildings, it is much the surest way to make a Model in Relievo and not to trust to a bare Design, or Draught.[30]

Wilton-Ely has further suggested a link between the introduction of models into English architectural practice and the adoption of a new, more elaborate

1. 所谓的用于重建圣保罗大教堂的“第一件模型”（1669–1670），来自肯恩等人，2004，第 187 页

2. 所谓的用于重建圣保罗大教堂的“伟大的模型”（1673–1674），来自肯恩等人，2004，第 190 页

3. N・霍克斯穆尔，圣保罗大教堂穹顶设计，约 1693–1695，来自希戈特，2009，第 165 页

想法。[37] 在某些情况下，这些任务被委托给参与者，似乎属于“设计模型”的范畴，主要涉及风格问题。在其他情况下，模型会由木匠或泥瓦匠制作，并且与建筑细节有明确的关系：这些似乎是工匠和建筑师们一起解决技术问题的工具 [38]，有时候使用的甚至是与最终结构相同的材料。

为圣保罗大教堂穹顶所做的模型是后一种类型用法的好例子。众所周知，穹顶是教堂建筑中最大胆的一部分，且许多历史学家都对其起源做过评价。通过分析施工过程中雷恩所委托完成的模型，有助于阐明设计过程中理论反思与技巧的作用。[39] 在 1684 年至 1689 年期间，针对穹顶的“看台”制作了一系列模型，而在 1690 年至 1695 年期间，石匠们受到委任为穹顶本身制作模型。从报告中简短的描述看来，这些模型是为了解决施工过程中最终解决方案的一些逐步细化的尝试。因此，于 1690/91 年 1 月至 2 月，支付给石匠爱德华・斯特朗“穹顶 1/4 部分模型”的费用 [40]，1691 年 4 月，再次支付“用小石块搭建部分穹顶模型的一部分”[41] 的费用。这些似乎都是为了用于研究提案中的结构如何在实操过程中以石材搭建，同时，石匠的专业知识被调动起来以推进建筑理念的细节发展。1694 年 6 月，支付给同一位爱德华・斯特朗“制作 1/8 大穹顶的大型模型”的费用。[42] 穹顶的一小部分被模型化，并牵涉到一位雕刻者这一事实，证明了细节在不断深化的进度。

architectural style,[31] and it seems clear this was an important aspect, both because the new style required more ‘explanation’, but also because it coincided (at least in part) with a new understanding of the role of the architect and of how design and building processes should be organised.

A case study: Christopher Wren’s use of models

Models in the construction of St Paul’s Cathedral

The current fabric of St Paul’s Cathedral in London is the result of the design efforts of Sir Christopher Wren (1632 – 1723) and his collaborators.[32] A medieval antecedent had stood on the same site, which had been recognised as being in need of restoration and of modernisation even before the Great Fire of London (1666).[33] Soon after the fire it was decided to pull down the medieval cathedral’s burnt out remains and start constructing a new one. In 1668 Christopher Wren (who had been appointed in 1666 as commissioner for the rebuilding of London,[34] and became surveyor of the King’s works in 1669) was asked to produce a design: the cathedral was completed in 1710 and Wren’s longevity allowed him to follow its construction through to completion.

As perhaps the most significant English architectural achievement of its age, St Paul’s cathedral has been the subject of voluminous scholarship, analysing many different facets of its erection, which is very well documented in its surviving building accounts.[35] Rather than focusing on the well-known presentation models (see Figures 1 and 2),[36] this paper concentrates instead on the (so far neglected) three-dimensional models that were actually used in the cathedral’s construction. The accounts record the use of at least seventy models: the exact number is difficult to determine - while some entries are very specific (noting both the model’s purpose and the materials used), others are much vaguer, only detailing payments to craftsmen for models made over certain periods. (An additional difficulty is that, in the 17th century, the term ‘model’ was also sometimes used for drawings and other building aids, such as moulds.)(Fig.1, Fig. 2)

Wren and his collaborators evidently used a large number of ‘working models’ to try out and develop their ideas.[37] In some cases these were commissioned to joiners, and seem to fall into the category of ‘design-models’, mainly concerned with stylistic issues. In other cases they were made by carpenters or masons, and clearly related to construction details: these seem to have been instruments by which craftsmen and the architect solved technical problems together,[38] and were sometimes even made from the same materials they intended to use in the final structure.

The models made for St Paul’s dome are good examples of this latter type of use. The dome is, famously, the most daring part of the cathedral’s architecture, and many historians have commented on its genesis. Analysing the models Wren commissioned during its construction helps to shed light on the roles of both theoretical reflections and skill in its design process.[39] Between 1684 and 1689 a series of models were made for the ‘tribune’ of the dome, and masons were commissioned to produce models for the dome itself between 1690 and 1695, which – judging from the brief descriptions in the accounts - were progressively more detailed attempts to work out the final solution for its construction. Thus the mason Eduard Strong was paid in January-February 1690/91 for a ‘Modell for ¼ part of dome’[40] and in April 1691 ‘For making part of a Modell in small Stones for part of the Dome’,[41] which seems to have been used to work out how the proposed structure could actually be built in stone, with the mason’s expertise being called on to develop the architectural idea in detail. In June 1694 the same Edward Strong was paid for ‘making a large Modell of a 1/8th of the Great Dome’.[42] The fact that an increasingly small part of the dome was modelled, and that a

差不多在同一时期，雷恩的助手尼古拉斯·霍克斯穆尔（1661–1736）[43]创作了穹顶的新设计——该设计的图纸留存了下来（请见图3）。这个设计在关键时刻展示了设计的过程是如何被在绘图桌边工作的建筑师，以及制作模型的匠人合力推进的。以模型作为“中间”物质，两者通过一种双向的过程分享互相的技能。在这里，两种“认知”相遇并结合了。因此，我们可以就在文献中经常提到的观点：即建筑模型的使用是一种单项的过程，在此过程中，建筑师指导他们的工匠——有待进一步修订。

目前为止，我们所关注的都是用于向客户展示的模型和工作模型，其作用旨在帮助针对风格上和技术上的问题发展出解决方案。有关模型的其他两个用途亦可见于圣保罗大教堂搭建报告。首先是技术理念的交流——其中一个例子是1692年由工匠制作的屋顶桁架的便携式模型以及用于“放置它的一个盒子”。[44]这或许是某一种手提箱，表明了雷恩打算用这个模型作为参照物，并将其带到其他的建筑工地，让客户和工匠意识到当时英国具有创新性的结构的特殊之处。[45]模型的另一个用途是作为施工合同的一部分。在这里，模型具有法律地位和功能：在圣保罗大教堂的报告中，我们可以发现若干例子，即工匠的合同特别涉及到那些制定了工作应该如何开展的模型，例如：

> 1705年7月18日：与木匠约翰·朗朗和理查德·詹宁斯及其继任者就搭建框架、提升并完成圣保罗大教堂西段大屋顶以使其适合承载台的事项达成一致……详情以以此为目的而制作并获批准的模型为依据。[46]

这种模型的使用并不是圣保罗大教堂所特有的，在其他的资料当中也有记载，例如上文中所提到的普拉特关于建筑的笔记。[47]

雷恩的结构模型：在数学与艺术规则之间

雷恩在写给圣保罗大教堂重建委员会的信中争辩说，模型的使用是“为了鼓励并使不理解纸上的设计与草稿的捐助者满意，同时也为了让下级的工匠能更清晰地领会他们要做的工作”[48]。借此，雷恩将自身置于一个传统里。其中，建筑师——其位置很显然“高于”工匠——运用模型与客户及施工人员沟通自己的想法。尽管如此，圣保罗大教堂搭建报告中的数据似乎也暗示着，在雷恩的实际操作过程中，模型是具有多重价值的工具，他运用模型作为试验性的设备以解决设计复杂的建筑元素的问题，以及如何通过石材与砖块来实现设计。[49]

雷恩还运用建筑模型帮助解决结构问题。除了圣保罗大教堂及其穹顶，（1663年呈递给英国皇家学会的）谢尔登尼安大剧院著名的屋顶结构模型（现已失传）也被证实具有同样的用途，其他还包括1665年搭建的坐落于剑桥的彭布罗克学院教堂的模型（1662）。这些都再次证实了当时在英国具有创新性的屋顶结构的一些细节。其他的例子包括雷恩对修复威斯敏斯特大教堂的建议，这使得我们可以更详细地查看雷恩的“数学”建筑方法。作为介绍性的部分，应该指出的是，此前雷恩就已经受邀担任修复哥特式建筑的顾问，其中最知名的项目包括老的圣保罗大教堂[50]和索尔兹伯里大教堂[51]。在这些项目中，他探讨了稳定性，以及会对塔身和十字架造成损伤的耐量的问题。在雷恩有关威斯敏斯特大教堂的写作中，展示了他对哥特式教堂“静力学”理论考量的进一步发展，尤其是针对扶壁、塔楼和尖顶的作用的思考：

> 我认为这位建筑师非常清楚，教堂中殿（注：教堂的构成像种拉丁式十字架，带有一个中心两个走廊）的四根柱子不足以成为强有力的接界……

carver was involved, testifies to increasing degrees of detail. At roughly the same time new designs for the dome – for which drawings survive (see Fig.3) – were made by Wren's assistant, Nicholas Hawksmoor (1661–1736).[43] This shows how, at key moments, the design process was being developed by the joint efforts of architects at their drawing tables and craftsmen making models, the two sharing their skills in a two- way process with the model as an 'in-between' object, in whose production two ways of 'knowing' met and combined. We could argue, therefore, that the opinion so often voiced in the literature – that the use of architectural models was a one-way process in which architects instructed their craftsmen – requires some revision.

So far, we have concentrated on the use of models for presentation to patrons and as working models whose purpose is to help develop solutions for stylistic and technical problems. Two other uses for models can be read from the St Paul's building accounts. First is the communication of technical ideas - one example of which is a transportable model of the roof trusses built in 1692 by a joiner together with 'a box to put it in'.[44] This was probably a sort of suitcase and indicates Wren's intention to use this model as a reference to be taken to other building sites, to make patrons and carpenters aware of the specifics of what was an innovative structure for England at the time.[45] A further use of models was as part of construction contracts, where the model had a legal status and function: we can find several instances in the St Paul's accounts where craftsmen's contracts refer specifically to models which define how work needs to be carried out – as, for example:

> July 18th 1705: Agreed with John Longland & Richard Jennings, Carpenters, and the Survivor of them, for framing, rasing, & finishing the great Roof of the West End of St Paul's Cathedral fit for the Plummer… according to the Modell Produced & approved for that purpose.[46]

This use of models was not peculiar to St Paul's, but is also documented in other sources, including, for example, Pratt's notes on architecture mentioned above.[47]

Wren's structural Models: between mathematics and rules of the art

Writing to the commission for the rebuilding of St Paul's, Wren argued for the use of models 'for the encouragement and satisfaction of benefactors that comprehend not designs and drafts on paper as well as for the inferior artificers' clearer intelligence of their business',[48] placing himself in a tradition in which the architect – clearly situated 'above' craftsmen – uses models to communicate his ideas to patrons and workforces. Nonetheless, the data from the St Paul's building accounts seems to suggest that models were much more polyvalent instruments in Wren's actual practice, and he used them as experimental devices to work out – with the help of the craftsmen's skills – the designs of complicated building elements and how they could be realized in stone and brick.[49]

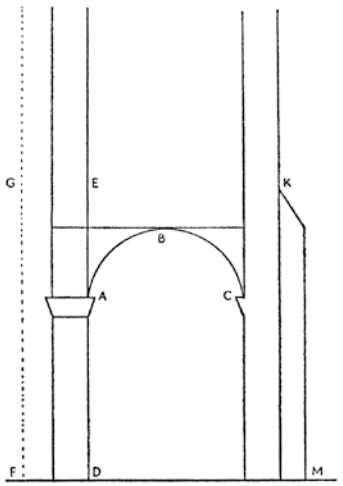
Wren also used architectural models to help solve structural problems. Apart from St Paul's and its dome, the (now lost) model of the famous roof structure of the Sheldonian Theatre (presented to the Royal Society in 1663) testifies to this kind of use, as does the (c. 1662) model for Pembroke College Chapel, Cambridge, constructed in 1665, which again shows details of a roof structure that was innovative for England at the time. Other examples include Wren's suggestions for the repair of Westminster Abbey, which allows us to look in more detail at Wren's 'mathematical' approach to architecture. By way of introduction, it should be noted that Wren had been already called in as a consultant on the repair of Gothic buildings in previous circumstances, most notably at Old St Paul's[50] and at Salisbury cathedral,[51] where he had discussed problems of stability and of resistance to weight that had caused damage in the tower and the crossing.

除非它们的体量超过其他的柱子…… 但是不能把它们做得更大，不过，却是可以把它们做得更重一些，以对抗压力，起到等量的效果。

而这就是为什么在处理所有这种形式的哥特式结构的时候，建筑师们都习惯于在中部建塔或尖顶，不仅是为了装饰，而是为了确认中柱能够承担推力。[52]

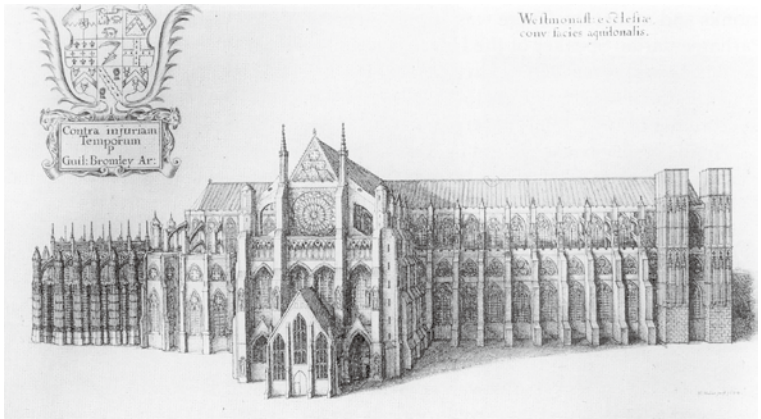
为了解释这个结论，雷恩在报告中加入了一张图纸（图 4），而他附上的文本就好像是一个几何示范："让 ABC 成为一个拱，以 C 为支点，对着不动的墙 KM，但是，A 在柱子 AD 的上方，它太小了以至于无法成为一个足够有力的接界，以应对 AB 拱的压力……"

由于威斯敏斯特大教堂中部的尖塔从未建成（图 5），因而位于十字交叉处的柱子向内弯曲，导致墙面开裂，所以雷恩建议首先修复柱子，"我已经考虑过如何通过一个模型来展示并表现"[53]。遗憾的是，这个模型并没有能够被保存下来，虽然我们确实拥有雷恩准备用来展示如何通过添加一个尖



4


6



5

4. 雷恩的草图展示了哥特式建筑的"稳定性标准"（雷恩，1750，第 301 页）

5. 加入尖塔之前的威斯敏斯特大教堂北向正面（W・霍拉的版画，约 1654）

6. 雷恩将尖塔添加到威斯敏斯特大教堂的模型（约 1720 年），来自科克，1995，第 131 页

Wren's writings on Westminster Abbey show the further development of such theoretical considerations about the 'statics' of gothic cathedrals, and in particular on the roles of buttresses, towers and spires:

I conceive the Architect knew very well, that the four Pillars above the Intersection of the Cross-nave would not prove sufficient Butment… unless they were much bigger than the other Pillars… but tho' they could not be made bigger, yet they could be made heavier to stand against the Pressure, which may prove an Equivalent.

And this is the Reason why in all Gothick Fabricks of this Form, the Architects were wont to build Towers or Steeples in the Middle, not only for ornament, but to confirm the middle Pillars against the Thrust.[52]

Wren explains this conclusion by adding a drawing (Fig.4) to his report, and his accompanying text is fashioned like a geometrical demonstration: 'Let ABC be an arch resting at C, against an immovable wall K M, but at A upon a pillar AD, so small as to be unable to be a sufficient Butment to the Pressure of the Arch AB.…'

As the steeple in the middle of Westminster Abbey had never been built (Fig.5), the pillars at the crossing were bent inward, causing the walls above to crack, so Wren suggested first restoring the pillars 'which I have considered how to perform and represented in a Model'[53]. Unfortunately this model has not come down to us, although we do have the 'presentation model' (Fig.6) Wren prepared to show how the construction of the church should have been finished by adding a steeple. Wren argued that this had been the original architect's intention and – as he 'demonstrated' in his sketch and accompanying text– would have ensured the crossing's stability.

The mathematical and mechanical knowledge available to architects in the 17th century provided no proper theory that could explain or predict the stability of the gothic structures Wren was repairing, nor of St Paul's dome. But Wren was certainly one of the scholars of the time who were engaged in advancing this knowledge, and in trying to apply what theoretical ideas were available.[54] His structural models were objects that we can say stood 'in-between' already existing knowledge and the new knowledge that was being created: and they also stand as objects that combined Wren's theoretical approach and knowledge with the skills and knowledge of the master craftsmen giving a material form to his ideas and making them feasible.

While this use of models particularly reflects Wren's 'mechanical' interests, his use of models to solve structural problems can be situated in a long tradition (to choose just one example, see Brunelleschi's models for the dome of S. Maria del Fiore). The question of the suitability of models to work out the size of structural elements to ensure the stability of a proposed building had been at the center of a long and significant scientific-technological debate about scaling up, which had been discussed in several extant architectural works. Vitruvius had touched on the topic, noting the failure of some machines that had been built by scaling-up perfectly functioning models: Alberti, on the other hand, insisted on the universality of the laws of proportions that should enable deriving the real object from a smaller version. Other Renaissance authorities – such as Andrea Palladio (1508-1580)[55] and Daniele Barbaro (1515-1570)[56]– had also maintained that models could be used to work out the size of elements for real buildings, and that failures of structures that had been enlarged from models must have been due to imperfections in the materials used, rather than to any fundamental problems of scaling.

Several scholars investigated the scaling problem in the 16th and 17th centuries. The debate was famously taken up by Galileo Galilei, in his Discorsi e dimostrazioni matematiche (1638), where he criticizes the use of models for such purposes. Galileo was (in his own words) founding a 'new science' concerned with

塔来完成教堂的结构“展示模型”（图 6）。雷恩坚持认为，这是最初的建筑师本人的意图，并且——就如他在草图以及相关文字中所“论证”的那样——能够确保十字交叉处的稳定性。

17 世纪建筑师可用的数学和机械知识并不能提供合适的理论以解释或者预测雷恩正在修复的哥特式结构，抑或是圣保罗大教堂穹顶的稳定性问题。不过，雷恩确实是在当时推进这种知识，并试图在实践中应用现有的理论观念的学者之一。[54] 我们可以将他的结构模型称为位于已有的知识和正在创造过程中的新知识之间的“中间”物质：它们还代表了将雷恩的理论方法和知识与工匠大师的技能和知识相结合，赋予其理念以物质形式，并使它们变得可行的物质。

虽然这种模型的使用特别反映出雷恩对“机械”的兴趣，但是他运用模型解决结构问题的这种方式却属于一个悠久的传统（在此仅选择一个例子，请参见布鲁内莱斯基为圣母百花圣殿所做的模型）。尺度缩放，一直是科技领域中一个悠久而重大的争议性话题。而其中的核心问题，就是在处理结构元素的尺寸以确保目标建筑物稳定性的过程中，模型的适用性问题。该问题已经在几本现存的建筑著作中展开过讨论。维特鲁威曾经提到过这个话题，他指出，一些机械的失败正是由于按比例增大某些功能完善的模型而造成的。另外，阿尔贝蒂则坚持比例定律的普遍性，认为应该可以从较小的版本中获取实物的比例。其他文艺复兴时期的权威，例如安德烈亚·帕拉第奥（1508–1580）[55] 和达尼埃莱·巴尔巴罗（1515–1570）[56]——也坚持认为能够运用模型来确定真实的建筑的尺度，通过放大模型导致的失败的结构一定是因为所使用材料的不完善，而非缩放这个基本问题。

一些学者研究了 16 和 17 世纪的尺度缩放问题。伽利略在其著作《关于两门新学科的谈话及数学证明》（1638）中开启了这场讨论。在书中，他批评了模型的这种用途。伽利略（用他自己的话来说）正在建构一种“新的科学”，这种新的科学关注材料的强度，并且（和当时其他的作家一样）是区分由于材料强度不够而造成的失败（可能和由缩放引起的尺度上的误差）与原有设计中所固有的稳定性的问题而引发的失败的早期尝试。[57] 现在我们知道，就模拟稳定性而言，模型非常有用，但是在计算结构单元的最小尺寸以预测其强度方面的帮助并不大。[58]

雷恩对建筑的兴趣是他已经在其他知识领域的学术方面有所建树之后发展起来的。他使用三维模型是出于研究和展示的目的——尤其是在天文学[59] 和解剖学领域[60]，同时还包括光学领域。这些其他知识领域的经验影响到他如何发展在圣保罗大教堂的设计，或者更笼统地说，影响到他在作为皇室著作的主检查员，以及建筑与结构事务方面的顾问这漫长的职业生涯中如何处理自己所面对的诸多问题。他在建筑领域中对模型的“实验性”使用似乎与他此前在其他领域的经验及其广泛的对于科学和方法论的兴趣有关——不过，还需要指出的是，他的方法与自 14 世纪晚期以来从意大利发展起来的悠久的理论与实践的传统一致。作为一名非常博学的人士，雷恩一定知晓这一传统。他的建筑活动非常适合欧洲在建筑与科学方面的“尖端”发展——这在他的英语环境中或许是异乎寻常的。这样的实践也许是由伦敦大火带来的如此难得的建筑机会所成就的。

从总体发展的角度来看，自 15 世纪开始，三维模型从意大利向欧洲其他地区的传播是重要的一步。在此过程中，用于设计流程管理和改善不同类别的参与者之间沟通的标准化的“工具”——包括正式的工具及技术性的工具——得到了发展，而专业化与职业化同样在这些参与者个体的领域中涌现

the strength of materials and (in common with other contemporary writers) made early attempts to distinguish failures due to insufficient material strengths (possibly associated with incorrect dimensioning from scaling up) and those derived from matters of stability inherent in the original designs.[57] We now know that models are quite useful for simulating stability, but are much less help in calculating the minimum sizes of structural elements to predict their strength.[58]

Wren's interest in architecture developed after he had already established his scholarship in other branches of knowledge. He used three dimensional models – particularly in astronomy[59] and in anatomy,[60] but also in optics – for both research and demonstration purposes. These experiences in other branches of knowledge influenced how he went about developing his design for St Paul's, and more generally how he approached the many problems that confronted him during his long career as surveyor of the King's works and consultant on architectural and structural matters. His 'experimental' use of models in architecture seems to relate both to his previous experiences in other fields and to his broad scientific and methodological interests – but it should also be noted that his approach aligned with the long theoretical and practical traditions that had developed in Italy since the late 14th century, of which Wren – an extremely erudite man – was surely aware. Perhaps unusually for his English milieu – and also, probably, made possible by the extraordinary architectural opportunities created by the Great Fire – his architectural activities fit extremely well with the 'cutting edge' of European advances in architecture and in scientific discourse.

The spread of three dimensional models from Italy to the rest of Europe from the 15th century onwards was an important step in a more general development that saw the growth of standardised 'instruments' – both formal and technical – for managing design processes and improving communication between different types of actors, within whose individual fields professionalization and specialisation was also emerging. It has been suggested that models became more important when the design process and the supervision of works on building sites became fragmented activities, shared between different actors.[61] The 17th century saw the development – particularly in France – of new techniques and a new 'language' for technical and architectural drawings,[62] a phenomenon that related to many other disciplines besides architecture. The models and drawings Wren made in medicine and astronomy – for example – became exemplary 'instruments' of the new way of 'doing' science. For Scamozzi, models were 'sensual demonstrations'[63]– for Ephraim Chambers, drawings equated to 'geometrical demonstrations':[64] both saw them as instruments to produce knowledge. Given that architecture can be seen as the activity 'par excellence' between 'science' and the mechanical arts, it is no surprise that the increasing importance of such tools became particularly evident in this field.

Conclusions: Models embodying and creating in-between knowledge

The European Early modern period is characterised by the development of numbers of artefacts including, for example, such objects as classical scientific instruments (much discussed), maps, models and drawings – that served to conjoin different knowledge systems. This essay has focused on three dimensional models and shown how, in many respects, they were used – and at the time consciously conceived– as 'in-between objects'. They may either 'simply' embody different kinds of knowledge in one object, or (in a more complex sense) combine different kinds of knowledge and skill in such a way that their creation actually generates new, 'in-between', knowledge (Table 1). They may be situated between different social groups, mediating between patrons and architects, architects and craftsman etc.; and can also function 'in-between' generalization and specificity, abstraction and materiality (as exemplified in their role as the basis of contracts)

出来。有人建议，当设计过程和建筑工地上的监督过程成为碎片化的活动，由不同的参与者分担的时候，模型会变得更加重要。[61]17 世纪，尤其在法国，见证了新技术及一种技术和建筑图纸新“语言”的发展[62]。这种现象与除了建筑之外的其他学科领域都有相关性。例如，雷恩在医学与天文学方面制作的模型及绘制的图纸成为了“从事”科学研究新方法的示范性“工具”。就斯卡莫齐而言，模型是“感性的示范”[63]。而对伊弗雷姆·钱伯斯来说，模型则等同于“几何论证”[64]：两者都将模型视为产生知识的工具。考虑到建筑可以被看作是在“科学”和机械艺术之间“卓越的”活动，那么，这类工具尤其是在该领域重要性的日益凸显就不足为奇了。

结论：体现并创造中间知识的模型

欧洲早期现代阶段的特征体现于一些人工制品的开发，其中包括类似（热门话题）经典科学仪器之类的物品，地图、模型与制图——这些物品被用于连接不同的知识系统。本文专注于三维模型，并从多个角度展示了如何——这是当时有意识的构想——将它们作为“中间物质”来使用。它们既有可能通过一个物体“简单地”体现了不同的知识类别，又有可能（在更加复杂的意义上来看）以某种方式综合了不同类别的知识与技能，其结果是它们的创造事实上产生了新的“中间”知识。（表 1）它们可能位于不同的社会群体之中，斡旋于客户与建筑师、建筑师与工匠等之间；也可以在一般化和特殊性、抽象性与实质性“之间”发挥其作用（体现在它们作为合同的基础这样的作用），或者从更广泛的意义上来看，介于艺术的一般规则与每个现场的特殊性之间；或者介于过去与未来之间，在已经证实的解决方案的安全性与对于进一步创新的期许之间；以及，作为理论与实践之间的中间物质。

在最后这一部分，我们可以观察到一个二分法。在文艺复兴时期出现了将模型的使用作为“感性的示范”这样一个高潮（就如斯卡莫齐所言），而模型也被提升到建筑创意计划官方实验性工具的地位。因此，它们超越了先前的角色（即作为劣等技艺的表达方式），并被公认为两个领域——理论与实践之间的调节器。这两个领域迄今为止一直被视为是存在着根本性的差异。从另一角度看，伴随建筑师对自身身份，即作为艺术家以及知识分子，同时，相对他们在中世纪时期的前辈，更加脱离开物质性和建筑工地——的新认识，模型成为了一种边界对象。忽略了模型的实际成因及其在施工过程中的应用，建筑师们倾向于描绘出这样一幅画面，他们使用模型指导“下级的工匠”并将与模型相关的知识流描述为单向性的。所以，虽然模型是心手合一的所在，且具有不同背景、来自不同认知传统的参与者们通过模型交流了大量的知识。也正是在这个场所，新的知识被间或创造出来，但是目前越来越多具有自我意识的建筑师正在将模型作为界标，把自己设定为具有创意的个体，凌驾于那些单纯执行其设计的人群之上。

*致谢：

作为 URKEW 项目的一部分，推动本文发展的研究获得了来自欧盟第七届框架计划（(FP7/2007–2013)/ 欧洲研究委员会拨款协议第 230326 号）下属欧洲研究委员会的资金支持。如果没有欧洲研究委员会以及项目首席调查员帕特里克·O’布赖恩的慷慨支持，这篇文章将难以成型。我的研究曾经作为“证据的性质，事实是如何传播的？”项目的一部分，接受利华休姆信托基金与英国国家经济和社会研究委员会的资金支持，而这部分早期的工作已经融入了此项研究。在此感谢给予资金支持的机构和玛丽·S·摩根，她鼓励我，让我有机会自由探索新的主题，并阅读了本文的早期版本。非常感谢所有与我探讨该文相关材料的同事们，特别希望向马尔滕·波拉和帕特里克·沃利斯致谢，感谢他们阅读了本文的早期版本并给出发人深省其非常有益的意见，还要感谢 Paraphrase 的乔·恩摩根在编辑方面给予的帮助。

or – in a wider sense – between the general rules of the art and the specificity of each site; in-between past and future, between the security of proven solutions and the hope of further innovation; and as objects in-between theory and praxis.

In this last respect we can observe a dichotomy. The Renaissance sees an upsurge in the use of models as ‘sensory demonstrations’ (as Scamozzi put it) and elevation of their status to that of official experimental instruments in the creative enterprise of architecture. Thus they outgrow their former role (as expressions of an inferior techne) and become acknowledged as mediating instruments between two spheres – theory and praxis – that had hitherto been recognised as being fundamentally distinct. On the other hand, with the development of architects’ new awareness of themselves as artists and intellectuals, more detached from materiality and the building site than their medieval predecessors, the model becomes a boundary object. Disregarding the actual genesis and use of models in the building process, architects tend to portray themselves as using models to instruct ‘inferior artificers’ and describe the knowledge flows associated with models as being unidirectional. So, while models are loci where mind and hand come together, and where substantial knowledge is exchanged between actors with different backgrounds and from different epistemic traditions – and where, at times, new knowledge is produced – increasingly self-conscious architects are now adopting them as boundary markers which set them apart as creative beings, above those who merely enact their designs.

Acknowledgements

The research that enabled the development of this paper received funding from the European Research Council under the European Union’s Seventh Framework Programme (FP7/2007-2013)/ ERC grant agreement No. 230326), as part of the URKEW Project. Without the generous support of the ERC and of the Project’s PI, Patrick O’Brien, this article could not have been written. Earlier work that fed into this study had been carried out while I was funded by the Leverhulme Trust and ESRC as part of the project: ‘The nature of evidence. How Well Do Facts Travel?’. My thanks go to the funding bodies and to Mary S. Morgan, who encouraged me and gave me the opportunity to freely explore new topics as well as read through earlier versions of this essay.

I am very grateful to all the colleagues with whom I discussed the materials of this paper, particularly I wish to thank, Maarten Prak and Patrick Wallis for reading earlier versions of this article and giving thought-provoking and very helpful comments, and Jon Morgan of Paraphrase for his editorial help.

Notes

[1]Roberts, Schaffer, Dear 2007.

[2]Mokyr 2010.

[3]Long 2011, see also Pamela Long’s paper in this volume. Other scholars have considered this topic in recent years, see for example the recent Maffioli 2010.

[4]For a discussion of the role of models during the Enlightenment, particularly for machines and ships, see Fox 2010.

[5]Of course – despite their distinctiveness – these two categories have never been completely separated. For the thesis that in a number of cases in the Renaissance they become more and more blurred, see P. O. Long 2011.

[6]As an example, see Carlo Fontana’s Templum vaticanum et ipsius origo (1694) where the author, in the section devoted to the construction of roofs inserts chapter XII, Causa perché sia necessaria l’ordinazione delli Tetti dalli Professori (Reasons why it is necessary that roofs are designed by professors), where he criticises practitioners (Mecanici), who act only on the basis of experience (ordinano, & operano alla cieca, solo da una mera pratica, Fontana 1694, 101).

[7]Three dimensional models were obviously used in many other areas - such as shipbuilding or in scientific enterprises such as astronomy and medicine - but these are outside the focus of this paper.

[8]Morgan and Morrison 1999.

[9]Chadarevian and Hopwood 2004.

[10]On the link between Wren’s architecture and the Baconian program see Li 2000 and Li 2007.

[11]For an example of models of architectural elements such as columns produced in Imperial Egypt in the context of building practice, see Feuerbach forthcoming.

[12]Aristotle mentions models used to decide between different proposed buildings: for this and other references from ancient Greece see Di Pasquale 1996, 77-78.

[13]Vitruvius 2009, Book 10, Ch. XVI.5, 317. In some translations, models are mentioned in

注释

[1] 罗伯茨，谢弗等，2007。

[2] 莫基尔，2010。

[3] 隆，2011 年，也请参见本卷中帕梅拉·隆的文章。近年来，其他的学者已经在考虑这个主题，例如，请见近来马菲奥利的文章，2010。

[4] 有关模型在启蒙运动中的作用，特别是关于机器和船舶的讨论，请参见福克斯，2010。

[5] 当然——尽管它们存在独立性——这两个类别从来没有完全分离过。在有关文艺复兴时期的许多文章当中，它们变得越来越模糊，请见 P·O·隆，2011。

[6] 作为一个例子，请参见卡洛·丰塔纳的《寺庙增值税起源》(1694)，作者在专门论述建筑屋顶构造的章节中插入了第十二章《专业人士设计屋顶之必要性的原因》。在此，他批评了仅仅依赖经验的从业者们（美卡尼奇）(他们仅通过实践来盲目操作，丰塔纳，1694，第 101 页)。

[7] 很显然，其他许多领域也运用了三维模型——例如：造船业或者包含了诸如天文学和医学领域的科学事业，不过，这些都不在本文的重点论述范围之内。

[8] 摩根和莫里森，1999。

[9] 查戴尔维安与霍普伍德，2004。

[10] 有关雷恩的建筑与培根的方案之间的关联，请参见李，2000，以及李，2007。

[11] 有关建筑元素模型的案例，例如埃及帝国时期在搭建过程中制造的柱子模型，请参见费尔巴哈即将出版的著作。

[12] 亚里士多德提到了运用模型在不同的拟建建筑物之间做出决策：有关该内容以及其他古希腊的，请参见迪·帕斯夸莱，1996，第 77–78 页。

[13] 维特鲁威，2009，《建筑十书》，第十六章，第 317 页。某些版本的翻译中，在《第一书》的第一章节（建筑师的教育）提到了模型，在这里，模型是作为表达设计的方式，不过，很有可能指的是建筑图纸。关于在古代，设计过程中模型使用的讨论，请参见斯科拉里，1988 年版，第 16 页，以及脚注 1–5，第 29–31 页，更多详细信息请见巴塞罗那当代文化中心，1997。近年来，有两次会议的主题是专门围绕模型的，其中包括古代的案例："模型与建筑"国际会议，慕尼黑建筑博物馆，2009 年 11 月 6–8 日；"模型：建筑项目中的工具"，夏约学院和法国古迹博物馆，巴黎，2011 年 5 月 20–21 日。

[14] 关于中世纪时期模型使用的案例可见于和由理查德二世的木匠大师休斯·赫尔兰设计且参与施工的威斯敏斯特大教堂大厅屋顶相关的材料，请参见沃尔德勒姆，1935 年。有关英国中世纪建筑实践中图纸的使用的讨论，请参见佩西，2007，而关于意大利的实践分析，请参见波利尼，2001。迪·帕斯夸莱，1996，76 页，认为在中世纪的意大利一定已经开始使用模型。

[15] 斯科拉里，1988，16 页，提到了大约 11 世纪，圣日耳曼 – 欧塞尔修道院的模型，作为已知最早的案例。关于中世纪后期以及文艺复兴时期的意大利模型，请参见莱皮克，1994，米伦与兰普格纳利，1994（与在威尼斯举办的展览同期出版，格拉西宫）和埃弗斯，1996；关于英国与法国建筑中的模型，请参见哈维，1972 年版；关于模型在德语国家的使用，请参见路透和哈根贝克，1994；关于欧洲巴洛克模型，也请参见米伦，1999（请参见由格拉西宫在都灵斯塔平齐狩猎小屋组织的展览目录册）。

[16] 帕奇切尼，1987，第 9 页。

[17] 帕奇切尼，1987，第 9 页。

[18] 斯科拉里，1988，第 18 页。

[19] 在文艺复兴时期，认为设计过程是一种与工匠的体力劳动相分离的精神／智力活动的想法变得更加明确且具有主导性。从某种意义上说，在建筑史上具有标志性意义的欧洲人物包括意大利的菲利波·布鲁内列斯基（1377 – 1446），法国的菲利贝尔·德·L'奥姆（约 1514–1570）以及西班牙的胡安·德·埃雷拉（1530 – 1597）。关于德·L'奥姆，请参见 P·波蒂，1996。

[20] 阿尔贝蒂 [1486]。手稿在 1450 年前完成，但直到 1486 年，阿尔贝蒂去世之后，这本书才印刷出来。

[21] 阿尔贝蒂，1988 [1486]，第 7 页。

[22] 阿尔贝蒂，1988 [1486]，第 33–34 页。

[23] 欧克林，1996，第 44–46 页。

[24] 墨索里尼，2006。

[25] 斯科拉里，1988，第 24–26 页。

[26] 欧克林，1996，第 47 页。

[27] 威尔顿 – 伊利，1967，第 27 页。此后案例的相关讨论，请参见威尔顿 – 伊利，1968。

[28] 沃顿，1624，第 65–66 页。

[29] 冈瑟，1928，这些笔记是普拉特在 1660 年写的。

[30] 钱伯斯，1740，第 565 页。

[31] 威尔顿·伊利，1967，第 28 页。

[32] 爱德华·伍德鲁夫是他的助手，约翰·提利森是他的工作秘书，而尼古拉斯·霍克斯莫尔则是后来加入这个团队的。

[33]16 世纪 20 年代，由英尼格·琼斯设计的文艺复兴风格的门廊被添加到了外立面上，旨在改变糟糕的建筑外观。

[34] 与罗伯特·胡克、休·梅、罗伯特·普拉特，爱德华·杰曼和彼得·米尔斯一起。

[35] 在此仅提一下最近的出版物：基恩，伯恩斯，2004，关于具体的建设过程，请参见坎贝尔，2007。

[36] 关于所谓"第一件模型"和"伟大的模型"的讨论以及它们的起源和在建筑方面重要性的描述，请参见黑格特，2004，第 186–189 页。关于圣保罗大教堂所使用模型的详细描述，请参见瓦莱里尼即将出版的著作。

book I, Ch. I (the education of the architect) as ways of representing the design, but it is most probable that what was meant there were drawings. For a discussion of the use of models in the design process in antiquity see Scolari 1988, 16 and footnotes 1-5, pp. 29-31, and more detailed information in Centre de Cultura Contemporania de Barcelona 1997. Two recent conferences have been devoted to models, including examples from antiquity: Models and Architecture, International Conference, Architekturmuseum Munich, 6-8 November 2009; The Model: A Tool in the Architectural Project, École de Chaillot and Musée des Monuments Français, Paris, 20-2May 201(proceedings forthcoming).

[14]An example of the use of models in medieval times can be found in connection with the design and construction of the roof of Westminster Hall by Hugh Herland, master carpenter to Richard II, see: Waldram 1935. For a discussion of the use of drawings in English medieval architectural practice see Pacey 2007, and for an analysis of Italian practice see Borgherini 2001. Di Pasquale 1996, 76 believes that models must have been in use in medieval Italy.

[15]Scolari 1988, 16 mentions a model for the Abbey of Saint-Germain d'Auxerre from the 11th c., as the earliest known example. For Italian models from late middle Ages and Renaissance, see Lepik 1994, Millon and Lampugnani 1994 (published in conjunction with the exhibition held in Venice, Palazzo Grassi) and Evers 1996; see Harvey 1972 for models in English and French architecture; for the use of models in German countries see Reuter and Beckenhagen 1994; and for European baroque models see also Milton 1999 (Catalogue of an exhibition organized by the Palazzo Grassi and held at the Stupinigi Hunting Lodge, Turin).

[16]Pacciani 1987, 9.

[17]Pacciani 1987, 9.

[18]Scolari 1988, 18.

[19]During the Renaissance the concept that the designing process was a mental/intellectual activity separated from the manual labour of the craftsmen became more explicit and dominant. European figures that mark the history of architecture in this respect are Filippo Brunelleschi (1377 – 1446) in Italy, Philibert De L'Orme in France (c. 1514 –1570) and Juan de Herrera (1530 –1597) in Spain. For De L'Orme, see P. Potié 1996.

[20]Alberti [1486]. The manuscript was finished by 1450 but the book was not printed until 1486, after Alberti's death.

[21]Alberti 1988 [1486], 7.

[22]Alberti 1988 [1486], 33-34.

[23]Oechslin 1996, 44-46.

[24]Mussolin 2006.

[25]Scolari 1988, 24-26.

[26]Oechslin 1996, 47.

[27]Wilton-Ely 1967, 27. For a discussion of later examples, see Wilton-Ely 1968.

[28]Wotton, 1624, 65-66.

[29]Gunther 1928, the notes were written by Pratt in the 1660es.

[30]Chambers 1740, 565.

[31]Wilton Ely 1967, 28.

[32]Edward Woodroofe was his assistant and John Tillison his Clerk of Works, while Nicholas Hawksmoor joined the team later.

[33]In the 1620s a porch designed by Inigo Jones in Renaissance style had been added to the façade as an attempt to remedy to what was perceived as the poor appearance of the building.

[34]Together with Robert Hook, Hugh May, Robert Pratt, Edward Jerman and Peter Mills.

[35]Just to mention recent publications: Keen, Burns, Saint 2004, specifically on the building process, see Campbell 2007.

[36]For a discussion of the so called 'First Model' and 'Great Model' and a description of their genesis and architectural significance see Higgott 2004, 186-189. For a detailed description of the models used in St Paul's, see Valeriani forthcoming.

[37]In the case of complex structures, the presentation model and the technical model can coincide, as the architect might want to impress the patron with his innovative techniques, or need to convince his audience of the feasibility of what he is proposing. See for example Brunelleschi and the masonry model of the Florentine dome built in 1418 without centring (Guasti 185,7 Docs. 18, 43; quoted after Prager and Scaglia, 1970, 30).

[38]A good example is the entry in September 1705 'E.S. a Mason 19 days. Making a Modell for securing the Work from wet at ye top of ye Lead Pipes at 2s 6d. £2.7.6', Wren Society (from now on cited as WS), vol. XV, 128.

[39]Information on the production of these models can also inform the discussion on the possible French inspiration for St Paul's dome (Summerson 1990).

[40]WS XV, 80.

[41]WS XV, 85.

[42]WS XV, 134.

[43]G. Higgot discusses two sets of drawings made in 1690-9and 1693-95 (Higgot 2009, 164 and

[37] 在结构复杂的情况下，展示模型与技术模型可以是重合一致的，因为建筑师可能希望藉由具有创意性的技巧给赞助人留下深刻的印象，或者需要让他的受众相信其提议的可行性。相关案例请见布鲁内莱斯基以及 1418 年建于佛罗伦萨圆顶的砖石模型，该圆顶并没有中心点（瓜斯蒂，第 185 页，文件 18、43；引用自普拉格与斯卡利亚，1970，第 30 页）。

[38]1705 年 9 月的条目是一个很好的例子，“E・S・，一名石匠，19 天。制作了一个模型以确保工作不受潮湿情况的影响。2.7.6 英镑”，雷恩协会（从现在起成为 WS），第 15 卷，第 128 页。

[39] 关于制造这些模型的信息还能够告知我们有关法国方面可能存在的对圣保罗大教堂穹顶设计的启发的讨论（萨默森，1990）。

[40]WS XV，第 80 页。

[41]WS XV，第 85 页。

[42]WS XV，第 134 页。

[43]G・希格特讨论了分别创作于 1690–1691 和 1693–1695 年期间的两套图纸（希格特，2009，第 164 页，图 87；第 165 页，图 152）。谈到穹顶中的两个圆锥形结构，他指出“雷恩研究出了侧面的图，在其石匠大师爱德华・施东的辅助下，以实验的方式用扶壁进行支撑与加固”（希格特，2009，第 164 页）。1692 年 8 月，支付了“里面的圆顶”的模型费用（WS，XIV，第 99 页）。自 1695 年 1–2 月起，开始搭建大拱门上方的圆顶（WS，XV，第 6 页）。N・霍克斯莫尔的职业生涯开始于为雷恩担任助手，此后，霍克斯莫尔本人成为了一名重要的建筑师；最近的关于他的著作，请参见哈特，2002。

[44]WS，XIV，第 100 页。

[45] 到了 1692 年，许多由雷恩负责的城市教堂已经建成，或是工程进展顺利。有一个例外，圣韦达斯特福斯特巷（屋顶建造于 1696–1699）：这个屋顶是由木匠约翰・朗兰建造的，因而，就这个项目而言，相对工匠，模型对客户更加有用。雷恩的另一座运用柱撑式三角桁架的建筑是牛津大学万灵学院（1721 年，未知木匠）。有关雷恩对柱撑式三角桁架使用的讨论以及他可能提到的经典模型，请参见瓦莱里尼，2011，与瓦莱里尼，2006。

[46]WS，第 16 章，第 28 页。其他的案例也可以从圣保罗大教堂的记录中查找。在威斯敏斯特大教堂的修缮记录中可以找到一个类似的（与雷恩相关的）例子：“要求工人依据模型修复旧屋顶上方的圆顶”（《法布里克订单》，1726 年 4 月 15 日）。

[47] 冈瑟，1928，第 22 页。

[48] 雷恩，《圣保罗大教堂修复报告》，雷恩，1750，第 277 页。

[49] 使用模型以确定组成拱顶的每块石头的形状在处理复杂几何形的情况下尤其明显，也是法国古典传统的特征。

[50] 雷恩有关教堂状况以及必要的干预的报告，雷恩，1750，第 274–277 页。

[51] 雷恩有关教堂状况以及必要的干预的报告，雷恩，1750，第 303–308 页。

[52] 雷恩，1750，第 300–301 页。

[53]“这位建筑师……明智地认为，如果他用铁将这些拱门连接在一起……这或许在他搭建塔楼并确保一切安全之前都是适用的。这些铁杆被盗走了，这就是 4 根柱子向内弯曲的原因……；不过，在第一根柱子被修复之前，什么都不能改动，我已经考虑过如何在一个模型中去表达和再现这种情况。”《雷恩 1750》，第 301 页。

[54] 针对雷恩为圣保罗大教堂的穹顶所做的设计而展开的有关数学思考对圆顶最佳形状（胡克的挂链原则）的影响的最新讨论（并参照了早期作品），请参见希格特，2009。

[55] 帕拉迪奥，1570，第 3 卷，第 18 页。

[56] 巴巴罗 [1556] 1987，第 128–129 页。

[57] 就文艺复兴时期有关材料的比例与强度问题的著作——在伽利略之前——而展开的讨论，请参见瓦厄里尼，2009 年。

[58] 有关模型在模拟稳定性而非预测强度方面的适用性的讨论，也请参见海曼，1968。

[59] 到了 17 世纪 50 年代，雷恩已经制作了他的 Panorganum Astronicum，这是一个展示地球、太阳和月亮周期性关系的模型。在观察了土星并发展出有关其圈环的理论之后（1654–1659），他于 1659 年制作了包括该星球及其圈环在内的模型以配合他就这个主题展开的讲座。不过，雷恩最著名的天文模型是 1661 年他向查尔斯国王展示的月球仪。因此，雷恩在天文学方面对模型的使用与教学以及示范的目的相关：它们是展示其理论的手段，或者作为珍贵的礼物制作出来馈赠给潜在的客户。制作天文模型的传统由来已久，可以追溯到几千年前。在接近雷恩的时代，我们可以见证伽利略（记录在其著作《对话》的注释中）用一个月球模型作为“实验对象”，通过望远镜研究具有可能性的，月球表面可见阴影的起源，请参见华莱士，2003，第 113 页。

[60] 雷恩把模型作为教具使用（他可能制作了解剖纸板模型来说明查尔斯・斯卡布罗爵士在外科医生大厅的讲座，请见杰比诺和约翰斯顿，2009，第 85 页，提到了贝内特，1976）不过（也有可能）是固定观察尸体的一种方式，并作为其关于人体各部分机械功能理论的物质形式。

[61] 这可能是影响模型在圣保罗大教堂搭建过程中使用的一个因素，不过它似乎并不是要点——虽然身兼多个委任——雷恩还是经常出现在圣保罗大教堂。

[62] 这同样也影响到圣保罗大教堂设计组织过程中具有创意的方式。关于圣保罗大教堂图样使用的讨论，请参见格比诺，约翰斯顿，2009，第 97–110 页。

[63]“模型是需要细致耐心地展示并运用的这样一个部分”，斯卡莫齐，1615，第一部分，第 15 章，第 51 页。

[64] 钱伯斯，1728，第 521 页，探讨“力学”这个术语：经过多次发现，无论主题为何，它对解码或绘制图表都有所帮助，因为在常见的几何演示中都会惯用到它；而通过这种方式来获取的知识则被称为“机械知识”。

fig. 87; 165 and fig. 152). Discussing the two cone like structure in the dome, he notes that ‘Wren arrived at their profiles, buttressing and reinforcements experimentally, aided by his master mason Edward Strong’ (Higgot 2009, 164). A model ‘of Legg of Dome on Inside thereof’ was paid for in August 1692 (WS, XIV, 99). The construction of the dome above the great arches started in January-February 1695 (WS, XV, p.6). After starting his career as Wren’s assistant N. Hawksmoor became an important architect in his own right; for a relatively recent monograph on him, see Hart 2002.

[44]WS, XIV, 100.

[45]By 1692 many of Wren’s city churches were already complete, or construction was advanced. An exception is, for example, St Vedast Foster Lane (roof built in 1696-99): here the roof was built by the carpenter John Longland, so that the model would have been useful more to the patrons than to the craftsmen. Another Wren building that uses king post trusses is All Souls College, Oxford (1721, carpenter unknown). For a discussion of the use of king post trusses by Wren and the likely classical models he referred to, see Valeriani 201and Valeriani 2006.

[46]WS, XVI, 28. Other examples are traceable in St Paul’s records. A similar instance (connected with Wren) is to be found in the documentation of the repairs to Westminster Abbey: ‘Ordered that the Dome be repaired to the top of the old Roof by the Workmen according to Model now laid before the Committee by the several workmen and Estimates by them given in.’ (‘Fabrick Orders’, April 15, 1726). Note that here the workmen themselves are producing and presenting the models.

[47]Gunther 1928, 22.

[48]Wren, Report on the repairs to St Paul’s Cathedral, in Wren 1750, 277.

[49]The use of models to work out the shape of each stone composing a vault is particularly evident in the case of complicated geometries, and in particular characterises the French stereotomic tradition.

[50]Wren’s report on the state of the church and the necessary intervention is published in Wren 1750, 274-277.

[51]Wren’s report on the state of the church and the necessary intervention is published in Wren 1750, 303-308.

[52]Wren 1750, 300-301.

[53]‘The architect … wisely considered that if he tied these Arches every Way with Iron… this might serve the Turn till he built the Tower to make all secure. These Irons… have been stolen away and this is the reason for the four Pillars being bent inward …; but nothing can be amended, till first the Pillars are restored, which I have considered how to perform and represented in a Model.’ Wren 1750, 301.

[54]For the latest discussion (and references to earlier works) of the influence of mathematical considerations on the best shape for a dome (Hooke’s hanging-chain principle) on Wren’s design for St Paul’s dome, see Higgot 2009.

[55]Palladio, 1570, III. 18.

[56]Barbaro [1556] 1987, 128-129.

[57]For a discussion of the Renaissance writings on the problem of proportions and the strength of materials –also before Galileo- see Valleriani 2009.

[58]Di Pasquale 1988. For a discussion of the suitability of models to simulate stability and not to predict strength see also Heyman 1968.

[59]By the 1650s Wren had already produced his Panorganum Astronicum – a model of the earth, sun and moon showing their periodic relationships. After observing Saturn and developing his theory of its rings (1654-9), he made a model of both planet and rings in 1659 to accompany his lectures on the topic. But his most famous astronomical model was the lunar globe he presented to King Charles in 1661. Wren’s use of models in astronomy is therefore related to didactic and demonstration purposes: they are a means to show his theories or are produced as precious gifts for potential patrons. The production of astronomical models has a very long tradition that goes back millennia. Closer to Wren’s own times we see Galileo using a model of the moon as an ‘experimental object’ to study the possible origin of the shadows visible on the lunar surface through the telescope, as he notes in his Dialogo, see Wallace 2003, 113.

[60]Wren used models as didactical aids (he probably produced anatomical pasteboard models to illustrate Sir Charles Scarburgh’s lectures at Surgeons’ Hall, see Gerbino and Johnston 2009, 85, which points to Bennett 1976) but (probably) also as a way of fixing the observations made on corpses and to give material form to his theories about the mechanical functioning of body parts.

[61]B. Contardi 1991, 10-11. This might be an element that influenced the way models were used at St Paul’s but it does not seem a central point as – despite his many commitments – Wren was present at St Paul’s regularly.

[62]This also influenced the innovative way in which the design process was organised at St Paul’s. For a discussion of the use of drawings at St Paul’s see Gerbino, Johnston 2009, 97-110.

[63]‘Il Modello é parte che viene dimostrata sensibilmente, & in atto’ Scamozzi 1615, Parte Prima, Libro Primo, Cap. XV, 51.

[64]Chambers 1728, 521, discussing the term ‘mechanics’: ‘it is frequently found helpful to decipher, or picture out in Diagrams, whatsoever is under consideration, as it is customary in common Geometrical Demonstrations; and the Knowledge obtained by this Procedure, is called Mechanical Knowledge’.

References

[1]L. B. Alberti, De re aedificatoria. On the art of building in ten books, (translated by Joseph Rykwert, Robert Tavernor and Neil Leach), (Cambridge, Mass., 1988 [1486]).
[2]Daniele Barbaro, Dieci libri dell'architettura di M. Vitruvio…, (Milano, [1556] 1987).
[3]J. A. Bennett, 'A note on theories of respiration and muscular action in England c. 1660', Medical History, 1976, 20: 59-69.
[4]M. Borgherini, Disegno e progetto nel cantiere medievale, (Venezia, 2001).
[5]J. W. P. Campbell, Building St Paul's, (London, 2007).
[6]Centre de Cultura Contemporania de Barcelona, Las Casas del Alma. Maquetas Arquitectónicas de la Antigüedad (5500a.C./300 d.C), (Barcelona, 1997).
[7]S. Chadarevian, N. Hopwood (eds.), Models, the Third Dimension of Science, (Stanford, 2004).
[8]E. Chambers, Cyclopædia, (London, 1740).
[9]T. Cocke, 900 Years: The Restorations of Westminster Abbey, (London, 1995).
[10]B. Contardi, 'I modelli nel sistema della progettazione architettonica a Roma tra 1680 e 1750', in B. Contardi, G. Curcio (eds.), In Urbe Architectus. Modelli, Disegni, Misure. La professione dell'architetto. Roma, 1680-1750, (Roma, 1991), 9-22.
[11]S. Di Pasquale, 'Leon Batista Alberti and the Art of Building', Nexus II: Architecture and Mathematics, (1988), 115-125.
[12]S. Di Pasquale, L'arte del Costruire tra conoscenza e scienza, (Veneza, 1996).
[13]B. Evers (ed.), Architekturmodelle der Renaissance - die Harmonie des Bauens von Alberti bis Michelangelo, (München 1996).
[14]U. Feuerbach, 'The use of Models in ancient Egypt', in Proceedings of the conference The Model, a Tool in the Architectural Project, published by Ecole de Chaillot, Cité de l'Architecture et du Patrimoine, Editions Lieux Dits, (forthcoming).
[15]C. Fontana, Templum vaticanum et ipsius origo. Cum Aedificiis maximè conspicuis antiquitùs, & recèns ibidem constitutis; editum ab Equite Carolo Fontana Deputato celeberrimi ejusdem Templi Ministro, atque Architecto, (Roma, 1694).
[16]C. Fox, The arts of industry in the Age of Enlightment, (New Haven and London, 2010).
[17]C. Guasti, La cupola di S. Maria del Fiore, Florence, 1857.
A. Gerbino, Stephen Johnston (eds.), Compass & Rule. Architecture as Mathematical Practice in England, (New Haven and London, 2009).
[18]R.T. Gunther, The Architecture of Sir Roger Pratt, (Oxford, 1928).
[19]V. Hart, Nicholas Hawksmoor: rebuilding ancient wonders, (New Haven and London, 2002).
[20]J. Harvey, The Medieval Architect, (London, 1972).
[21]J. Heyman, 'The rubber Vaults of the Middle Ages and other Matters', Gazette des Beaux-Arts, March 1968, 177-188.
[22]G. Higgot, 'The Fabric to 1670', in Keen et alia 2004, 171-190.
[23]G. Higgot, 'Geometry and Structure in the Dome of St Paul's Cathedral', in Gerbino and Johnston 2009, 155-172.
[24]D. Keen, A. Burns and A. Saint, St Paul's. The Cathedral Church of London 604-2004, (New Haven and London, 2004).
A. Lepik, Das Architekturmodell in Italien, 1335-1550, Römische Studien der Bibliotheca Hertziana; 9, (Worms, 1994).
[25]S. Li, 'Christopher Wren as a Baconian', in The Journal of Architecture, 2000, 5: 235-266.
[26]S. Li, Power and Virtue: Architecture and Intellectual Change in England 1660-1730, (London and New York, 2007).
[27]P. O. Long, Artisan/Practitioners and the Rise of the New Sciences, 1400-1600, (Corvallis, OR, 2011).
[28]C. S. Maffioli. La via delle acque (1550–1700): Appropriazione delle arti e trasformazione delle mathematiche, (Firenze, 2010).
[29]H. A. Millon, V. Magnago Lampugnani (eds.), The Renaissance from Brunelleschi to Michelangelo: the representation of architecture, (London, 1994).
[30]L. Milman, Sir Christopher Wren, (London, 1908).
[31]H. A. Milton (ed.), The triumph of the baroque: architecture in Europe, 1600-1750, (Milano, 1999).
[32]J. Mokyr, The Enlightened Economy: An Economic History of Britain, 1700-1850, (New Haven and London, 2010).
[33]M. S. Morgan and M. Morrison, Models as Mediators. Perspectives on Natural and Social Sciences, (Cambridge, 1999).
[34]Mauro Mussolin, 'Forme in fieri. I modelli architettonici nella progettazione di Michelangelo', in C. Elam (ed.), Michelangelo e il disegno di architttura, (Venezia, 2006), 95-111.
[35]C. Newmann, 'Sir Charles Scarburgh', British Medical journal, 1975, 3: 429-430.
[36]W. Oechslin, ‚Das Architekturmodell zwischen Theorie und Praxis', in: B. Evers (ed.), Architekturmodelle der Renaissance, (München, 1996), 40-49.
[37]R. Pacciani, 'I modelli lignei nella progettazione rinascimentale', Rassegna, anno IX, dicembre 1987, 32: 6-19.
A. Pacey, Medieval architectural drawing: English craftsmen's methods and their later persistence (c.1200-1700), (Stroud, 2007).
[38]Palladio, I Quattro Libri dell'Architettura, (Venezia, 1570).
[39]P. Potié, Philibert De L'Orme. Figures de la Pansée constructive, (Marseille, 1996).
[40]F. Prager, G. Scaglia, Brunelleschi, Studies of his technologies and inventions, (Cambridge MA, 1970).
[41]H. Reuter, E. Berckenhagen, Deutsche Architekturmodelle. Projekthilfe zwischen 1500 und 1900, Jahresausgabe des Deutschen Vereins für Kunstwissenschaft, (Berlin, 1994).
[42]L. Roberts, S. Schaffer, P. Dear (eds.), The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialisation, (Amsterdam, 2007).
[43]Vincenzo Scamozzi, L'idea Dell'Architettura Universale, (Venezia, 1615).
[44]Massimo Scolari, 'L'idea di modello', Eidos, June 1988, 2: 16-39.
[45]J. Summerson, 'J.H. Mansart, Sir Christopher Wren and the dome of St Paul's Cathedral', Burlington Magazine, 1990, 132/ 1042: 32-36
[46]S. Valeriani 'Sir Christopher Wren and the use of models in the construction of St Paul's cathedral,' in Proceedings of the conference The Model, a Tool in the Architectural Project, published by Ecole de Chaillot, Cité de l'Architecture et du Patrimoine, Editions Lieux Dits, (forthcoming).
[47]S. Valeriani, 'Facts and Building Artefacts: What Travels in Material Objects?' in P. Howlett, M. S. Morgan (eds), How Well Do 'Facts' Travel?, (Cambridge, 2011), 43-71.
[48]S. Valeriani, 'The Roofs of Wren and Jones: A Seventeenth-Century Migration of Technical Knowledge from Italy to England', Working papers on The Nature of Evidence: How Well Do 'Facts' Travel?, 14/06, LSE, Department of Economic History.
[49]M. Valleriani, 'The Transformation of Aristotle's Mechanical Questions: A Bridge Between the Italian Renaissance Architects and Galileo's First New Science', Annals of Science, 66/2: 183-208.
[50]M. Vitruvius, On Architecture, translated by R. Schofield, (London, 2009).
[51]P.J. Waldram, 'Science and Architecture: Wren and Hooke', Journal of the Royal Institute of British Architects, 1935, 42.9: 558.
[52]W. A. Wallace, 'Galileo's Jesuit Connections and Their influence on His Science' in: Jesuit science and the republic of letters, edited by M. Feingold, (Cambridge Mass., 2003), 99-126.
[53]J. Wilton-Ely, 'The architectural Model', Architectural Review, July 1967, CXLI: 26-32.
[54]J. Wilton-Ely, 'The architectural model: English baroque', Apollo Magazine, Oct. 1968, 88: 250-59.
[55]H. Wotton, The Elements of Architecture… from the Best Authors and Examples, (London, 1624).
[56]Wren, Parentalia or Memoirs of the Family of the Wrens, (London 1750).
[57]Wren Society, vol. XIV, (Oxford, 1937).
[58]Wren Society, vol. XV, (Oxford, 1938).
[59]Wren Society, vol. XVI, (Oxford, 1939).

This article was originally published in History of Technology, Edited by Ian Inkster, Volume 31, (Bloomsbury, 2012), 26–46

本文原载于《技术的历史》，编辑：伊恩·英科斯特，第 31 卷，布鲁姆斯伯里出版公司，2012 年，第 26–46 页。

西蒙娜·瓦莱里亚尼博士 V&A/RCA 设计史硕士项目，高级导师（V&A）
汪　芸 中国美术学院

Dr. Simona Valeriani Senior Tutor (V&A), V&A/RCA History of Design MA