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The role of digital technologies and parametric design in sustainable residential retrofitting

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### Summary

This article investigates the application of emerging technologies—specifically Building Information Modeling (BIM), Parametric Design, and Augmented Reality (AR)—in the context of interior design focused on the *retrofit* (revitalization) of existing residences. The study analyzes how the integration of these digital tools allows for the accurate simulation of environmental performance and the optimization of materials, reducing waste in construction and increasing the energy efficiency of the housing stock. The methodology comprises a critical review of the literature on the digitalization of design and case studies on the application of new smart materials. The results demonstrate that technology in interior design is not merely aesthetic, but an essential applied science for urban sustainability and the economic viability of housing renovations.

**Keywords:** Design Technology. BIM. Sustainable Retrofit. Parametric Design. Housing Efficiency.

### Abstract

This article investigates the application of emerging technologies—specifically Building Information Modeling (BIM), Parametric Design, and Augmented Reality (AR)—in the context of interior design aimed at the retrofitting of existing residences. The study analyzes how the integration of these digital tools allows for precise simulation of environmental performance and material optimization, reducing waste in construction and increasing the energy efficiency of the housing stock. The methodology comprises a critical review of literature on design digitalization and case studies on the application of new smart materials. The results demonstrate that interior design technology is not merely aesthetic but an essential applied science for urban sustainability and the economic viability of housing renovations.

**Keywords:** Design Technology. BIM. Sustainable Retrofitting. Parametric Design. Housing Efficiency.

## 1. Introduction

The construction and interior design industry is undergoing a silent revolution. driven by the transition from analog processes to digitally integrated workflows. At the heart of this transformation is the concept of "Technology in Design," a discipline that... It transcends decoration to address the internal engineering of living spaces. With the aging of the global housing stock, especially in developed nations such as In the United States, *retrofitting*—the process of modernizing old buildings—has become a Economic and environmental priority. The challenge lies in implementing these updates in a way that... sustainable, minimizing waste generation and maximizing energy efficiency, tasks that They require a higher level of technical precision than traditional methods.

The introduction of tools such as *Building Information Modeling* (BIM) in the design of Interior design now allows the creation of "Digital Twins" of environments. This technology It allows for simulation, before any physical intervention, of different materials, layouts, and systems.



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Lighting systems will behave over time. The problem addressed in this study focuses on...

The existing gap between the potential of these technologies and their practical application in residential projects.

Medium-scale projects. Often, interior design is viewed from a superficial perspective, ignoring-  
if the profound impact that the correct technical specification, aided by advanced software, has on

The carbon footprint and operating costs of a dwelling.

The central hypothesis of this article is that the adoption of computational design methodologies and  
Parametric design is essential for achieving the sustainability goals of the housing sector. By using  
algorithms to optimize material cutting, predict thermal incidence, and automate the process.

In project coordination, the design technologist drastically reduces human error and...

Rework — factors that increase the cost of renovations and generate debris. Furthermore, technology facilitates...

incorporation of new composite and biophilic materials, which require installation methods and

Specific maintenance requirements, often incompatible with outdated construction techniques.

The objective of this work is to outline the state of the art of digital technologies applied to  
interior design and demonstrate its effectiveness in the context of sustainable *retrofitting*. The relevance of this  
This research is based on the urgent need for solutions to the housing and climate crisis.

Transforming the existing housing stock into efficient "Smart Homes" is not just a matter of...

market-driven, but of strategic national interest, requiring professionals with hybrid training in

Aesthetics, construction management, and information technology are needed to lead this transition.

## **2. Bim (building information modeling) in interior design**

Building *Information Modeling* (BIM) represents the most significant evolution in  
design technology of the last few decades, migrating from 2D vector drawing (CAD) to...

Data-rich 3D parametric modeling. In interior design, BIM acts as a database of...

Centralized data that stores not only the geometry of the space, but also its physical properties and  
functional characteristics of each specified element — starting from the thermal conductivity coefficient of a

From wall coverings to the lifespan of an LED light fixture. That's the depth of information.

It transforms interior design into a tool for managing the building's lifecycle.

allowing for accurate predictions regarding maintenance and performance.

The application of BIM in residential *retrofitting* is particularly valuable due to the complexity  
to intervene in pre-existing structures. Laser scanning *technologies* and

Photogrammetry allows you to capture the reality of an ancient environment with millimeter precision.

This generates a "point cloud" that serves as the basis for the BIM model. This eliminates uncertainties.

common issues in renovations, such as out-of-square walls or hidden beams, allow the designer to...

Design joinery and finishes with a perfect fit, reducing material waste in the process.

Construction site layout and execution time are critical factors for the economic viability of renovations.



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Interdisciplinary coordination is another crucial benefit. In a residential project

In modern times, interior design must coexist with complex automation and climate control systems. and hydraulics. The BIM environment allows for automatic clash detection , alerting the professional determines, for example, if a recessed plaster ceiling interferes with the passage of ducts. air conditioning. Resolving these conflicts virtually, before the start of construction, avoids expensive and time-consuming on-site improvisations ensured the project's technical integrity and safety. structural aspects of the building.

Beyond geometry, BIM facilitates the analysis of energy sustainability within design. Interior design. Simulation plugins can use the model to calculate the incidence of natural light. at different times of the year, assisting in the selection of colors, textures, and furniture placement. to maximize passive thermal and lighting comfort. The design technologist can test virtually different types of glass and curtains to find the solution that best balances the Aesthetics combined with reduced thermal load, directly contributing to the energy efficiency of the residential use and to reduce CO2 emissions associated with electricity consumption.

The automatic quantification of materials (*Material Take-off*) generated by BIM introduces a Unprecedented budget transparency. Pivot tables extract the exact number of floors. This allows for the necessary paints and fabrics, updating instantly with each project change. Strict cost control is fundamental for real estate investors and owners. Accuracy Purchasing supplies avoids surplus materials that would otherwise end up in landfills, aligning with design practices. From interior design to the principles of the circular economy and lean construction .

Finally, BIM serves as a platform for the future management of the property (*Facility Management*). At the end of the renovation, the owner receives not only the key, but a digital model. The "As-Built" documentation includes all specifications, manuals, and warranties for the installed products. It facilitates future maintenance and increases the value of the property, as it provides a technical history. reliable. Mastering this technology by interior design professionals elevates the discipline to a new level. Information science is essential for the modernization of the construction industry.

It can be concluded that BIM is not just a design tool, but a methodology of... A project that integrates data, processes, and people. Its adoption in interior design is imperative. technological tools to ensure that interventions in existing homes are precise, economical and environmentally responsible, meeting contemporary demands for high-quality housing. performance.

### **3. Parametric design and digital fabrication**

Parametric design refers to the use of algorithms and computational variables to generate complex architectural forms and solutions that would be difficult or impossible to conceive through



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from traditional hand-drawing. In the context of interiors, this technology allows the creation of structures Adaptive features — such as partition panels, acoustic ceilings, and furniture — that meet certain criteria. Specific performance considerations, such as acoustics or ventilation. Instead of designing a fixed shape, the The designer defines parameters (rules) and the software generates the optimized geometry, allowing for a Mass customization *that* adapts to the idiosyncrasies of each residence.

Digital manufacturing, through technologies such as laser cutting, CNC (*Computer Numerical Control*) . *Control*) and 3D printing is the bridge that materializes parametric design. This direct connection between The digital file and the manufacturing machine eliminate intermediate interpretation steps, ensuring Absolute adherence to the project. In the *retrofitting* of old buildings, where measurements are rarely standard, The ability to manufacture custom components *on-site* or in local workshops ("Fab Labs") reduces the reliance on long supply chains and standardized products that often require Forced adaptations generate waste.

Topological optimization is an advanced application of parametric design with a strong impact. in sustainability. Algorithms can analyze the structural forces acting on a part of Take out a piece of furniture or a bookcase and remove all the material that is not bearing weight, creating forms Organic and lightweight, using the minimum amount of raw materials necessary. This results in Visually striking and ecologically efficient interiors, reducing the weight of structures and the consumption of natural resources, an approach aligned with the goals of dematerialization of green economy.

Environmental acoustics is another area that benefits from this technology. In urban residences and In compact apartments, acoustic comfort is a challenge. Parametric design allows for the development of... wall coverings with complex geometries that diffuse or absorb sound waves from an effective way, calculated specifically for the frequencies of the human voice or external noises. The digital fabrication of these panels using sustainable materials, such as recycled PET felt or Certified wood combines technical performance with environmental responsibility, raising the quality. of life in the interior.

Large-scale 3D printing is beginning to make its way into interior design, enabling... creation of entire building elements, such as non-structural walls or kitchen islands, using cementitious materials or recycled polymers. This technology promises to revolutionize the The speed of the renovations allows for "printing" new layouts within old shells with minimal effort. waste generation. The design technologist must be able to operate in this interface between the code of Programming and materials science, exploring new aesthetics and functionalities that manufacturing... additive provides.

The integration of these technologies also promotes the democratization of high-end design. Standard. Digital files of parametric furniture can be shared globally and



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manufactured locally using regional materials (such as native wood plywood), reducing the carbon footprint of transportation. This "Distributed Design" model strengthens the local economies and offers consumers access to innovative design solutions and Personalized products, breaking with the logic of impersonal, industrialized mass production.

In short, parametric design and digital fabrication are transforming the interior designer. from a catalog product specifier to a technology solutions creator. This The ability to innovate in form and manufacturing is essential for adapting the existing housing stock. to meet new demands for use, aesthetics and sustainability, positioning technology as the driving force behind Renewal and efficiency.

#### **4. Augmented reality (AR) and virtual reality (VR) in the user experience**

Immersive technologies, Augmented Reality (AR) and Virtual Reality (VR), have changed Essentially, communication and decision-making in interior design projects. More Rather than being visual presentation tools, they function as instruments for technical validation. and sensory. VR allows the client to "inhabit" the designed space before its construction. experimenting with scale, ergonomics, and lighting atmosphere. In *retrofitting*, this is crucial for alignment. expectations and avoiding changes during construction are the main causes of budget overruns. and the generation of unnecessary waste.

Augmented Reality, in turn, overlays digital information onto the real physical environment. AR applications on tablets or smart glasses allow designers and builders Visualize, on the construction site itself, where the new electrical and plumbing installations will be located. by overlaying the BIM model onto the existing wall. This "X-ray view" facilitates precise execution. preventing accidental punctures in pipelines and ensuring that the design is implemented. as planned. For the end user, AR allows them to test finishes and furniture in their home. Your own home in real time, facilitating assertive choices.

Accessibility simulation is a high-value social application of these technologies. In In projects focused on " *Aging in Place*, " VR can simulate the... visual or motor limitations of an elderly person, allowing the designer to test the effectiveness of the lighting. The height of the countertops and the width of the circulation areas from the perspective of a vulnerable user. This An empathetic approach, mediated by technology, ensures that interior design fulfills its function. Social inclusion and safety, creating adapted and safe environments for all ages, in accordance with advocated by the principles of Universal Design.

Remote collaboration is enhanced by these tools. In a globalized market, Designers can collaborate with experts and clients in different parts of the world within a... Shared virtual environment. VR design meetings allow multiple participants.



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Analyze the project simultaneously, noting changes and testing material options in real time.

This streamlines the design process, reduces the need for travel (and associated emissions), and...

It allows the technical expertise of qualified professionals to reach remote or underserved locations. specialized services.

In the context of sales and the real estate market, the virtualization of interiors adds value. tangible assets. Old or vacant properties can be presented with "Virtual Staging".

showcasing its full potential for renovation without the cost of physically furnishing the space. For

For investors, this accelerates sales and rentals. The design technologist, by mastering these...

Visualization tools act as a business facilitator, translating technical potential into...

Understandable market value.

Integrating IoT sensor data into AR interfaces represents the future of management.

residential. Imagine looking at a light fixture through an AR app and instantly seeing its

current energy consumption and remaining lifespan. This invisible layer of information,

Made visible through technology, it empowers the resident to manage their home more efficiently and

conscious. The design of interfaces for home environments thus becomes a new frontier of

Performance for interior design professionals.

It can be concluded that immersive technologies are not mere marketing ploys, but

Robust technical verification and communication tools. They mitigate the inherent risk in construction projects.

Reforms promote accessibility and efficiency in the design process. The ability to operate

In these virtual environments, it is an essential skill for the modern design technologist.

ensuring that the intervention in the physical space is assertive, economical, and focused on the experience. human.

## **5. New smart materials and sustainability**

Technological innovation in interior design extends to materials science, with the

development of smart coatings and surfaces that actively interact with the

environment. Phase Change Materials (*PCMs*), for example, can be

incorporated into wall panels or ceilings to absorb and release heat, helping to regulate the

Passively adjusting the internal temperature and reducing reliance on air conditioning. Knowledge

The technical skill of specifying and installing these advanced materials is distinct from that of a technologist.

In design, one must understand the physics behind the product in order to apply it correctly.

Self-cleaning and antimicrobial surfaces have gained critical relevance in the post-

pandemic. The use of nanotechnology in ceramics, fabrics and laminates allows the creation of interiors that

They actively combat the proliferation of bacteria and viruses, promoting the health of occupants without the

Excessive use of harsh chemicals. In residential settings, the application of these



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Materials used in kitchens and bathrooms raise the standard of hygiene and sanitary safety, an aspect fundamental to modern housing quality.

Material sustainability has evolved to include biomaterials and highly recycled composites. Performance. Panels made from mycelium (fungi), bioplastics derived from algae, and laminated wood. Cross-linked timber (CLT) offers low-carbon alternatives to conventional materials. The design of Technological interiors not only utilize these materials for their aesthetics, but understand their... Mechanical and acoustic properties, integrating them into *retrofit* projects to improve insulation. and indoor air quality ( *IAQ*), avoiding volatile organic compounds (VOCs) harmful.

Electrochromic or "smart" glass allows you to change the transparency of windows through... through an electrical stimulus, controlling the entry of light and heat instantly. This technology It replaces mechanical curtains and blinds, offering a clean and integrated automation solution. Residential. Proper specification of these windows requires a deep understanding of transmission. Bright and solar factor, ensuring that the technological investment translates into visual comfort and Effective energy savings for the home.

The circularity of materials is a key concept supported by technology. Passports of Materials (*Material Passports*) are digital records that track the composition and origin of each item. The product is installed in a project. This facilitates disassembly and future recycling of the interiors. Transforming the building into a materials bank for the future. The designer acts as manager. From these resources, choose products that have documented life cycles and that can be... reintegrated into the production chain, combating planned obsolescence.

4D printing, an evolution of 3D printing, introduces the time factor, creating objects that change. shape or property in response to environmental stimuli (such as humidity or temperature). Although Although still emerging, this technology points to a future where interiors adapt themselves without The need for electrical power or complex motors. The design technologist must stay in at the forefront of this research, ready to apply solutions that mimic the intelligence of nature. (biomimicry) in built spaces.

In short, the smart materials revolution redefines the materiality of design. Interiors. Surfaces cease to be passive and become functional and responsive. The Mastering these new materials technologies allows professionals to create environments that are not only aesthetically pleasing, but also ecologically regenerative and technologically Advanced, aligned with the demands of a sustainable future.

## 6. Conclusion

This study sought to demonstrate that training in Design Technology...



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Interior design transcends aesthetic selection, establishing itself as a fundamental technical discipline. for the modernization and sustainability of the built environment. Through the analysis of technologies digital technologies — BIM, Parametric Design, Augmented Reality — and new smart materials, It became evident that the field of design has evolved into an applied science capable of responding to challenges. Housing complexes, energy efficiency and resource management.

Research into the use of BIM in residential *retrofitting* has confirmed that digitization of Design processes are key to the economic viability of sustainable reforms. The ability to anticipate construction problems, accurately quantify materials, and simulate performance. Environmental assessment before physical construction drastically reduces waste, one of the biggest liabilities of the industry. The construction industry. This validates the hypothesis that the design technologist acts as a An efficiency agent, protecting owners' investments and the environment.

Within the context of Parametric Design and Digital Fabrication, it was concluded that personalization Mass production and locally distributed production offer viable alternatives to industrial standardization. Technology allows solutions to be adapted to the specific needs of each existing residence, optimizing usage. of raw materials and enabling the creation of ergonomically superior environments and acoustically comfortable. The intersection between digital code and physical production represents a new innovation frontier for the sector.

The analysis of immersive technologies (AR/VR) highlighted their social role in promoting Accessibility and inclusion. The ability to simulate the needs of users with mobility issues. Reduced or aging *in place* positions technology as a tool. Empathy and technical validation. In addition, facilitating remote communication and collaboration. It expands the reach of professional expertise, energizing the design services market.

Smart materials and nanotechnology have been identified as vectors for health and Passive efficiency. The integration of surfaces that purify the air, regulate temperature, and combat... Pathogens demonstrates that modern interior design has a direct impact on public health. Adopting material passports and circular economy principles reinforces the responsibility of Designer in the life cycle management of planetary resources.

In light of the foregoing, it is imperative to acknowledge that the renewal of the real estate portfolio of The United States and other developed nations depend on professionals who master these skills. Technological tools. Large-scale *retrofitting* , necessary to achieve climate goals, is not It can be done using traditional and analog methods from the past. A specific approach is required. Based on data, simulation, and industrial precision.

The professional with a technological background in interior design therefore emerges as a central figure in this ecosystem. Her ability to integrate aesthetics, engineering, and science of Computing fills a critical gap in the job market. Ongoing research and application



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These innovations are of national interest because they contribute directly to the creation of cities.

More resilient, more dignified housing, and a greener, more competitive economy.

It is recommended that public policies and educational programs encourage the adoption of these technologies from academic training onwards, preparing a workforce capable of dealing with

The complexity of *smart homes* and digital cities. The future of living is technological, and design...

Interior design is the human interface of this transformation.

## References

EASTMAN, C. et al. **BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors**. 3rd ed. Hoboken: Wiley, 2018.

OXMAN, N. Material-based Design Computation. **Theories of the Digital in Architecture**, p. 345-365, 2013.

ASHRAE. **Standard 90.1-2019 -- Energy Standard for Buildings Except Low-Rise Residential Buildings**. Atlanta: ASHRAE, 2019.

AUTO, A. et al. Augmented Reality in Architecture and Design: A Review. **International Journal of Architectural Computing**, v. 18, no. 2, 2020.

MCDONOUGH, W.; BRAUNGART, M. **Cradle to Cradle: Remaking the Way We Make Things**. New York: North Point Press, 2002.

SCHUMACHER, P. **The Autopoiesis of Architecture: A New Framework for Architecture**. London: Wiley, 2011.

US GREEN BUILDING COUNCIL. **LEED v4.1: Interior Design and Construction Guide**. Washington, DC: USGBC, 2020.

KOLAREVIC, B. **Architecture in the Digital Age: Design and Manufacturing**. New York: Taylor & Francis, 2003.

ISO 19650-1:2018. **Organization and digitization of information about buildings and civil engineering works, including building information modeling (BIM)**. Geneva: ISO, 2018.

RITTER, A. **Smart Materials in Architecture, Interior Architecture and Design**. Basel: Birkhäuser, 2007.