

# Obsolete Ways of Designing

## Scale Models at the Time of Digital Media Technologies

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In the 1970s, along with the other forms of architectural representation, the scale model began to attract attention as an object itself. Exhibitions and scholarly works concentrated more on the models as media of architectural conception and important communicational tools. Before that time it was unusual for museums to focus on models and they were usually included alongside other forms of architectural representation in the shows and were meant to *illustrate* current projects.<sup>1</sup> In England more model-based shows appeared in the 1970s with increasing frequency having models as objects in their collections that could be viewed in their own right. This initiative shifted to America and in 1976 in New York was held the first exhibition that truly focused on the model itself—"The Idea as Model." While arguing that models like architectural drawings, could have a great artistic and conceptual power and gain more importance in design and communication, the catalogue published in 1981 posited also that "models assume greater importance (or "reality") during periods of radical change, when architecture is shifting direction".<sup>2</sup> This statement sounds amazingly true for the practices of some contemporary architects, whose thinking flourishes in the moment of rapid development of the technologies for digital reproduction and circulation of architectural images.<sup>3</sup> The recent architectural exhibition „Content" showcased the work of the Office for Metropolitan Architecture of Rem Koolhaas and witnessed for a similar revival of the importance of the scale models as objects that are to be viewed and appreciated in their own right (not merely as physical illustrations of architectural projects and ideas; fig. 1).

Thought as a liberation of the architect from his heavy material duties (of drawing and sketching on the board), the digital tools were meant to render possible a different way of thinking architecture. But at the time when digitalisation was flourishing and novel ways of illustrating and communicating the architectural projects were developing, a traditional medium of architecture experienced a re-

vival—the architectural drawing. Numerous theorists of architecture have attempted to explain its revival and changing status at the beginning of the 1970s<sup>4</sup> and have often found an answer in the crisis experienced by architecture and the architectural production at the time—crisis of the commissions and crisis of the values of the modernist doctrine. The moments of crisis, stated the theorists of architecture in the 1980s, when building constructions are rare and the ideas are tentative, are also moments in which we can witness the revival of the architectural drawing, as it becomes the medium of the romantic dreams of the creativity. Today, in a moment of architectural boom in the far-East countries and growing complexity of the buildings and the cities designed, contemporary architecture experiences a renaissance of models; model making regains power as design practice in the architectural offices of leading architects.

Though scale models are important tools in architectural design, accounts on models are not abundant as compared to the noteworthy literature on drawings in architecture. The fashionable question in the 90s "Why architects draw?" has found numerous answers.<sup>5</sup> Although the interest on models has increased tremendously in recent years,<sup>6</sup> and so is the curiosity in the collections of architectural models,<sup>7</sup> there are no accounts outlining how architects engage in model-making and how precisely models function in design process today. Existing classification systems of models do not explain how a model interacts with its user, and do not contribute to the understanding of the use of a model as part of an educational process.

Amid the accounts on the functions of models enlisted in design literature, several ones have pinpointed that models play as:

*Expressions of internal energies and fantasies of the architect's mind's eye. The model translates the imaginary project existing only in the head of an architect<sup>8</sup> and transforms the inherently subjective ideas into physical and tangible prototypes.<sup>9</sup> Design*



Fig. 1: The show "Content" in Rotterdam

is considered as being a process of transfer of powerful subjective imagination into physical form<sup>10</sup> in a moment of delirium and concealment.<sup>11</sup> Models are used to express messages.<sup>12</sup>

*Communicational tools:* they serve as an immediate comprehensible means of communication among architects, and from the other side with non-specialists<sup>13</sup> and clients that often cannot visualize the building without the help of the model.<sup>14</sup> Models serve as a guide for workmen in construction.<sup>15</sup>

Tools for *narrating* the building that are meant to collect, articulate and memorize the precise spatial information about it.<sup>16</sup> Models provide a tool for the examination of the relationship between the site and the surrounding district, the shape of the area, the number and the order of the parts of the building.<sup>17</sup> Replicating ancient Greek and Roman buildings from the past models are used to create a comprehensive view of architectural history.<sup>18</sup>

*Presentational tools:* Models are powerful instruments for the presentation of the building to larger audiences and persuasion of client and sponsors.<sup>19</sup>

*Didactic tools:* models are used to teach and transfer knowledge from the master architect to the apprentices in the studio.<sup>20</sup>

*Artworks:* models could have *artistic or conceptual* relatively independent *existence*,<sup>21</sup> which explains the growing fascination of contemporary artists to experiment with models and display them in museums. Besides being a self-reflexive expression of architect's insights and concepts, the architectural model could achieve a quasi-independent status.<sup>22</sup>

The theories on models mentioned above show little attention to how designers really work with models on a daily basis as well as to the complexity of the experimental and cognitive work executed with models in architectural design and education. So what exactly is an architectural scale model? What are its meanings and modalities of actions in design enquiry? What does it mean to design with scale models at the time of digital media technologies? What are the forms of literacy and competence of scale models in design practices, their agency, and specific ways of mobilizing a variety of heterogeneous actors? Can we talk about a revival of models in architectural practices and communication in contemporary architecture?

Using the Actor-Network-Theory developed by Bruno Latour and Michel Callon<sup>23</sup> I followed architects at work at OMA in the period of 2001–2004, and studied extensively the practices of the team working on the project for the extension of the Whitney Museum of American Art in New York.<sup>24</sup> I

followed both architects and models in their routine practices and accounted watchfully their actions and transactions in complex spatial settings, the materialization of the successive operations they perform on a daily basis and the foreseen and unforeseen consequential effects they trigger. In this ethnographical survey of practitioners at work a better knowledge about models as participants (not just as representational tools) in design was gained.

So, instead of seeking to establish a typology of ways of designing, based on after-the-fact analysis of architects' accounts (interviews, autobiographies), my intention was to gain first-hand information about models-and-architects-in-action, and the modalities of knowledge production and communication through models. This study drew on a variety of sources about architectural design: conversations among architects at work at OMA; in-depth interviews with architects, engineers, clients and proto-users of the building; observation of the office environment, practices, rites and working habits; personal (rather dilettantish) participation in model making; visual accounts of the actors' non-discursive actions such as: movements, grasps, gestures, and reactions. Using this variety of sources, I followed designing architects from the model shop to the public presentations and questioned the development of their projects remaining close to them and the course of their actions, intervening and participating in little tasks. I observed them in many situations in which they learned from each other, from the master architect, from the cutting instruments, from the models. I followed how architects agree and disagree over models, how they are given identity as a group, how they attribute meaning to their actions, engage in the repetitive rituals of team discussions and public presentations, thus gradually gaining access to their own definitions of what it means to think architecturally, of what it means to design.

## Models in action at OMA

### 1. *Inspecting the scale models*

The numerous models generated throughout design process provide architects with a variety of ways to *observe* the building. A comprehensive observation of this complex entity is furthered from the very first brainstorming at the Office for Metropolitan Architecture (fig. 2).

"We take these models seriously and try to analyze the intention and always try to *look for new and interesting ideas out of very naïve looking models*. I'm sure that some architects can laugh when they look at this, but we are pretty serious to analyze these models." (interview with Sho)

The models are closely observed and allow the not-yet-existing building to be perceived and

appreciated. By reacting to models, and letting themselves being surprised and acted upon, as well as by presenting models to many clients, external visitors, and colleagues, architects can detect the consequences of models' actions, and those who will experience them further on. The physical models allow the building to be *experienced* as a matter, tactually or sensibly vouched for.

The building appears in the design studio as an object in direct sensual experience: perceived by some architects as a beautiful and gripping object and by others as disgusting and weird. Its advantages are explained by architects at work in a rich sensual register: tactility, visual richness, corporal accessibility and easy manipulation. That is what makes also the physical models *act* in a different way than the computer models. As architects can touch physical models and turn them around, they can sense them and models can *tell* them more. The tactile, sensual and easy modifiable physical models are much more powerful in *sparking* architects' imagination than other visuals in the studio. They have a stronger spatial presence whereas the computer models remain hidden on the hard drives; the sketches and plans share the flatness of the tables and the drawing boards. Physical models actively intervene in various design operations and engage in interaction with the office environment. They capture time, space and humans' attention and assemble architects in the physical space (see fig. 3). All models, even the unsuccessful ones, are kept and accumulated in the office, thus progressively collecting the elements needed for the build-

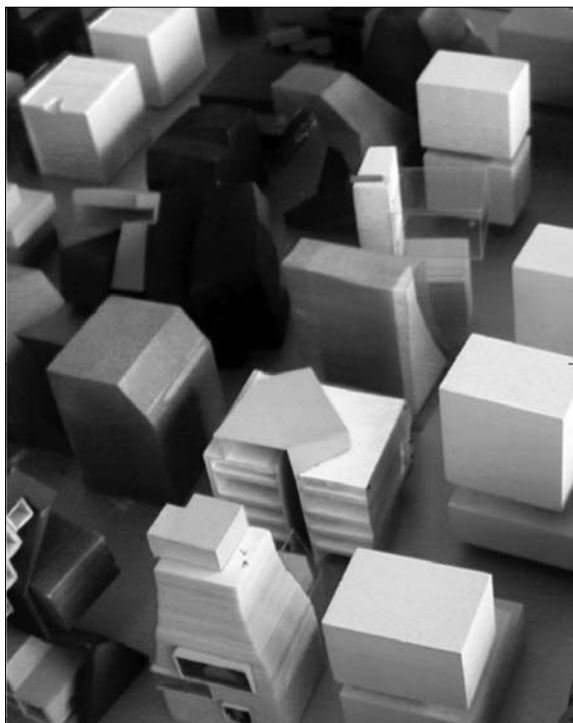


Fig. 2: Experimental models at OMA (copyrights OMA)

ing to be defined. As architects act in this very dense "model" environment, every single encounter with foam try-outs, models and materials from different projects can flash their imagination and can serve as a cognitive input for a new shape.

There is a particular moment in the observation process when "something" in the model compels, invites to be seized, and is being perceived by the architects. In the act of models' appreciation, architects enter in a dialogue with them and this dialogue can trigger new possibilities for the building.

"Sometimes the things that are more grotesque or more repugnant in models may have some interesting qualities in the *process of inspection*." (interview with Kunlé; fig. 4)

The "something" in the model points also to the opportunity for the master architect to grasp the last development of a project for a few minutes only as he usually supervises many projects at the same time. It also denotes a very distinctive feature of design—its reversibility—models are kept, because it makes it possible for architects to get always back to them: "there is *something* in a small model, and after two weeks, going back to the model you can see this thing". Another architect can go back to this model and interpret it with other assumptions. The model environment stimulates new encounters of models-and-architects.

As seen in these examples, models' observation is in the basis of cognition in design—a tentative and enduring process, in which architects probe different scenarios for the building to happen. In this process "models spark architects' imagination" and "tell them more", and that is how designers learn from their models on a daily basis, and at the same time constantly incorporate the knowledge gained into them to make them more "talkative" and compelling. That is, a process of shared knowledge, an even-handed dialogue.

## 2. Testing the models

Models at OMA are submitted to various tests, assembled, probed and measured to gain know-



Fig. 3: A gathering around a model (photo: Torsten Schroder)

ledge about the building-to-come. The tests with models aim at probing parameters and data connected to the building. They set the conditions required for further operations, imply a palette of questions concerning the unknown elements of the building and account for ability to cope with the new variables that are added to the existing experimental conditions (fig. 5).

"The entry is a difficult question of Whitney, because there is already the entry of the Breuer building, so, do you have a second entry, do you keep the Breuer building's entry, and we had all these issues." (interview with Carol)

A model is quickly fabricated to answer the questions of "what are the conditions for the entry?" "What should the entry look like?" This completely unknown feature of the Whitney extension has to be defined, and additional knowledge about the entry possibilities should be gained through modelling. Thus, knowing the building requires continuous operations and test in work, where any knowing establishes itself through continued research with models. Every newly obtained feature of the building is quickly visualized via models so that architects can witness the materialisation of their assumptions and can see how exactly the model, as an entity, will look with this particular element changed

The "entrance model" is, as we can witness, the visual answer of the question: what is the entry like? Architects assume, build the model, test, and by doing so they get an answer to this question, and extract dispositional knowledge rather than

factual one, knowledge "how" and "where", not knowledge "what". Models also probe the different scenarios for the entry and pose new questions about the entry conditions, thus operating as powerful interrogative and testing devices. This shows the "epistemological uniqueness" of design, to use Donald Schön's term, lying in the double character of this process, of simultaneously defining and answering the design questions.

In the series of experimental tests with models the gross fact of a huge and unknown building is progressively discriminated into a number of independent questions referring to variables: circulation issues, entrance conditions, structure, etc. Some of them had never before been observed or even thought of in connection with the fact. After their definition, new models are produced and staged on the table, thus, new facets and scenarios of the building are defined. So, experimenting with models is the chief resource in architectural reasoning about the building. Tests are done "to see *immediately* how it looks", argue architects; contemplation of models in the office environment can often stimulate new experiments with variable conditions. Thus, through models knowing appears to be observable in exactly the same sense as are the things that are known; there is no "something known" apart from its knowing and identifying, and there is no process of knowing the building apart from the features and aspects that are being identified (fig. 6).

Depending on the questions that are being addressed in the process of testing, answered and



Fig. 4: inspection of working models (photo: the author)



Fig. 5: the entry model of the Whitney Museum Extension (photo: the author)

posed anew by the models themselves, designers are performing taking different points of view and mobilize a divergent repertoire of knowledge. Every single model of the building that extracts new knowledge is constantly confronted to the given conditions and parameters that are known. At that moment architects say: "now, we *know* more." There is an important cognitive dimension of the process of gaining new "answers" to queries related to the building and confronting them to old parameters. When architects say, "now we know more", it means that new data is gained and added up to the existing, and that is what would lead designers to the final building. To know a distant object is to lead to it by the numerous mediators (models) that develop harmoniously towards the reality of the building; in this process more features of the building are defined, more unknowns are being transformed into known(s), and architects feel point to point that one direction is being followed. This process of adding up new data is all that architects practically mean by knowing the building at all.

Thus, architects question actively their models, test, probe and measure them, in a way that they serve as faithful instruments of investigation. Instead of being aesthetic illustrations of designers' insights, models play as "collaborators" in design enquiry and provide answers to architects' questions, assumptions and uncertainties. They also generate multitudes of new queries. That is, a process of interrogations, in which both designers and foam models exchange properties and transform more unknown features of the building into known(s).

### 3. Knowledge transfer in 2D-to-3D and 3D-to-2D translations

Architects at OMA use a variety of visuals simultaneously: "the more tools, the better, because all of them are necessary", argues Sarah. Thus, models



Fig. 6: A "dialogue" of architects and models

never act alone in design, but always appear within the fine network of diagrams, plans, sketches, collages, and act according to their performances and explanatory potentials. There is no strict logic of sequential usage of the visuals:

"They happen *simultaneously* and *one informs the other* as you go. Maybe the diagram will give you some kind of clarity about the physical model, or some sketch model that somebody did can have something actually inspiring or compelling and you go back and find that on the diagram and see what are the relationships between them." (interview with Carol)

Sketches, diagrams, models, drawings, panels and collages flock the office environment all together: they share the cognitive weight of the building and make it observable in a cooperative effort. Very often the special volumetric information gained with the model has to be translated into flat images of different sorts: pictures, collages, photomontages, or computer models. Once the model is built, architects take a picture of it, which is then transferred to the computer screen and can bear numerous corrections and manipulations with Photoshop allowing architects to see the model in a different way—at a closer distance. The spatial adjacency of computers' screens and improvised model shop corners facilitate cognitive activities with models that are conterminous and additive to the computer visualisations. We can notice a discrepancy in the rapidness of visuals' production: a model of Whitney fabricated in one hour needs more than five hours of additional Photoshop work for the production of a good image of it. The montage can entirely manipulate the image on the computer screen to the extent that architects are often surprised by the differences:

"I'm always *amazed* once you take photos of a model *how much different they look*, and how different information they provide you with than the model itself. Even if you have the model sitting here and the picture here, you can have completely different perception of the space. I think that if you take pictures of this, so you are able to get a better idea of the sequence of movements through the spaces, or the way the materials are applied to the spaces, and also the scale of art in comparison with the people." (interview with Sarah, June 2002)

Architects spend hours manipulating images of Whitney models on the screen. I followed them in these manipulations and I almost wondered why architects do not begin modelling straight ahead on the screen instead of engaging in numerous time-consuming craft operations of foam slicing and shaping. They argue that screen models "allow discovering things" and obtaining new data about the building; they can extract an accurate description of a particular portion of the building, or even describe it entirely. On the screen you can "zoom the

model and zoom and zoom, and you will have every detail that you want", says Erez. This process of unlimited zooming can continue to the extent that a minor detail like the door handle can be defined with precision on the screen. When such details are being visualized, the model loses the capacity to account elements, which are visible on the physical models: site specificity, relations with the adjacent buildings, street and cityscape.

Hence, although physical models prevail in this office, there is a simultaneous process of modelling on screen and modelling with foam. In this way all aspects of the building can be accounted: details and proportions (on the screen) and spatial and volumetric capacities of the building (in the immediacy of the foam model).

The feeling of scale and spatial presence cannot be sketched nor drawn and it remains unique on the physical models and cannot be obtained with computer images. Architects constantly go back to the two-dimensional presentations of the building, back and forth, between foam models and diagrams, sketches and models, screen and paper. The interaction of drawings, models and photography provides a more realistic picture of the building. As Porter put it: "it is through the adoption of multi-views of its impression and its metamorphic testing along two, three and four dimensions that we allow a new conception to 'breathe' and simultaneously extend our power of visualisation. By making drawings from physical models and transferring graphic information into three-dimensional constructs we also *increase our knowledge* and experience of media."<sup>25</sup> At OMA I observed a continuous transmission of information among the different visuals, zooming into details and zooming *out* to the bigger representation with more context elements, converting the imperceptible traces of the image into foam features of the model; context into content. The 2-D representations of a model serve like a microscope that allow architects to have a closer view on the model and discover things that cannot be noticed in an usual 3-D setting of observation. A specific kind of hidden dispositional knowledge gets communicated and revealed in the 2D-to-3D and 3D-to-2D translations. The knowledge discovered in the careful examination of flat images of a model incites architects to go back to the physical model and modify it afterwards according to that series of minuscule changes perceived in the process of zooming the images on the screen. After the model is corrected and "made up" during long hours of repetitive Photoshop-moves, architects produce photomontages with the purpose to see how the building looks in the streetscape with adjacent buildings around and how it fits into the city fabric; that is, to obtain dispositional knowledge at a larger contextual level. The photomontage accommodates more context elements and

brings more details about people, buildings, city, cars, and trees. On its basis, a new site model can be produced. Thus, flat images are tools for generating better models; models are tools to make better images.

## Models Regain Power

The examples of work with models at OMA reflect on how architects learn from their models about the-building-to-come and how various heterogeneous material settings function to generate epistemological effects. Mobilizing the models through 1) inspection, 2) testing, probing and experimenting with models, and 3) knowledge transfer in 2D-to-3D and 3D-to-2D translations, architects from OMA gain new data about the future building. Design activities, as many authors have argued, are collective and collaborative. The social nature of the design process has been studied in terms of how designers interact with other human actors (clients or professional colleagues) and how these social interactions influence the activities of teamwork in design. Following the design methodology of Koolhaas, we can witness that more often today architects think-while-modelling, and humans share their cognitive activities with a variety non-humans.<sup>26</sup> Scale models are used as important cognitive tools in the design enquiry and are applied to understand unknown features of the building. Incorporating the results of previous investigations of designers, as well as the site conditions and the requirements of client and sponsors, models form the starting points for further steps of the building's refinement, and trigger new directions of exploration. They function as instruments of investigation and experiment, measurement and correction. Knowing a building is a complex process: it requires activities that are socially distributed amongst architects, and technologically distributed between people and artefacts in design. The "distributed cognition"<sup>27</sup> of designing architects are embedded in the collective practices of work with models and is equally shared by a variety of visuals as models never act alone: sketches, diagrams, drawings, panels, collages and models flock the office environment all together, share the cognitive weight of the building and make it observable. Acting complementarily, they shape a process of continuous *knowledge transfer*, in which the building is gradually getting known.

The ethnography of the practices of the office of Koolhaas and the recent shows "Content" that criss-crossed the most prominent European exhibition venues in 2004 and 2005 witness for the greater power that physical models gradually regain at the time of digital media technologies both in the design process and in the communication with clients. In the model-dominated environment of

the office of Koolhaas digital images play a secondary role whereas physical models prevail.

One of the main concerns of architectural theory remains to show how the idea "comes" to the designer, triggers design reflection and enacts practices. Having in mind these examples from the design practices of the office of Koolhaas, can we still state that architecture today is produced by imaginary, which is materialized in numerous digital images? Following architects at work at OMA, we can rather argue that architectural imagination derives from a *process of executive doing*, a tedious and time consuming process of manipulation of matters, physical environments and tools. This *process of making* is also a *process of knowing*, a process of knowing with eyes and fingers, in which

the corporeal involvement and expression of designers matter to a greater extent for the production and communication of knowledge, and the non-discursive actions co-exist with the discursive ones. As seen in the office of Koolhaas, physical models make a building observable and thinkable in time and space and enable us to gain access to the various ways, in which architects "think with hands". What they actively strive to achieve in design venture is to render their models more talkative, inquisitive and versatile, so as to make possible that at a certain point models as non-humans begin to act upon their makers and interact with architects and visuals, sharing together the process of making and the cognitive weight of a building-to-come.

Notes:

- 1 Moon, K., *Modeling Messages. The Architect and the Model*, Monacelli Press, New York 2005.
- 2 Pommer, R., *The Idea of 'Idea as model'*, in Frampton, K. and Kolbowski, S. (eds.) *Idea as Model*, New York: Institute for Architecture and Urban Studies/Rizzoli 1981.
- 3 Colomina, Beatriz, *Privacy and publicity: modern architecture as mass media*, MIT Press, Cambridge 1994.
- 4 *Images et Imaginaires d'Architecture*, Centre Georges Pompidou, 1984.
- 5 Robbins, E. and Cullinan, E., *Why architects draw*, MIT Press, Cambridge 1994; Blau, E. and Kaufman, E. (eds.), *Architecture and its image*, Canadian Centre for Architecture, Montreal 1989; Porter, T., *How architects visualize*, Van Nostrand Reinhold, New York 1979; Evans, R., *Translations from drawing to building*, MIT Press, Cambridge 1997; Lebahar, J.-C., *Le dessin d'architecte : simulation graphique et réduction d'incertitude Parenthèses*, Roquevaire 1983.
- 6 Clarisse, C., *Ma quiete d'architecture, Maquettes d'architectures*, Elsevier Publishing Company, Amsterdam, London, New York 1993; Millon, H., *In The Renaissance from Brunelleschi to Michelangelo. The Representation of Architecture* (Ed., Millon, H. A. a. L., V. M.) Bompiani, Milan 1994, pp. 19–75; Reuther, H. and Berckenhagen, E., *Deutsche Architektur-modelle. Projekthilfe zwischen 1500 und 1900*, Berlin 1994; Kurrent, F. (ed), *Scale models: houses of the 20th century*, Birkhäuser, Boston 1999.
- 7 Schwanzler, B., *Architektur-Modelle und Sammlungen*, Wien 1994; Croy, O. and Elser, O., *Sondermodelle. Die 387 Häuser des Peter Fritz Versicherungsbeamter aus Wien*, Hatje Cantz Verlag, Wien 2001.
- 8 Clarisse, see note 6.
- 9 Busch, A., *The Art of the Architectural Model*, Design Press, New York 1990; v. Gerkan, M. u. P. (Ed.), *Idea and Model. 30 years of Architectural Model*, Hamburger Architektur Sommer, Hamburg 1994; Moon, see note 1.
- 10 Porter 1979, see note 5; Porter, T. and Neale, J., *Architectural Supermodels. Physical Design Simulation*, Architectural Press, Oxford 2000.
- 11 Silveti, J., *Representation and Architecture*, Carnegie-Mellon University 1982.
- 12 Moon, see note 1.
- 13 Porter and Neale, see note 10.
- 14 Cowan, H. J., Gero, J. S., Ding, G. D., Muncey, R. W., *Models in Architecture*, Elsevier Publishing Company, Amsterdam, London, New York 1968.
- 15 Klotz, H., *Filippo Brunelleschi: The Early Works and the Medieval Tradition*, Rizzoli, Intl Pubns, New York 1990.
- 16 Busch, see note 9.
- 17 Alberti, L. B., *On the Art of Building, in Ten Books*, MIT Press, Cambridge 1988.
- 18 Richardson, M., *Model Architecture, Country Life Vol 21*, 1989, pp. 224–227.
- 19 Millon, H. 1994, see note 6; Bonfilio, P., *Fallingwater: the model*, Rizzoli, New York 2000.
- 20 Schön, D. A., *The reflective practitioner: how professionals think in action*, Basic Books, New York, USA 1983; Schön, D. A., *Educating the reflective practitioner: toward a new design for teaching and learning in the professions*, Jossey-Bass, San Francisco 1987.
- 21 Frampton, K, Kolbowski, S. and Institute for Architecture and Urban Studies, *Idea as model*, Institute for Architecture and Urban Studies/Rizzoli International Publications, New York 1981.
- 22 v. Gerkan, M. u. P. (Ed.) 1994, see note 9.
- 23 Latour, B. and Woolgar, S., *Laboratory Life Sage*, London 1979; Lynch, M., *Discipline and The Material Form of Image: An Analysis of Scientific Visibility, Social Studies of Science Vol 15*, 1985, pp. 37–66; Knor-Cetina, K., *Epistemic Cultures. How the Sciences Make Knowledge*, Harvard University Press, Cambridge 1999; Latour, B., *Reassembling the Social. An Introduction to Actor-Network-Theory*, Oxford University Press, Oxford 2005.
- 24 Yaneva, A. (2005), *Scaling Up and Down: Extraction Trials in Architectural Design*, in *Social Studies of Science*, 35(6): 867–894; Yaneva, A. (2006), *Shaped by Constraints: Composite Models in Architecture*, in Inge Hinterwaldner and Markus Buschhaus (eds.), *The Picture's Image. Wissenschaftliche Visualisierung als Komposit*, München, pp. 68–84.
- 25 Porter (1979), see note 5.
- 26 Latour, B. (2005), see note 23.
- 27 Hutchins, E. (1995), *Cognition in the Wild*, MIT Press, Cambridge.