



DIGITAL TECHNOLOGIES IN THE MANUFACTURE OF PACKAGING PRODUCTS

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Abstract. *An overview of the main digital technologies (AR, VR, AI, and digital printing methods) used in the design, development, and manufacturing of packaging products throughout their life cycle is provided.*

The main digital technologies that have revolutionized packaging design and production include augmented reality (AR) and virtual reality (VR), which open up new opportunities for enhanced efficiency, expanded creativity, and improved collaboration between clients and original equipment manufacturers.

By using AR and VR technologies, packaging manufacturers can enhance training programs, virtual educational simulations, and standardize work instructions. Virtual training environments improve employee education on how to properly handle packaging equipment, adhere to safety protocols, and troubleshoot potential issues without any additional risks. Digital work instructions make it easier for companies to standardize their operations and ensure consistent information at each workstation, reducing time, errors, and cognitive load on employees. Another advantage of digital work instructions is access to them in multiple languages at the touch of a button.

Packaging designers can also use AR and VR technologies to create virtual prototypes and 3D models of their designs. This immersive experience allows them to evaluate packaging concepts in a simulated real-world environment, gaining valuable insights into product appearance, functionality, and user interaction. VR and AR also allow designers to visualize and fine-tune packaging concepts, boosting creativity while reducing costs and accelerating development processes by cutting down the time and resources spent on creating physical prototypes.

The integration of digital twins into packaging design enables continuous monitoring of performance and behavior throughout the entire lifecycle. Manufacturers and clients can virtually simulate handling, transportation, and storage of products, identifying potential flaws and vulnerabilities before moving into production. This leads to reduced design flaws, minimized waste, and ultimately, cost savings.

Through the use of AR and VR technologies, collaboration between clients, equipment manufacturers, and the workforce is enhanced by overcoming geographical barriers, ensuring seamless communication and cooperation regardless of location. Interactive virtual meetings and design sessions allow stakeholders to collaboratively explore packaging concepts, share ideas, and make real-time adjustments. Clients can virtually interact with 3D visualizations of products, providing a dynamic feedback loop that fosters creativity and ensures the final design meets all requirements and expectations.

Additionally, AR can be used in marketing and sales, creating an interactive experience for consumers and increasing sales. Customers can virtually try out products, better understand their value, and thus increase the likelihood of purchase.



As this technology continues to evolve, further progress can be expected in eco-friendly packaging solutions and a more connected global packaging industry. The application of AR/VR technologies is a transformative force that will shape the future of packaging design for years to come [1].

Regarding printing technologies and methods, for a long time, flexographic printing was considered the only method for producing packaging, especially for mass and popular consumer goods. However, the modern market dictates new conditions: changing consumer demand and growing interest in packaging products; orders for small but personalized batches of packaging to minimize risks and avoid excessive waste. Flexographic plate production requires significant time investment, and setting up equipment for small print runs is economically inefficient. An alternative is the creation of hybrid production or the addition of digital printing to flexographic lines. Another advantageous option is investing in separate digital equipment for printing on roll materials, thus shifting to a more sustainable "print-on-demand" model, which is ideal for small batch packaging production.

Digital printing, whether used as a standalone technology or in combination with traditional methods, allows packaging manufacturers to quickly and cost-effectively produce small runs with variable designs while avoiding overproduction and unnecessary waste. In the packaging industry, reducing waste also requires optimization of packaging designs [2]. To improve the printing process, software, artificial intelligence (AI), and automation are used. They help optimize all processes, making them more environmentally friendly and efficient. These technologies are applied in digital, hybrid, and analog printing.

Key Advantages of Digital Printing in Reducing Waste.

1. **Print-on-Demand Model.** This approach enables the production of only the necessary amount of packaging, eliminating excess. It reduces ink, material, and energy consumption, as well as minimizes the need for recycling and transporting surplus products.

2. **Late-Stage Customization.** Digital printing allows for the addition of final design elements directly during production (discount information, QR codes, or expiration dates).

3. **Elimination of Printing Plates.** The production of printing plates can account for over 10% of the annual budget. Digital printing eliminates this need, reducing waste, saving time, and minimizing water and chemical usage.

4. **Reduced Carbon Footprint and Costs.** Lower resource and energy usage results in decreased carbon dioxide emissions across all stages of the supply chain.

Thus, digital technologies combined with digital printing represent a step toward a sustainable future, where ecology and profitability go hand in hand [3].

References

1. 4 Ways Digital Technologies Revolutionize Packaging Design and Processes. <https://www.packagingdigest.com/smart-manufacturing/4-ways-digital-technologies-revolutionize-packaging-design-and-processes>.
2. Environmentally sustainable packaging technologies - the advantages of digital printing. <https://domino-kiev.com.ua/news/ekologichno-stiyki-tekhnologii-dlya-pakuvannya-perevagi-tsifrovogo-druku>.
3. The Future of Print Industry in 2025 and Beyond. <https://radixweb.com/blog/the-future-of-print-industry>.