The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2024

Volume 32, Pages 568-574

IConTES 2024: International Conference on Technology, Engineering and Science

From Concept to Reality: How 3D Printing Transforms Architectural Model-Making

Bushra Zalloom
Zarqa University

Abstract: Integrating technology in architectural model-making, particularly 3D printers, has transformed the design process, enhancing precision, efficiency, and creative potential. 3D printing allows architects to rapidly produce complex physical models with high levels of detail that traditional handcrafting methods often struggle to achieve. This technology supports the design processes, enabling faster prototyping and experimentation with various forms and structures. It also promotes sustainability by reducing material waste and encouraging the use of eco-friendly materials. Furthermore, digital fabrication tools such as 3D printers facilitate collaboration and communication by providing clear, tangible representations of architectural concepts. As a result, it has become an essential tool in contemporary model-making, enhancing creativity, precision, and innovation in both educational and professional settings. Using advanced technology in model-making reshapes architectural education and practice, drives innovation, and improves workflow efficiency. This paper presents the model-making process for the Zarqa University campus in Jordan, and the challenges it faces throughout the work, it also highlights the pluses and minuses of using this technology.

Keywords: Model-making, Digital fabrication, 3D printing

Introduction

Traditional techniques of model-making needs a significant number of manual labor and produces a considerable material waste unlike the modern process of additive manufacturing that builds materials layer by layer. The modern technology in model-making using 3D printing decreases mistakes, increases accuracy, and enhances sustainability. This technology is considered as an environmentally friendly process since it reduces waste and uses only the required materials (Duarte, 2020). By using 3D printing technology precise physical models are produced from digital plans, and concepts are tested to enable architects to make fast modification and develop their design (INJ Architects, 2024). Moreover, models that are created using this technology enables architects to include detailed features that are hard to be made with traditional techniques. Architects may use 3D printing to build unique and complicated forms that were previously hard to produce, they may create models with intricate curves, geometries, and overhangs that are difficult to create by hand. They can save money because 3D printing reduces the need for expensive molds and equipment. This gives a great option for professionals to produce models rapidly without losing quality, and cut expenses without sacrificing presentation and design requirements (INJ Architects, 2024; Khalil & Matar, 2021).

The traditional handcrafting of models, even with advanced tools, involves significant labor and can be limited in terms of the detail and complexity achievable. The automation of this process ensures that the models match the original design specifications exactly, reducing the chances of human error and making it easier to visualize design concepts in full (Lim & Shakir, 2020). In complex projects, this level of detail can also help in identifying potential issues before actual construction begins, improving the efficiency of the planning and building phases.

In general, 3D printing has transformed architectural model-making by improving precision, speeding up the design process, lowering costs, enhancing creative possibilities, and supporting sustainability, giving architects more flexibility and efficiency in their workflows. 3D printing provides architects with the creative freedom to push the boundaries of traditional model-making, enabling them to explore designs that are more visually compelling and technically accurate.

From Concept to Reality

Figure 1. The model transformation from concept to reality

The concept of model-making in this study is to represent the Zarqa University campus on a suitable scale, 1:350 is selected, for visitors to get general information about the campus contents, main faculties, available services, recreation areas, and green outdoor spaces. Figure 1 shows the transformation from the initial stage where pavements, streets, lighting, and some printed buildings to a detailed model. While 3D printing revolutionizes the speed and precision of architectural model-making, careful attention must be paid at every step—from design and slicing to post-processing—to ensure the model meets aesthetic and structural expectations. Creating the architectural model using 3D printing involves a detailed workflow from concept to final output, this process includes:

Design Phase (Creating a 3D Model)

- *Digital Modelling:* The first step is to create a digital 3D model using architectural design software like AutoCAD, Rhino, Sketch-Up, or Revit. Architecture Students at Zarqa University develop detailed digital models for all buildings on the campus using Revit, these models reflect the intended structure, with all necessary elements like walls, floors, windows, and other features.
- *Optimization for 3D Printing*: The model must be optimized for 3D printing by ensuring that all parts are watertight (no gaps or holes) and suitable for the printer's specifications. Elements like wall thicknesses sometimes need to be adjusted to ensure they can be accurately printed. Ensuring that the digital model is properly optimized for printing can be challenging, as not all design elements may be suitable for 3D printing.
- *File Conversion:* Once the digital model is complete, it is converted into a format that the 3D printer can read. STL (stereo lithography) is used to create the university Campus and represent the geometry of the model.

Slicing the Model

- *Slicing Software:* The STL file is then processed using slicing software (such as Cura or PrusaSlicer). The software divides the 3D model into thin layers and generates the corresponding G-code, which provides instructions for the 3D printer on how to print each layer.
- *Setting Parameters:* The slicing process allows users to set specific parameters such as layer height, infill percentage, print speed, and support structures (for overhangs or complex shapes). The IT engineers at Zarqa University help the architects in setting these parameters.

Preparing the 3D Printer

- **Selecting Materials**: Architects can choose from various materials, including PLA (Polylactic Acid), ABS (Acrylonitrile Butadiene Styrene), resin, or even more advanced materials like concrete for large-scale models. Material selection depends on the project's requirements for durability, detail, and finish. Accordingly, the PLA 1.75mm material was selected, mainly snow white colour, for the walls and grey for the ceilings, Figure 2. Choosing the right material for strength, detail, and aesthetic requirements is crucial and can impact both the cost and outcome.

Figure 2. Material and color selection

- **Calibrating the Printer**: Before printing, the 3D printer, Figure 3, is calibrated to ensure accuracy. This involves leveling the print bed and checking the nozzle alignment to avoid any printing errors. The IT engineers at Zarqa University also help the architects in Calibrating the Printer.

Figure 3. The 3D printer used in model making

Printing the Model

- *Layer-by-Layer Printing*: The printer then begins the process of building the model layer by layer, following the instructions in the G-code. The time required for printing depends on the model's complexity, size, and print speed. In general, each building takes about one working day, and each ceiling about 14 hours, Figure 4.

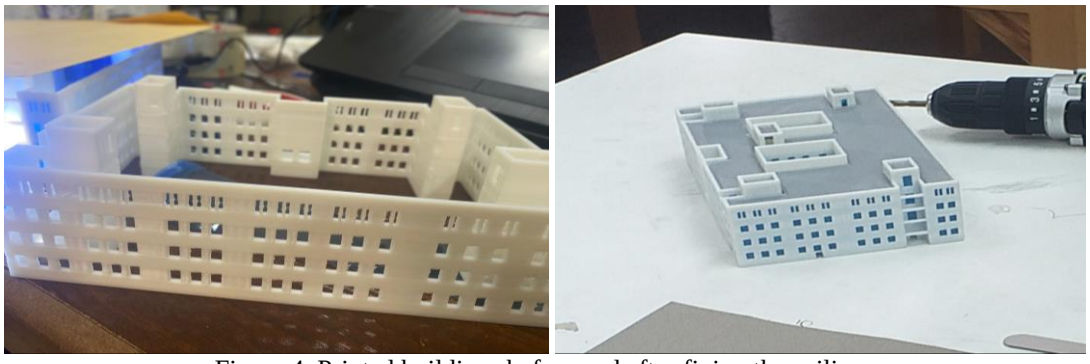

Figure 4. Printed buildings before and after fixing the ceilings

- *Monitoring the Process*: During printing, it is important to monitor the process to ensure everything is proceeding correctly. Adjustments can be made if issues like filament jams or warping occur.

Post-Processing

- *Removing Support Structures*: After printing, support structures, that are temporarily used, are carefully removed from the model without damaging the delicate features.
- *Sanding and Smoothing*: Depending on the material used, sanding or smoothing is required to remove visible layer lines and achieve a clean finish. This work takes extra time but improves the quality of finishing.
- *Painting and Finishing*: For presentation purposes, some parts of the model are painted or treated with different coatings to enhance its appearance or realism.

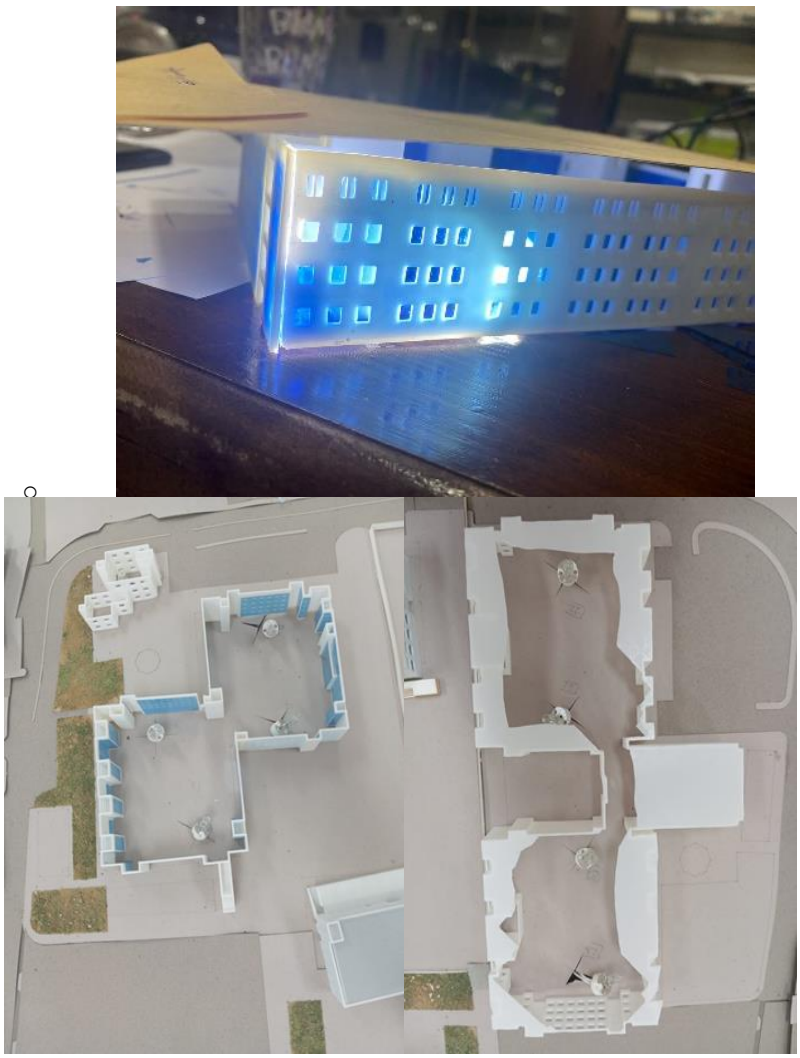

Figure 5. The post-processing phase

- *Lighting:* In parallel, the electrical engineers work on lighting the model as requested by the architects. Figure 5 shows the post-processing phase of lighting and removing support structures.

Assembling Components

- *Model Assembly*: Some buildings in the architectural model were printed in multiple parts (due to printer size constraints or design requirements), these components are assembled and glued together to form the complete model.

Presentation:

- *Display and Use:* The final 3D-printed model is used for client presentations, providing a tangible and detailed representation of the architectural concept. Therefore, after finishing the work, the model is located at the main hall of the university presidency to be accessible and seen by all visitors, Figure 6.

Figure 6. The campus model at the presidency hall at Zarqa University

Results and Discussion: Pluses of Using 3D Printing for Model-Making

Using 3D printing in architectural model-making offers numerous advantages, but it also poses challenges that practitioners and educators must navigate. While technology brings about innovation and efficiency, certain technical, material, and process-related hurdles need to be addressed. Here's a breakdown of the pluses and minuses of using 3D printing in model-making:

Speed and Efficiency:

- Rapid Prototyping: 3D printing allows for faster production of models compared to traditional handcrafting. Designers can quickly convert digital files into tangible objects, adjusting designs and printing new versions within hours or days rather than weeks (Perez & Gonzalez, 2020; INJ Architects, 2024).

1. Time-Intensive for Large or Detailed Models:

- Slow Printing Times: While 3D printing offers efficiency in terms of workflow, the actual printing process can be time-consuming, particularly for large or highly detailed models. It may take several hours or even days to print a single complex model.
- Post-Processing: Once printed, models often require post-processing, such as cleaning, sanding, or assembling, which can add time and effort to the workflow (Montero, 2019).

2. Material and Design Limitations:

- Material Constraints: While 3D printing offers a variety of materials, each type of material comes with its own limitations in terms of strength, texture, or appearance. Some materials may not capture the intended aesthetic, or they may not be suitable for certain architectural elements (INJ Architects, 2024).
- Scale Restrictions: Depending on the size of the printer, there are limitations on how large a single model can be printed. For larger projects, models may need to be printed in sections and then assembled, which can introduce seams or require more effort in post-processing (Perez & Gonzalez, 2020).

3. Technical Challenges:

- Learning Curve: 3D printing requires knowledge of both digital design software and the printing process itself. Architects and students must invest time in learning the technology to fully leverage its capabilities (Khalil & Matar, 2021).
- Printer Malfunctions: Like any advanced technology, 3D printers can experience technical issues such as jams, misalignments, or software errors, which can disrupt workflows and delay projects (INJ Architects, 2024; Khalil & Matar, 2021).

4. Environmental Concerns

- Plastic Waste: While 3D printing can reduce overall material waste, many printers use plastic filaments, which can contribute to environmental concerns if not properly managed.

Conclusion

Technology may be a strong instrument in contemporary architectural practice since its benefits frequently exceed its drawbacks. The 3D printing technology has improved efficiency, originality, and accuracy in the field of architectural model-making. Still, there are various disadvantages such as expenses, time consuming, and technological restrictions. Architects as well as students gain from increased creativity in creating novel ideas, and improved workflows when cutting-edge technology is included into the model-making process. Using 3D printing, models may be produced with extreme details. These technologies are prompting how architecture develops in the future by developing the model-making process for use in both professional and educational settings.

This study recommends the incorporation of 3D printing technology into architectural education and practice. This would enable architects to design and implement complicated forms and structures that are challenging to create, while also providing them with innovative tools to practice with. The practical exposure increases creativity, problem-solving skills, and design ideas that connected to digital manufacturing. A more dynamic and comprehensive experience is produced when architects are able to quickly prototype models, test their concepts, and collaborate with other disciplines to produce the final product.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the author.

Acknowledgments or Notes

* This article was presented as an oral presentation at the International Conference on Technology, Engineering, and Science (www.icontes.net) held in Antalya/Turkey on November 14-17, 2024.

* The author acknowledges the Deanship of Research at Zarqa University for funding this project

References

Baker, A. (2017). 3D printing in architecture. The promise and the challenges. *Journal of Architectural Technology*.

Duarte, S. (2020). The role of 3D printing in architecture: A design perspective. *Design Studies, 66*, 145-162.

INJ Architects. (2024). *Exploring traditional construction and 3D printing*. Retrieved from https.//injarch.com/exploring-traditional-construction-and-3d-printing/

Jiang, H., & Hu, Y. (2022). Exploring the potential of 3d printing in sustainable architecture. *Sustainability, 14*(3), 1248.

Khalil, A., & Matar, S. (2021). Digital fabrication and the future of architectural design: Opportunities and challenges. *International Journal of Architectural Computing, 19*(1), 3-12.

Lim, S., & Shakir, M. (2020). 3D printing in architecture. current trends and future directions. *Design Studies, 68*, 100-120.

Montero, L. (2019). 3D Printing as a tool for architectural representation and model-making. *Journal of Architectural Education, 73*(4), 502-513.

Pérez, R., & González, M. (2020). Challenges of 3D printing in architecture: A review. *Journal of Building Engineering, 30*, 101292.

Tafuri, A. (2018). 3D printing in architecture from vision to reality. *Architectural Design, 88*(4), 78-85.

Wang, X., & Wang, D. (2019). 3D printing current and future directions in Architecture. *Architecture Research, 9*(2), 53-60.

Zalloom, B. (2022). Smart cities using GIS technology in urban infrastructure development at migration areas. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 18*, 64-71

Author Information

Bushra Zalloom
Zarqa University
Zarqa, Jordan
Contact e-mail: *bzalloom@zu.edu.jo*

To cite this article:

Zalloom, B. (2024). From concept to reality: How 3D printing transform architectural model-making. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 32*, 568-574.