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# 3D printing in the production of furniture and interior elements

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## Abstract

The article examines the characteristics inherent to the process of manufacturing furniture and interior elements using additive manufacturing (3D printing). The main technological processes (FDM, SLA, SLS) are analyzed, and the role of the digital workflow from CAD modeling to post-processing of finished products is demonstrated. As an example, an RPET/DPFNP filament derived from recycled polyethylene terephthalate and date palm nanoparticles is investigated for FDM printing of furniture prototypes. The advantages of using recycled and bio-based composites in the furniture industry are presented. The methodology ensures reduced production cycles, decreased waste, and opens new opportunities for small-batch, personalized furniture manufacturing. The information presented in the article will be of interest to researchers and lecturers in additive manufacturing and materials science who are developing new polymers and composites for high-strength, aesthetically versatile 3D-printed decor, as well as to design theorists and ergonomics specialists seeking to integrate personalized interior solutions within the context of sustainable production. Furthermore, practical process engineers in the furniture industry and startup initiatives in digital prototyping will be able to glean important insights into process scalability, optimization of topology-optimized structures, and the economics of additive manufacturing.

**Keywords:** 3D printing; Additive technologies; Furniture; Interior elements; RPET; Date palm nanoparticles; Composite filament; Eco-friendly production; Circular economy

## 1. Introduction

In the context of rapid advancements in digital technologies and Industry 4.0, additive manufacturing (3D printing) has become a transformative factor for traditional sectors, including furniture production. Mass customization, waste minimization, and high precision in component fabrication enable manufacturers to satisfy the demands of today's consumer, who expects originality, sustainability, and rapid market introduction of new models. Specifically, the application of 3D printing in furniture manufacturing has already progressed from isolated experimental prototypes to small-batch production, promising to fundamentally reshape the industry's technological chains and bolster its competitiveness [1].

In the literature on the application of 3D printing technologies to furniture manufacturing and interior elements, four principal thematic research clusters emerge. The first cluster comprises foundational reviews that synthesize materials, methods and major developmental trajectories in additive manufacturing. For example, the study by Ngo T. D. et al. [3] offers a detailed classification of polymeric, metallic and composite materials employed in 3D printing. Yang S., Du P. [1] examine the direct applicability of various 3D printing techniques within furniture design, presenting prototypes of complex geometries and discussing the integration of digital workflows with conventional production methods.

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The second cluster encompasses investigations into novel materials and strategies to enhance the environmental sustainability of additive manufacturing. Jiang Z. et al. [4] explore the extrusion of polymer composites enriched with nanomaterial additives to improve the mechanical and thermal properties of printed components. Elessawy N. A. et al. [2] propose biodegradable filaments produced from recycled solid waste and assess their impact on interior design and furniture longevity. Comparable efforts to repurpose PET waste for filament production are demonstrated by Oussai A., Bártfai Z., Kátai L. [8], while Ahmad N. D. et al. [9] focus on reinforcing polylactic acid with cellulose nanocrystals to create composite filaments with enhanced stiffness and biocompatibility.

The third cluster includes studies that directly demonstrate the implementation of additive technologies in furniture and interior projects. Jain P. K., Jain P. K. [7] regard 3D printing as a tool for producing next-generation household objects, highlighting design flexibility and waste reduction in small-batch production. Liu Y. [10] analyzes the optimization of printing parameters—feed rate, extruder temperature and infill density—to achieve the desired surface finish and dimensional accuracy for interior decoration applications.

The fourth cluster consolidates research on the pedagogical and artistic dimensions of 3D printing adoption. Kalenda P., Rath L., Glor H. [5] describe a methodology for organizing off-site events in which scientific models are fabricated via 3D printing, thereby fostering interdisciplinary learning. Guo S. D. [6], in turn, investigates the emergence of artistic practices grounded in additive manufacturing, illustrating the integration of original digital forms with traditional art techniques.

Overall, the literature reveals certain contradictions: on one hand, several studies prioritize environmental sustainability through the use of recycled and biodegradable materials; on the other hand, most prototype projects still rely on conventional polymers without fully addressing end-of-life considerations. A gap persists between theoretical reviews and practical research: comprehensive evaluations of the durability and ergonomics of 3D-printed furniture—as well as safety standards and compatibility with traditional manufacturing processes—remain scarce. Furthermore, the economic feasibility of large-scale adoption of additive technologies in the furniture industry, the integration of digital design platforms with production management systems and the engagement of end users in terms of aesthetic and functional requirements warrant further investigation.

**The purpose** of the article is to analyze the characteristics of applying 3D printing technology in furniture manufacturing and interior component production.

**The scientific novelty** lies in conducting a comprehensive analytical and synthetic investigation of modern additive technologies and environmentally friendly composite materials, exemplified by RPET/DPFNP filament, to identify and systematize their synergistic potential in transforming production cycles within the furniture industry towards customization, resource efficiency, and a circular economy.

**The hypothesis** posits that adopting 3D printing in the production of furniture and interior components achieves an optimal balance of mechanical strength and environmental sustainability, thereby opening new opportunities for small-batch and customized furniture manufacturing.

As a **methodological** basis, a comparative literature analysis of additive manufacturing and biocomposites was conducted.

## 2. Technological basics of 3D printing for furniture production

Modern additive manufacturing technologies are officially standardized under ASTM F2792 and are categorized into seven fundamental groups. However, in furniture production, three methods have become the most widespread, owing to their broad applicability, material variability, and adaptability to small-batch part fabrication.

Fused Deposition Modeling (FDM) involves the extrusion of a thermoplastic filament through a heated nozzle, followed by layer-by-layer deposition to build the part. The simplicity of the equipment design, its configurable versatility, and the wide range of polymer formulations (including ABS, PLA, PETG) secure this technique's leading position in prototype development and small-series furniture components [1].

Stereolithography (SLA) is based on the selective curing of a liquid photopolymer using a laser or a digital light projector (DLP). High geometric accuracy (up to 25 μm) and exceptional surface smoothness make SLA the preferred choice for parts requiring a jewelry-quality finish. However, the limited availability of durable photopolymers restricts its application in the production of large functional assemblies [3].

Selective Laser Sintering (SLS) entails the layer-by-layer sintering of powdered materials (polyamide, metal, or ceramic blends) using a laser beam. The elimination of support structures allows the fabrication of functional elements with complex internal geometries. The final part requires post-processing, including the removal of unsintered powder and, if necessary, impregnation or heat treatment to enhance mechanical properties [2].

Table 1 Below provides a comparative overview of these additive processes

**Table 1** Comparative characteristics of additive processes (compiled by the author based on the analysis of [1-3])

| Technology | Working Principle | Main Materials | Resolution (μm) | Advantages | Limitations |
|---|---|---|---|---|---|
| FDM | Material extrusion | ABS, PLA, PETG, composites | 100–300 | Low-cost equipment; wide range of filaments | Rough surface finish; support structures required |
| SLA | UV curing | Photopolymer resins | 25–100 | High precision; excellent surface finish | Brittle parts; limited resin options |
| SLS | Laser sintering | Nylon, polystyrene | 100–150 | No support structures required; strong parts | Expensive powder; complex post-processing |

In furniture manufacturing, additive manufacturing materials must meet stringent requirements for mechanical strength, wear resistance, and surface finish aesthetics.

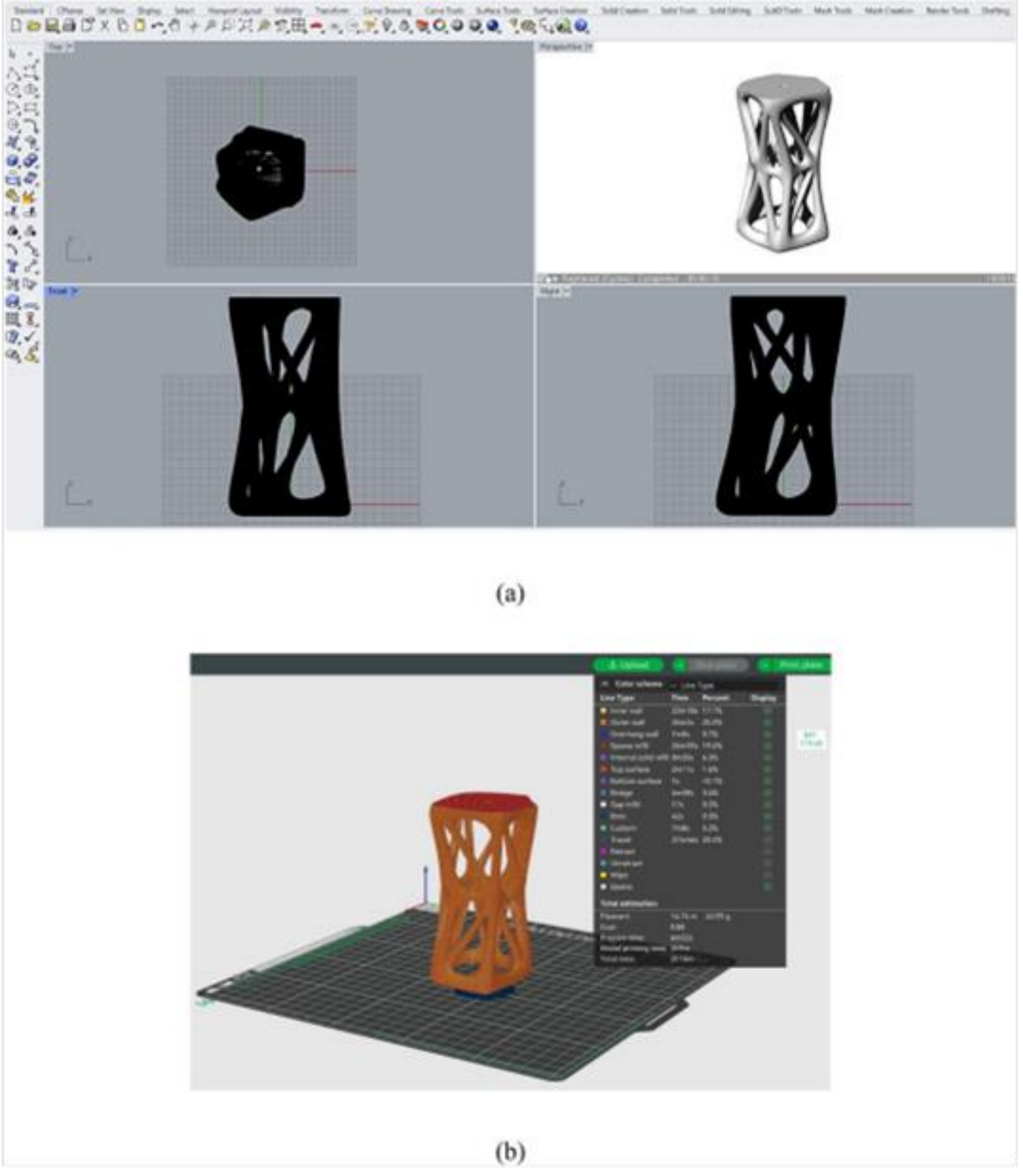
Thermoplastic polymers used in fused deposition modeling (FDM) exhibit varied performance characteristics: acrylonitrile butadiene styrene (ABS) offers high impact resistance; polylactic acid (PLA) provides low warpage and biodegradability; and polyethylene terephthalate glycol (PETG) combines strength with thermal stability. The incorporation of wood–polymer composites or natural fillers, such as date pit nanoparticles, enhances structural rigidity and environmental sustainability [2].

Photopolymer resins employed in stereolithography (SLA) deliver ultra-high detail resolution, yet many commercial formulations suffer from insufficient mechanical stability and significant shrinkage during curing, which restricts their use in load-bearing furniture components.

Powdered polymer materials for selective laser sintering (SLS), predominantly based on polyamide 12 powders (PA12), provide excellent impact resistance and thermal stability, making them the preferred choice for manufacturing exterior and decorative furniture elements [5, 6].

The complete digital workflow for additive furniture production comprises four stages:

- 3D modeling entails generating geometry in CAD software (AutoCAD, SolidWorks, Rhino3D) while accounting for allowable tolerances and the specific characteristics of the chosen technology [4]. Figure 1 presents an example of a 3D object's development.



(a)

(b)

**Figure 1** (a) The design of the 3D object, organic 3D form of a side table, (b) Stereo-lithography format of the 3D design, software used Bambu studio slicer [2]

- Post-processing and slicing. Preparation of the STL model, mesh error correction, and specification of printing parameters in the slicer (Cura, Slic3r, Bambu Studio): layer height, infill density, support structures.
- G-code Generation. Conversion of printing parameters into machine instructions that account for extruder movement speeds and heating and cooling temperatures.
- Printing and Post-Processing. Fabrication of the part and subsequent finishing: removal of support structures, sanding, heat treatment, or painting [3]. Figure 2 illustrates the manufacturing process of the interior object and its final form.

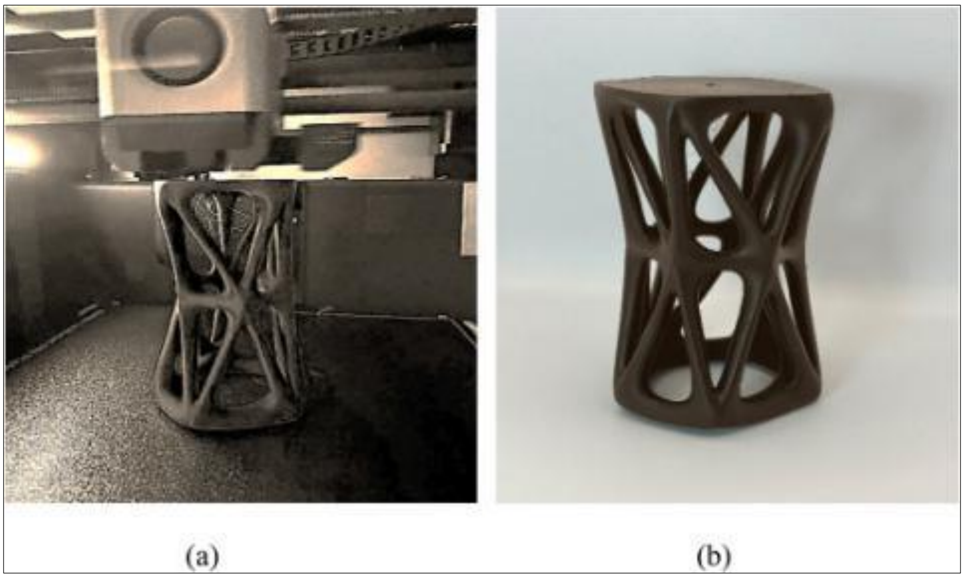


**Figure 2 (**a) The process of creating 3D object design, (b) the final object in 3D structure [2]

Thus, the effective integration of all stages of the digital cycle enables not only a reduction in time-to-market and operational costs but also a flexible response to end-consumer demands, ensuring a high degree of personalization and the minimization of production waste.

## 3. The introduction of 3D printing in the design and production of furniture

A key advantage of additive manufacturing in the furniture industry is rapid prototyping, wherein a digital 3D model is directly transformed into a physical prototype without the need for costly tooling. During the conceptual design phase, 3D prototypes facilitate evaluation of form, ergonomics, and visual appearance of furniture prior to the commencement of mass production [1, 7]. Multiple iterative tests of facade variants, joint configurations, and decorative elements ensure design optimization and shorten development cycles by 30–50% compared to conventional mock-ups [1, 2]. An illustrative example of experimental interior finishing is the prototype villa by Shanghai Yingchuang, produced using integrated printing techniques for both interior and exterior finishes and architectural components, as shown in figure 3.

**Figure 3** An example of using 3-D technologies for the interior decoration of a Shanghai Yingchuang villa, made using integrated printing for interior and exterior decoration and architecture [1]

Traditional technology for producing complex molds (metal stamping dies, silicone matrices) demands considerable time (several weeks) and resources (thousands of euros per set). Additive methods can be applied to:

- Rapid tooling: 3D printing of plastic or composite molds suitable for injection molding or vacuum forming, with an accuracy of ±0.1 mm [1].
- Reduction of tooling production costs by 40–60% and production time to 2–3 days [3].
- Furniture assembly depends on fasteners (screws, dowels, metal connectors). Additive printing enables:
- "Monolithic printing" of hybrid components (frame + connector) with integrated hinges and latches, increasing structural rigidity and simplifying assembly [1, 9].
- Use of infill and optimized lattice structures to reduce weight while maintaining strength [2].

With the advent of large-format industrial 3D printers (capable of printing up to 1 $m^3$ in a single run), additive processes are steadily progressing toward the production of finished furniture:

- Fabrication of complete chairs, stools, and coffee tables without subsequent assembly [1].
- Incorporation of internal cavities and vaulted structures—unachievable through milling or stamping—opening new design possibilities.

Table 2 presents the results of the comparison between traditional and additive methods in furniture manufacturing.

**Table 2** Comparison of traditional and additive methods at key stages of furniture production (compiled based on the analysis of [1, 2])

| Stage | Conventional Method | 3D Printing | Key Advantages |
|---|---|---|---|
| Prototyping | Manual assembly of wooden mock-ups | Direct fabrication of 3D models in plastic or composite | Rapid idea validation; cost reduction of up to 50% |
| Mold and tooling fabrication | CNC milling of metal and silicone molding | 3D printing of molds using UV-curable resins or composites | Lead time reduced from weeks to days; cost savings of up to 40% |
| Component production | Procurement of standardized fasteners | Printing of integrated connectors and modules | Simplified assembly; reduced weight; enhanced strength |
| Final component fabrication | Adhesive bonding and mortise-and-tenon joints | Printing of monolithic structures | Complex geometries; elimination of assembly operations |

Thus, the implementation of 3D printing provides the furniture manufacturer with cross-functional flexibility, reduces tooling and parts inventory, and shortens the time-to-market for new products.

## 4. Eco-friendly composite materials for 3D printing of furniture and interior elements

One of the driving forces behind sustainable development in additive manufacturing within the furniture industry is the shift to composite filaments produced from recycled polymers and natural fillers—agricultural waste, wood flour, and cellulose. These materials combine high mechanical and aesthetic properties with environmental responsibility. Polyethylene terephthalate (PET) is widely used in bottle packaging, but most post-consumer bottles accumulate in landfills. Recycling PET into filament for Fused Deposition Modeling (FDM) printing enables:

- Reduce plastic waste generation and the burden on municipal waste systems [9,10];
- Preserve high mechanical strength of final parts: tensile strength of recycled PET (RPET) filament reaches 25–26 MPa, with a modulus of approximately 880 MPa [2].

However, pure RPET filament exhibits relatively high melt flow and shrinkage during printing, which limits dimensional accuracy in complex geometries. To decrease energy consumption and carbon footprint, biobased fillers are actively investigated:

- Date palm fiber nanoparticles (DPFNP). Elessawy N. A. et al. [2] developed an RPET filament containing 10 wt % DPFNP. Incorporating DPFNP increases thermal stability, reduces melt flow, and doubles tensile strength to 49.4 MPa, with a modulus of 846.7 MPa.

- Wood flour. PLA filaments loaded with 20–30 wt % wood flour exhibit tensile strength of 30–35 MPa and a modulus of 2000–3000 MPa at a printing temperature of approximately 200 °C.
- Cellulose fibers. PLA composites containing 10–20 wt % cellulose fibers deliver tensile strength of 28–32 MPa and a modulus of 1800–2200 MPa [1,2].
- Fillers derived from agricultural waste not only lower filament production costs but also enhance stiffness and visual texture, imparting a natural finish to printed parts. The key parameters of three common composite filaments can be compared as follows:
- Circular economy. RPET filaments with agricultural fillers reintroduce waste into the production cycle, reducing consumption of virgin resources.
- Carbon footprint reduction. PLA composites with natural fibers require less energy to produce than pure PLA, significantly reducing $CO_2$ emissions.
- Cost savings. The cost of 1 kg of eco-friendly RPET/DPFNP-based filament is 15–25 % lower than that of commercial pure PLA filaments.

Thus, the transition to composite filaments based on recycled PET and biobased fillers from agricultural waste demonstrates an effective combination of mechanical, aesthetic, and environmental advantages: RPET reduces landfill burden while retaining tensile properties, and the addition of 10 % date palm fiber nanoparticles doubles tensile strength to 49.4 MPa and improves thermal stability; similarly, PLA filaments with 20–30 % wood flour or 10–20 % cellulose fibers exhibit a modulus of 1800–3000 MPa at tensile strengths of 28–35 MPa, imparting a natural texture to printed parts.

## 5. Conclusion

The study demonstrates that the integration of additive manufacturing technologies at every stage—from digital design to post-processing—dramatically enhances the flexibility, speed, and environmental performance of furniture production. An analysis of key technologies (FDM, SLA, SLS) revealed their strengths and limitations in the fabrication of prototypes, molds, connectors, and finished products.

Research on the RPET/DPFNP composite confirmed the hypothesis that the use of 3D printing in furniture manufacturing and interior components improves performance metrics (tensile strength nearly twice that of pure RPET), maintains high thermal stability, and reduces melt flow, thereby ensuring the reliability of FDM printing for complex furniture geometries.

The proposed methodology presents the following advantages:

- Accelerated development — rapid prototyping and rapid tooling shorten the time from concept to first sample.
- Resource efficiency — recycled PET and agricultural waste are reincorporated into production, reducing raw-material and disposal costs.
- Sustainability — the use of bio-based fillers and waste minimization adheres to circular-economy principles.

Future research should focus on in-depth optimization of filler geometry and printing parameters to enhance the strength of large-scale components, as well as on the development of a unified digital platform for automated management of the design–print–assembly pipeline. Ultimately, the combination of 3D printing and eco-friendly composites will enable the production of next-generation, high-tech, personalized, and resource-efficient furniture.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

There is no conflict of interest

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