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FROM LINE TO PIXEL

OD KRESKI DO PIKSELA

Abstract

The paper analyses the changes in the architect's workshop over the years, taking into account the evolution of the methods and tools used in the design process, and presents the solutions used at European universities such as the Delft University of Technology, the Politecnico di Milano, the Royal Institute of Technology in Stockholm and the Zurich Federal Polytechnic to identify the best tools for design. By analyzing the workshops, the available technologies and devices, it was shown that working with physical models enables designers to maintain a realistic approach therefore finding a balance between the digital and physical worlds. Computer technology can deceive our senses, but it is up to architects to ensure that we still remain connected to reality.

Keywords: architecture, digital design, physical models

Streszczenie

W pracy analizowano zmiany w warsztacie architekta na przestrzeni lat, uwzględniając ewolucję metod i narzędzi używanych w procesie projektowania. Celem określenia najlepszych narzędzi do projektowania przedstawiono również rozwiązania stosowane na europejskich uczelniach, takich jak Uniwersytet Techniczny w Delft, Politechnika Mediolańska, Królewski Instytut Techniczny w Sztokholmie i Politechnika Federalna w Zurychu. Analizując warsztaty oraz dostępne technologie i urządzenia, wykazano, że praca z modelami fizycznymi umożliwia projektantom utrzymanie realistycznego podejścia, co pozwala na znalezienie równowagi między światami cyfrowym a fizycznym. Technologia komputerowa może zwodzić nasze zmysły, jednak do architektki powinny czuć, byśmy wciąż pozostawali związani z rzeczywistością.

Słowa kluczowe: architektura, projektowanie cyfrowe, modele fizyczne

1. INTRODUCTION

An architectural model is a spatial pattern, which is a scaled-down and often abstract image of reality, used for spatial design and presentation of buildings or parts of buildings. It serves to clarify the principles and features of designed objects and identify potential problems, offering architects a tool for developing and defining architectural concepts. It allows interpretation and reflection on the hypotheses adopted, affecting people's cognitive impressions, similar to the exploration of the real environment.¹ Models enhance the sense of space,

¹ J. Słyk, *Modele architektoniczne*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2018.

aesthetics and materiality, giving the viewer the opportunity to individually experience the spatiality of the designed object through the choice of observation angle. Modeling is particularly important in architectural education. With its help, students can practically explore concepts, improve design skills and prepare for professional work. A model can be considered as having a reflective role within analysis and a generative role within synthesis.² Models are a form of communication with the audience and communication between instructors and students, enabling tangible understanding of design concepts and interaction with the audience. The balance between the material and virtual dimensions has an impact on the training of future architects.³

Traditional handmade models have largely been replaced by more sophisticated and interactive digital models that support the architectural design process at various stages. Today, traditional materials such as cardboard and wood are giving way to synthetic and plastic materials. The development of numerical processing and 3D printing technologies has made it possible to create physical, three-dimensional objects based on virtual models.

2. MODELS IN ARCHITECTURAL PRACTICE

The working model experimentally accompanies the entire design process, allows flexibility and the possibility of further modifications. Presentation models are three-dimensional representations of the future appearance of the building, made with high accuracy. They represent the final stage of design and are used in architectural competitions to demonstrate solution proposals. Adjustment of scale, degree of simplification and materials is crucial and must accurately reflect the character of the designed space. At larger scales, a faithful representation of reality is sought, which is crucial for verifying functionality, form and detail. At smaller scales, the priority is to focus on the main ideas of the project. In the process of creating architectural models, real surfaces and materials are transferred to the model through abstractions, preserving the specific properties of the materials.

2.1. PHYSICAL MODELS

In ancient Egypt, scaled recreations of gates and houses placed in tombs were meant to provide the dead with access to their homes. In ancient Greece and Rome, models were used to test formal and technical solutions, refine details and proportions, and symbolically represent ideas, such as the Parthenon, considered a model of the heavens.⁴ Gothic cathedrals served as religious models, presenting the Christian faith. Miniature buildings illustrated the offering of the building to God.⁵ In Renaissance Italy, specialized craftsmen made models, which were evaluated in terms of structure, form, construction and cost. An example is a brick-and-wood model of the shell-less static scheme of the dome of the

² M. Vrontissi, *The physical model in structural studies within architecture education: paradigms of an analytic rationale?* [in:] Proceedings of IASS Annual Symposia, Amsterdam 2015.

³ A. Polewka, *Synergistic use of drawing and model in didactics = Synergiczne wykorzystanie rysunku i modelu w dydaktyce*, "Przestrzeń i Forma" 2020, no. 43, pp. 71–94, DOI: 10.21005/pif.2020.43.B-04.

⁴ *Ibidem*, p. 76.

⁵ *Ibidem*.

Florentine basilica by Brunelleschi.⁶ Models were built and subjected to static load tests, examining the structures experimentally. In the 17th and 18th centuries, the structural aspect was the main focus of modeling interest. The Great Model of St. Paul's Cathedral, designed by Christopher Wren and built under the supervision of carpenter William Cleere, was built after the Great Fire of London in 1666 and was an important element of communication between the architect and builders.⁷ In historicism, models took on new importance as tools for the study of architectural history, becoming part of private collections.⁸

The Bauhaus School played a key role in shaping the modern approach to modelling, emphasizing the relationship between theory and technological skills. Students honed these skills through practical work with a variety of materials. Antonio Gaudi used models made of inextensible string and sandbags to design the Sagrada Familia Basilica, which illustrated the optimal arrangement of ribs. Frei Otto created models from soap foam and wires, exploring minimal surfaces and optimal designs aimed at reducing the volume and weight of canopies. During the realization of the EXPO pavilion in Montreal, the placement of masts and cable anchor points were tested using polyester fabric models connected to sensors.⁹ Architects are now using model making to push the boundaries of architecture and sculpture, as we see in the work of Frank O. Gehry.

2.2. DIGITAL MODELING

During World War II, advancements in CAD (Computer Aided Design) technology began to develop thanks to research at military procurement research centers. The Whirlwind computer created by Jay Forrester, controlled by perforated tapes, was equipped with electron tubes and enabled it to interface with a three-axis milling machine.¹⁰ In 1962–1963, Ivan Sutherland created the Sketchpad application, which made it possible to display and make changes to visualized spatial solids. In the 1970s, Pierre Bézier and Paul de Casteljau, working for the car manufacturers Renault and Citroën, developed the Bézier curve, which was based on deep parameterization and manipulation of points that affect the shape of the resulting surface. This work helped to establish a standard for geometric objects known as NURBS (Non-Uniform Rational B-Spline).¹¹ Samuel Geisberg is considered the creator of the first commercial application Pro/ENGINEER in 1987, based on the idea of parametric modeling.

The development of solid modeling was the result of the work of those who developed the algorithmic engines used in CAD software.¹² Autodesk, founded by Mike Riddle, revolutionized CAD by making it possible to work on standard computers, which in the 1980s transformed CAD applications from corporate systems to tools for individual engineers and architects. The tools were configured to correspond to the structure of a building, with

⁶ J. Słyk, *op. cit.*

⁷ A. Polewka, *op. cit.*, p. 77.

⁸ G. Świttek, *Gry sztuki z architektury*, Wydawnictwo naukowe Uniwersytetu Mikołaj, Kopernika, Toruń 2013.

⁹ *Ibidem*, p. 115.

¹⁰ J.F. Reintjes, *Numerical Control: Making a New Technology*, Oxford University Press, New York 1991, p. 34.

¹¹ D.F. Rogers, *An Introduction to NURBS*, Morgan Kaufmann Publishers, San Francisco 2001.

¹² D.E. Weisberg, *The Engineering Design Revolution*, 2008, <http://cadhistory.net/> (access: 22.03.2023).

metadata characterizing elements such as finishes and material types. The classification of elements evolved, leading to standards known as BIM, first used in 1992 by researchers at Delft University.¹³ In 1984, Graphisoft unveiled a prototype of ArchiCAD called “Radar,” and its counterpart at Autodesk is Revit.

Grasshopper 3D is currently one of the most popular parametric model editors for architects. It offers components that perform operations on data, drawing from parameters entered via a list, slider or graph. Digital architectural modeling is gaining recognition in the architectural world, especially through its use by avant-garde architects such as Zaha Hadid and Patrik Schumacher.

Computerization has made it possible to accurately define and visualize complex topologies. All design elements are assigned to a virtual building, which creates a database whose basic ordering scheme is a geometric model. This model is materialized through projection, and design elements can be represented by text, drawing, video, model or virtual reality. The most important consequences of using the digital environment in architecture are the interactive flow of information, the human perception of the model space, and the possibility of automatic materialization in 3D, such as through 3D printing. The virtual model, unconstrained by the properties of the physical material, can be freely scaled, enabling photorealistic visualizations.

2.3. AUGMENTED AND VIRTUAL REALITY AND VOLUMETRIC SPACE

Augmented reality (AR) integrates virtual elements with real images, enabling interactive access to data. Key to the operation of AR systems are devices capable of recognizing the environment and displaying data, as well as markers for spatial orientation. Examples include see-through displays like Google Glass, which superimpose virtual images onto the real world, and modern Virtual Retinal Displays, which project images directly onto the retina. Virtual reality (VR) creates an artificial environment, defined by Sherman and Judkins in 1992 using five characteristics: intuitiveness, interactivity, intensity, illustrativeness, and immersion.¹⁴

In the 1960s, Ivan Sutherland and Bob Sproull created the Sword of Damocles device, a prototype of modern VR goggles that respond to the user’s head movements. Progress continued in the 1980s with Jaron Lanier and Thomas Zimmerman of VPL Research, who developed innovative devices such as the Data Glove, which allowed accurate transmission of hand movements into the simulation world.¹⁵ Modern spatial manipulators, such as 3D phantoms, allow sculpting in virtual models, simulating the physical properties of materials. VR opens up new possibilities in architecture, enabling projects without physical constraints, as exemplified by Asymptote studio’s projects such as the virtual New York Stock Exchange and the virtual Guggenheim Museum.

¹³ G.A. van Nederveen, F.P. Tolman, *Modelling multiple views on buildings*, “Automation In Construction” 1992, no. 1(3), pp. 215–224.

¹⁴ B. Sherman, P. Judkins, *Glimpses of Heaven, Visions of Hell: Virtual Reality and Its Implications*, Hodder & Stoughton, London 1992.

¹⁵ I.E. Sutherland, *A head-mounted three dimensional display* [in:] *Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, Part I*, Association for Computing Machinery, New York 1968, pp. 757–764.

3. ANALYSIS OF EUROPEAN UNIVERSITY WORKSHOPS

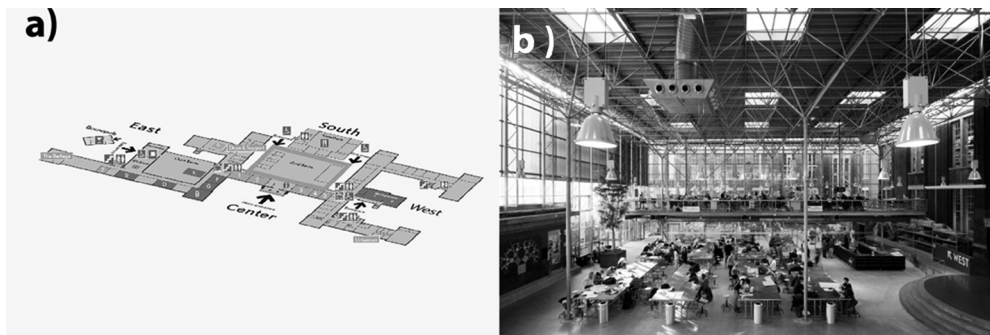
Technological advances seem to be leading to the abandonment of traditional model making, which requires manual labor to process materials, generates waste and takes up more space to store the necessary machinery. Compared to a computer, which has all the necessary tools built in, the tools for making physical models are more problematic, require a stationary presence and cannot be easily shipped to the other side of the world. The exception is when a 3D model is shipped and printed on a 3D printer on site. Thus, the computer proves to be much more practical and handy.

Nevertheless, physical models are still used for the design itself. At the beginning of the design work, it is easier to operate with blocks that correspond to individual rooms to better see the spatial relationships between them. Such simple modeling is still present in architectural practice at universities and even in meetings with clients. It allows for easier representation of certain relationships, using available materials and involving all participating investors in the design process.

An analysis of the workshop equipment of four leading architectural universities in Europe was carried out: TU Delft, ETH Zurich, Politecnico di Milano, KTH in Stockholm.

3.1. TU DELFT

The Faculty of Architecture and Built Environment at TU Delft in the Netherlands is one of the best architecture departments in the world. One of the two covered courtyards is a modeling center, where there are workbenches and rooms with the necessary equipment. On one side of the space with tables is a woodworking workshop, on the other side are CAM-lab studios offering digital fabrication machines such as laser cutters, 3D printers and CNC milling machines, and a painting workshop where concrete or plaster casting is also possible.¹⁶

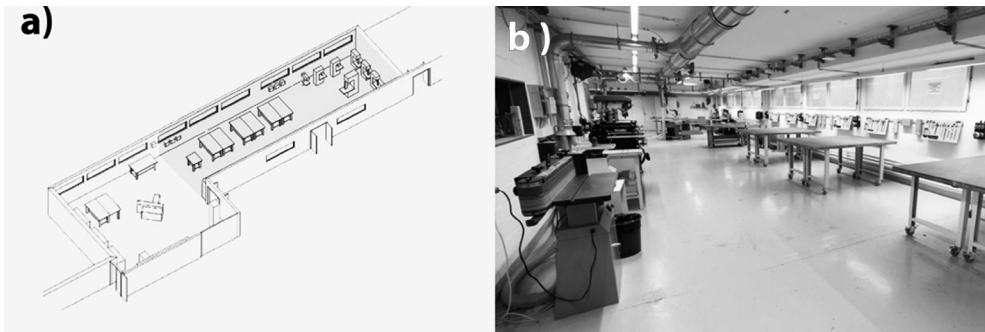


- III. 1. a) Diagram of the first floor of the Faculty of Architecture at Delft University of Technology, with workshop space in the center, source: *Floor plan* [in:] TU Delft, <https://www.tudelft.nl/en/architecture-and-the-built-environment/about-the-faculty/the-building/floor-plan> (access: 10.03.2023); b) workshop space of the Faculty of Architecture Delft University of Technology, source: *Het gebouw* [in:] TU Delft, <https://www.tudelft.nl/bk/over-faculteit/het-gebouw> (access: 10.03.2023).

¹⁶ bk modellinghall, <https://nmc360.tudelft.nl/bk/modellinghall/> (access: 10.03.2023).

3.2. RAPLAB, ETH ZURICH

The Department of Architecture at the ETH Zurich University has two workshop units as part of the centralized Raplab organizational unit equipped with tools from traditional craftsmanship to digital fabrication. The 750m² “HILL” unit includes a wood workshop, a digital workshop, a pouring workshop, a painting workshop, and a CNC machine workshop. The 100m² “ONA” unit consists of a wood workshop and a digital workshop and has 10 machines.¹⁷



- III. 2. a) Diagram of the wood workshop of the Hill Raplab unit of the Department of Architecture at ETH Zurich, source: *HWS Wood Workshop* [in:] Rapid Architectural Prototyping Laboratory. Raplab – ETHZ D-ARCH, <https://raplab.arch.ethz.ch/hws/> (access: 10.03.2023); b) wood workshop of Raplab ETH Zurich unit, source: *HWS Wood Workshop* [in:] Rapid Architectural Prototyping Laboratory. Raplab – ETHZ D-ARCH, <https://raplab.arch.ethz.ch/hws/> (access: 10.03.2023).

3.3. LABORA, POLITECNICO DI MILANO

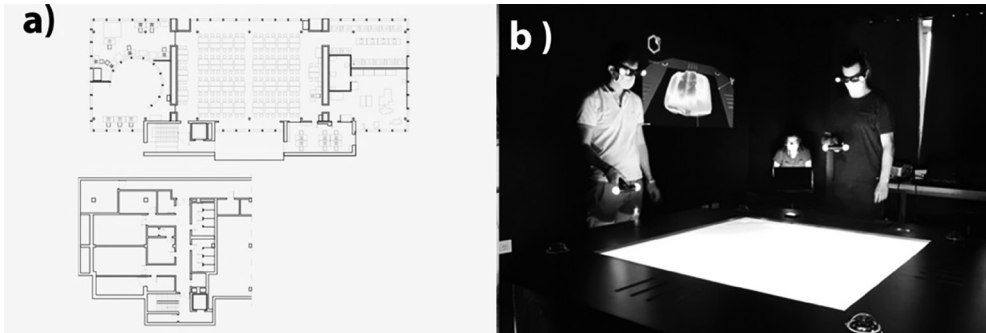
The approx. 700m² LaborA workshop at the Politecnico di Milano is located in a separate building adjacent to the Department of Architecture, Built Environment and Construction Engineering. The largest room houses tables for making physical models. Available are: a carpentry workshop, a room with a CNC machine and styro-cuts, and a room with 3D printers, and a painting workshop. A virtual theater for immersive 360° project simulation and a hologram laboratory for 3D virtual simulation on a special table are also available.¹⁸ The virtual theater is a 7m diameter cylinder that supports projection of 360° images and videos and 3D models displaying a virtual scene on the walls and floor. Simulations can use a bicycle and a walker transferring the user’s movement into the virtual world.¹⁹ Thanks to remote controls, it is possible to manipulate the 3D visualization.²⁰

¹⁷ *Raplab* [in:] Rapid Architectural Prototyping Laboratory. Raplab – ETHZ D-ARCH, <https://raplab.arch.ethz.ch/raplab-general/> (access: 10.03.2023).

¹⁸ *LaboraA physical and virtual modelling laboratory* [in:] School of Architecture Urban Planning Construction Engineering, <https://www.auc.polimi.it/en/students/services/labora-physical-and-virtual-modelling-laboratory#c3912> (access: 10.03.2023).

¹⁹ *Labora* [in:] Politecnico di Milano, <https://www.polimi.it/ricerca/la-ricerca-al-politecnico/laboratori/grandi-infrastrutture/labora> (access: 10.03.2023).

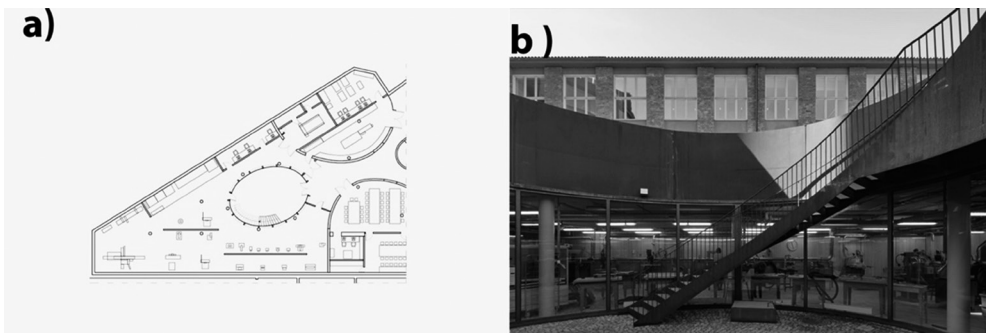
²⁰ *Tools & Facilities* [in:] LaborA Virtual and Physical modelling, <https://www.labora.polimi.it/tools-and-facilities/> (access: 10.03.2023).



- III. 3. a) Floor plans of the workshops of the Department of Architecture, Built Environment and Construction Engineering of the Polimi, source: *LaborA physical and virtual modelling laboratory* [in:] School of Architecture Urban Planning Construction Engineering, <https://www.aaic.polimi.it/en/students/services/labora-physical-and-virtual-modelling-laboratory#c3912> (access: 10.03.2023); b) hologram table in use at LaborA at Politecnico di Milano, source: *Labora* [in:] Politecnico di Milano, <https://www.polimi.it/ricerca/la-ricerca-al-politecnico/laboratori/grandi-infrastrutture/labora> (access: 10.03.2023).

3.4. KTH ROYAL INSTITUTE OF TECHNOLOGY IN STOCKHOLM

KTH's School of Architecture and the Built Environment is a unit of six departments and seven advanced research centers, which is part of one of five departments operating within the renowned institution of the Royal Institute of Technology. The workshop designed for students includes a band saw, drill press, disc grinder, cylindrical grinder, wide-belt grinder, leveler, format saw, angle saw, laser cutter, styro-cut, 3D printer, vacuum molder, CNC milling machine.



- III. 4. a) Floor plans of the workshops of the School of Architecture and the Built Environment of KTH, source: *KTH School of Architecture* [in:] EUMiesAward, <https://miesarch.com/work/3686> (access: 10.03.2023); b) view of the workshop from the courtyard, source: *School of Architecture at the Royal Institute of Technology / Tham & Videgård Arkitekter* [in:] ArchDaily, 9.12.2015, <https://www.archdaily.com/778460/school-of-architecture-at-the-royal-institute-of-technology-tham-and-videgard-arkitekter/56663299e58ece70b60005e3-school-of-architecture-at-the-royal-institute-of-technology-tham-and-videgard-arkitekter-photo> (access: 10.03.2023).

4. SUMMARY

An analysis of the teaching programs and equipment of Europe's largest architectural universities proves that physical modeling still plays a key role in curricula. Despite the growing popularity of digital technologies and virtual presentations, physical models remain an indispensable tool both in the teaching process and in communication with clients. Physical modeling allows students to better understand the space, proportions, and materiality of designed objects. The process of creating models teaches accuracy, precision and critical thinking, which is essential for future architects. In addition, physical models allow investors to experience projects in real life, which is often difficult to achieve with virtual visualizations.

Virtual presentations, despite their advantages, can mislead viewers and interfere with the perception of the actual space. Clients, accustomed to beautiful but often unrealistic visualizations, may find it difficult to properly evaluate a project. Physical models, thanks to their tangibility and three-dimensional form, allow for a better understanding and evaluation of the proposed architectural solutions.

In the context of the increasing digitization and virtualization of our environment, maintaining a balance between digital technologies and traditional working methods is crucial. Architects, in order not to lose their sense of space and connection to reality, should continue to use physical models as an integral part of the design process.

In today's commercial world, effective selling plays a key role, which is all about products. Architecture, in this reality, has become a product to be sold quickly and successfully. Visualizations help greatly in this regard as they deceive our senses, especially the senses of those who are not required to have spatial imagination and technical knowledge. The project elicits admiration, but the reality can be completely different. In a drawing of an apartment, the furniture may be scaled down, while a virtual tour of the property will make it seem larger due to the wide angle of the camera. Design flaws are more difficult to hide in a tangible, physical model, especially when you consider the human scale.

Architecture is not a product and should not be sold that way. Architecture is the fruit of the joint work of the designer (not just the architect) and the developer. To achieve this, their collaboration is needed, which cannot take place exclusively in the virtual space. Physical modeling remains an integral part of architectural education at leading European universities for good reason. Its presence in the curricula guarantees future architects a comprehensive development of skills and better preparation for the realities of professional work. It is worth continuing and developing these traditions to ensure high quality education and client satisfaction with projects. With the rapid development of technology, architects must find a balance between traditional methods and modern tools to meet the demands of a digitized society. Digital tools, while powerful, can lead to distorted perceptions of space, which affects client expectations. A key challenge is to combine technology with traditional techniques to ensure realistic and accurate representations of future projects.

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