international DESIGN JOURNAL
Print ISSN 2090-9632
Online ISSN 2090-9640

Technology and Interactive Architecture: The Impact of Technological Innovations on Building Design and User Experience,

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Abstract

Interactive architecture is considered as one of the contemporary ideas which emerged as a result of technological advancements and the emergence of environmental, functional, and human issues that traditional architecture was unable to solve, the interactive architecture requires dynamic architecture that is adjusted to adapt with internal and external conditions through movement, interaction, flexibility, and integration with people and the environment. The research explains interactive architecture's concept, definition, history, goals, advantages, and the role of interactive architecture in achieving adaptive design by conducting a comparative study of pioneering architecture projects of some countries that have adopted the idea of interactive architecture and analyzing these projects to extract the interactive technologies used and their role in improving building performance. Finally, the research indicates that the future of architecture is increasingly dependent on technology, as these innovations are expected to continue to reshape the urban environment, opening the way for smarter and more sustainable buildings that meet the needs of modern societies more efficiently.

Keywords

Interactive Architecture, Technology, smart building, Artificial Intelligence, Adaptive Design

Paper received March 1, 2025, accepted on April 16, 2025, Published online May 1, 2025

Introduction

The main goal of Interactive architecture is to offer a stable, optimal solution with the presumption that future circumstances will not remain constant, but it is alterable. However, current and upcoming technology advancements, and unforeseen climatic changes, and the need to create adaptive buildings, it is more reasonable to presume more flexibility in building usage. According to studies and statistics, these changes will affect the relationship between human and building, necessitating new concepts' development and adaptation for user ease. By adapting and altering to engage with various contexts, interactive architecture develops as a solution to alter the current situation and offer a better insight of the future.

Research Problem

The research addresses the limitations of traditional architecture in adapting to rapid environmental, social, and technological changes. The key challenges include:

1. The need for buildings that actively respond to environmental and functional changes.
2. Create Integrating smart technologies and kinetic systems into architectural designs that create more adaptable and sustainable spaces.
3. Provide design solutions that minimize the negative impact of surrounding conditions while maximizing user comfort and experience.

Research Goals

This study aims to explore and clarify the concept of interactive architecture as a modern approach in architectural design by focusing on:

1. Environmental Aspect: Examining how buildings respond to environmental variables by regulating climatic factors such as temperature, air movement, humidity, lighting

CITATION **Dalia Eldamaty (2025), Technology and Interactive Architecture: The Impact of Technological Innovations on Building Design and User Experience, International Design Journal, Vol. 15 No. 3, (May 2025) pp 11-19**

(natural and artificial), as well as acoustic insulation to reduce noise and vibrations.

2. Functional Aspect: Enhancing the performance of functional spaces by increasing their flexibility and adaptability to users' needs, while also developing self-operating systems for greater efficiency.
3. Aesthetic Aspect: Investigating the psychological and aesthetic impact of interactive architecture, which offers dynamic and ever-changing designs that create a new visual experience for the user.

Research Methodology

The research is based:

1. Descriptive approach: where technological developments in architecture are reviewed. The research is based on sources including Academic books and Scientific articles published in specialized architectural journals and Official reports from international organizations such as UN-Habitat, USGBC, and McKinsey
2. Comparative approach: by comparing case studies to evaluate the efficiency of interactive technologies in achieving sustainability and improving the functional performance of buildings.
3. Analytical approach: by analyzing data from case studies to identify future challenges and come up with results and recommendations for future researches.

Research Limitations:

- The research focuses on modern technologies that have been applied in projects during the last two decades.
- The analysis is limited to architectural and technological impacts without addressing the economic aspects in detail.
- The study may face limitations related to the availability of accurate data for some recent pilot projects.

Interactive Architecture Concept

- Royal Institute of British Architects (RIBA)

"Interactive architecture is a design approach that integrates smart technology into buildings, allowing them to interact with users and the environment, through adaptive systems such as moving facades, smart lighting, and embedded sensors." (1)

- International Union of Architects (UIA)

"Interactive architecture is defined as an architectural practice that integrates digital technologies and sensory systems to create adaptive spaces that respond to changing usage and environmental conditions, enhancing user experience and resource efficiency." (**2**)

- Institute for Advanced Architecture of Catalonia (IAAC)

"Interactive architecture seeks to create buildings that can adapt and interact with external and internal stimuli using artificial intelligence, smart materials, and sensors, allowing for more sustainable and advanced environmental architecture." (**3**)

- Smart Cities Council (SCC)

"Interactive buildings are part of smart cities, where technology is used to create environments that can automatically respond to climate, usage patterns, and energy efficiency, making them more sustainable and comfortable for residents." (**5**)

Interactive architecture is a new design approach that focuses on real communication between users and spaces, allowing them to respond effectively to changing needs. This approach creates a continuous relationship between society and the built environment, allowing buildings to adapt to individual, social, and environmental requirements. Interactive architecture integrates technology and movement in an architectural formula, incorporating human response and the environment. With the use of intelligent systems, moving components, and adaptability in applying various strategies, interactive architecture is more thorough. In general, interactive architecture seeks to give people a productive and comfortable workplace.

Objectives OF Interactive Architecture:

The interactive architecture aims to achieve three primary objectives:

1. Environmental aspect: The structure can be made to regulate its internal environment or external factors that have an adverse effect on it. In order to maintain human comfort, it may regulate climatic changes, features, and forms. This can be accomplished by altering the building shell's properties. interactive buildings can dynamically modify their state to take advantage of energy-saving techniques like building orientation and openness. It is also possible to boost passive cooling and passive solar. (**6**)
2. Functional aspect: By offering more flexibility and adaptability, interactive buildings seek to enhance the functionality of self-operating systems and functional areas. The degree of engagement distinguishes interactive

architecture from adaptable space. Although these structures were adaptable but not interactive, earlier trends depended on people manually altering parts and modifying geometric forms. In order for a structure to successfully adjust to changes, interactive architecture depends on feeling and perceiving information from users or the surroundings. (**7**)

3. Aesthetical aspect: the goal of interactive structures is to satisfy human needs in terms of both aesthetics and psychology by designing unique architecture with shifting looks for different uses. By rethinking how the physical environment shapes the viewer's surroundings, they want to disrupt the monotony of traditional architecture. (**8**) (**9**)

2- International Experiences

2.1 Al Bahar Tower - Abu Dhabi, UAE

- Features a dynamic interactive facade based on the traditional Mashrabiya technique but with modern technology.

-The facade contains a smart moving shading system that interacts with the movement of the sun, reducing energy consumption and improving cooling efficiency inside the building. (**10**)

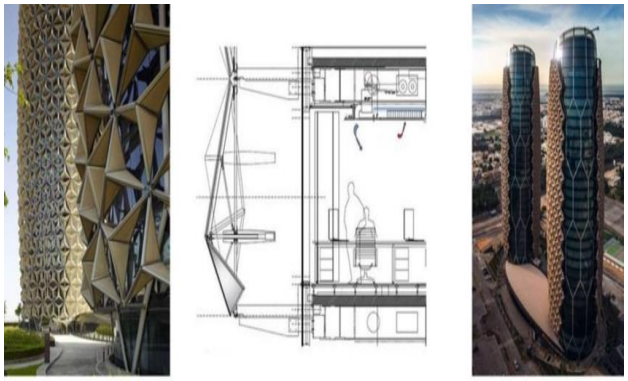

Figure (1) Al Bahar Towers, an administrative office center, Abu-Dhabi, UAE.

2.2 The Crystal Museum - London, UK

- One of the most sustainable buildings in the world, it relies on smart energy and water management systems.
- Uses interactive technology that allows visitors to interact with the building's environmental data through smart screens. (11)

2.3 Media-TIC Building - Barcelona, Spain

- Features a smart interactive facade made of ETFE material, which responds to lighting levels and temperature to reduce energy consumption.
- It contains an interactive LED lighting system that displays data on energy consumption and weather conditions. (12)

Figure (2) The Crystal Museum - London, UK

Figure (3) Media-TIC Building interior design - Barcelona, Spain

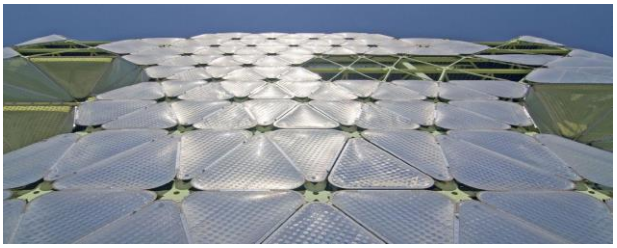

Figure (4) Media-TIC Building façade- Barcelona

2.4 Galleria Center city Facade Building - South Korea

- It contains a huge interactive LED facade that can change colors and patterns based on digital interactions.
- It is used as a means of communication with the public, where changing digital messages and art can be displayed. (13)

Figure (5) From the exterior, the Galleria boasts a dynamic double layered facade intended to stimulate use experience.

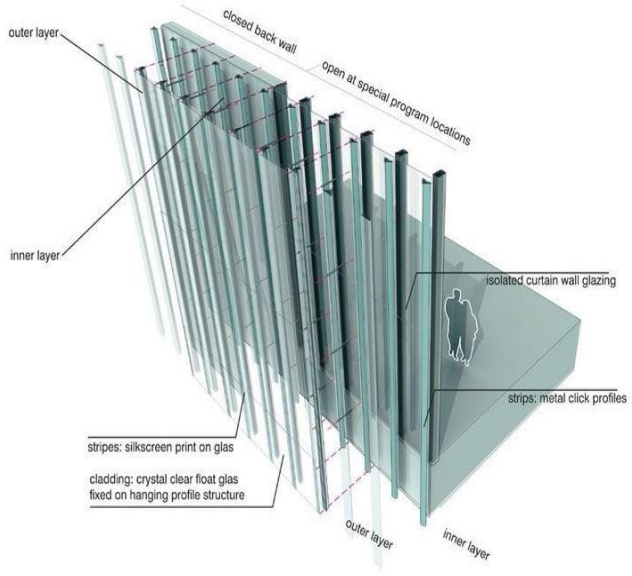

Figure (6) The lighting design was developed in parallel with the architecture and capitalizes on the double layered facade structure.

2.5 **Pavilion Zero – Expo Milan 2015, Italy**

- It uses augmented reality (AR) and virtual reality (VR) technology to create an interactive experience for visitors, where they can wander inside virtual environments within the exhibition.
- It displays environmental data in an interactive and visual way to raise awareness about sustainability. (14)

Figure (7) The Pavilion Zero by Michele de Lucchi at Milan EXPO 2015

2.6 **The Green Void Building – Sydney, Australia**

It features a dynamic interactive design that uses smart lighting systems and visual effects that change based on the movement of visitors inside the building. (15**)**

- It relies on artificial intelligence to adjust lighting, temperature and ventilation based on actual use.
- LAVA's process of optimized minimal surface design and CNC (computer numeric code) fabrication technology allows the sculpture to reveal a new dimension in sustainable design practice.
- the work succeeds in achieving sustainability and optimum efficiency in material usage, construction weight, fabrication and installation time, while at the same time achieving maximum visual impact in the large atrium space.
- The pavilion is easily transportable to any place, can be quickly installed, and is fully reusable.

Figure (8) The computer-model, based on the simulation of complexity in naturally evolving systems, feeds directly into a production-line of sail-making-software and digital manufacturing.

2.7 **Kiefer Technic Showroom Facade – Austria**

- A building with a unique design where its interactive facade moves according to the movement of the sun, providing effective thermal insulation and reducing air conditioning consumption.

- It uses hydraulic motors to move the external panels, making it a dynamic building. (16)

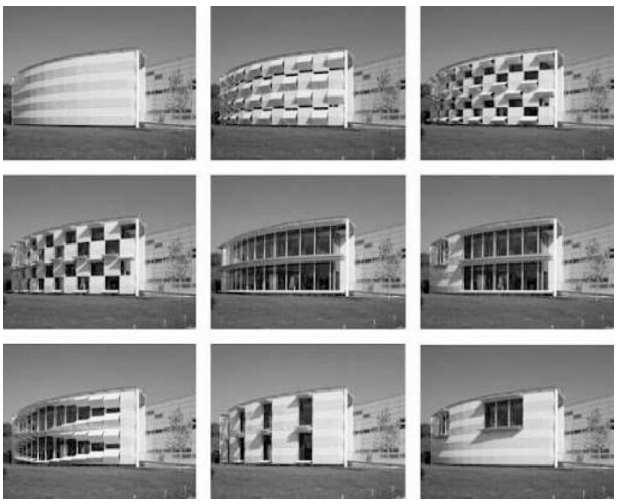

Figure (9) Kiefer Technic Showroom Facade – Austria

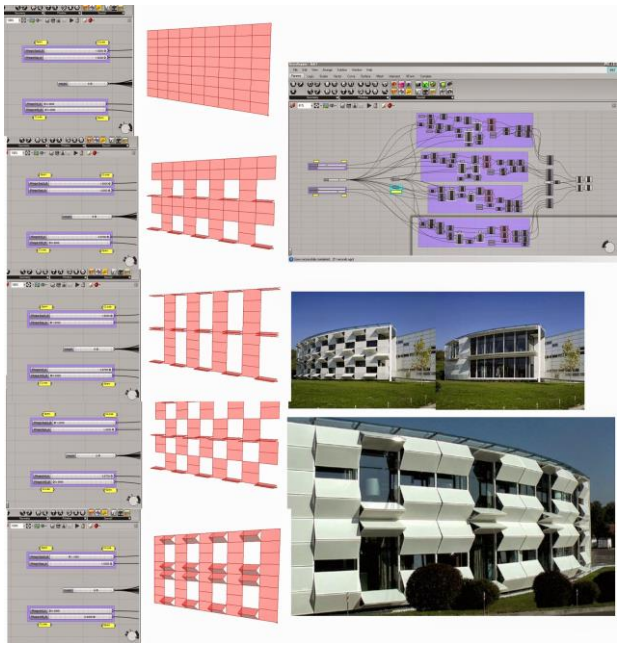

Figure (10) occupants can adjust temperature and light

2.8 **The Shed – New York, USA**

An interactive cultural center featuring a movable exterior that can expand and retract as needed, allowing the spaces inside to be configured to host different events. (**17**)

- It uses intelligent robotic systems to adjust the structure of the building based on the type of event and the number of attendees.
- the Shed offer an open-air space or a closed one sub-dividable to multiple smaller spaces. It also includes gallery space, several theaters, and rehearsal labs with a hall that allow for the manipulation of temperature, light, and sound.

Figure (11) The Shed – New York, USA

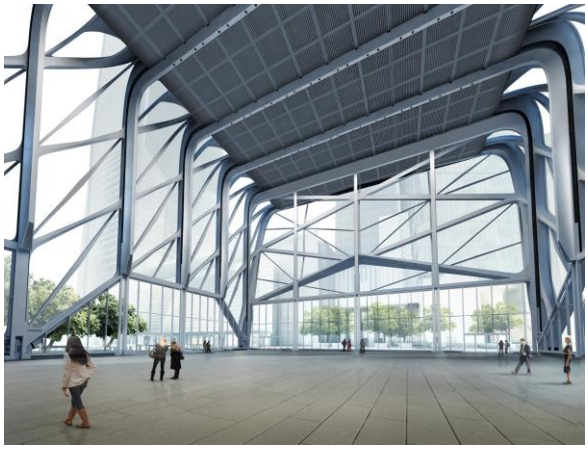

Figure (12) An interactive cultural center featuring a movable interior that can expand and retract as needed

Figure (13) An interactive cultural center featuring a movable exterior

3-Comparing examples of buildings that have adopted the idea of interactive architecture, the techniques used, and their impact on improving building performance.

Table (1) Comparison table of global and international examples

THE BUILDING	Interactive technology used	Role in Improving Building Performance
Al Bahar Tower – Abu Dhabi	**Mashrabiya smart moving facade**	**Reduce energy consumption by controlling shading and natural cooling**
The Crystal – London	**Intelligent energy and water management systems**	**Improve efficiency and environmental sustainability through user interaction**
Media-TIC – Barcelona	**Interactive facade that controls lighting and temperature**	**Reduces the need for air conditioning and artificial lighting, which reduces energy consumption**
Galleria Center city – South Korea	**Interactive LED facade**	**Provides a dynamic digital communication tool and improves visual interaction**
Pavilion Zero – Expo Milan	**Virtual reality and augmented reality**	**Creates an interactive educational and awareness experience for visitors about sustainability**
The Green Void – Sydney	**Smart lighting based on visitor movement**	**Improves the user experience and reduces waste in electricity consumption**
Kiefer Technic Showroom – Austria	**Dynamic moving facade**	**Improves thermal insulation and reduces the need for industrial heating and cooling**
The Shed – New York	**Moving structure based on smart robots**	**Changes the building configuration to accommodate different events with high flexibility**

These examples illustrate how modern technologies can make architecture more efficient and dynamic.

- Interactive technology helps improve sustainability, reduce energy consumption
- Enhance user experience within buildings.
- Contributes to creating a smart environment that is responsive to climate change and user needs.
- Interactive technology makes it possible to design smarter, more efficient, and more sustainable buildings through 3D printing, artificial intelligence, virtual reality, and interactive interfaces, buildings interact with the environment and users in unprecedented ways
- maximizing resource utilization and enhancing human comfort.

As technology continues to advance, we can expect to see more innovations that will redefine design and construction, making architecture more flexible, sustainable, and integrating with the needs of users and society.

Result

Interactive architecture seeks to design structures that can accommodate shifting needs and unforeseen future circumstances that conventional architecture is unable to handle. To attain greater comprehensiveness, it entails communication between architecture and both people and the environment. Incorporating diverse aesthetic values that enhance the sensory experience with elements that enhance the user experience of space and everyday life is the aim. Applications of interactive architecture combine technical and physical elements to create creative, affordable, and adaptable design.

- Technology has become an essential part of the architectural design and implementation process.
- Achieving greater sustainability and greater efficiency in resource and energy consumption.
- Evolving the user experience with architecture through artificial intelligence and digital interaction.
- Paving the way towards smarter and future-proof buildings and cities.

Recommendations

1- Encouraging the use of advanced technology in design and construction:

- Encouraging architects and designers to integrate artificial intelligence and

generative design to improve project efficiency.
- Expanding the use of 3D printing in construction to reduce costs and reduce waste.

2- Developing standards and legislation that support interactive architecture:
- Enacting laws and legislation that encourage the adoption of smart materials and interactive technologies in buildings.
- Setting new environmental standards for buildings that use artificial intelligence and the Internet of Things.

3- Encouraging research and development in the field of architectural technology:
- Supporting research projects that study the impact of technology on the efficiency and sustainability of buildings.
- Providing government and private funding to develop smart and sustainable buildings that use the latest technologies.

4- Encouraging the use of virtual and augmented reality technologies in the design and construction stages:
- Integrating VR and AR technologies into the design process to provide an accurate visualization of buildings before implementation.
- Use these technologies in training workers and engineers to improve implementation efficiency.

5- Developing more sustainable and intelligent building systems:
- Expanding research into the use of renewable energy within buildings through artificial intelligence.
- Developing smart energy management systems, ventilation and air conditioning to increase environmental efficiency.

6- Enhancing education and training in the field of interactive architecture:
- Updating academic curricula in architecture colleges to include smart technologies.
- Providing specialized training courses in interactive design, 3D printing, and the Internet of Things.

7- Launching pilot projects to apply interactive technology:
- Implementing pilot smart building projects to study the impact of interactive technology on environmental and economic performance.
- Expanding the construction of smart cities based on artificial intelligence and the Internet of Things technologies.

8- Enhancing cooperation between different sectors:
- Encouraging cooperation between the public and private sectors and universities to develop smart architectural solutions.
- Enhancing partnerships with technology companies to accelerate the adoption of digital solutions in construction.

Summary of recommendations:

- Focus on technological innovation to improve the quality and efficiency of buildings.
- Enhancing sustainability through smart materials and environmentally friendly technologies.
- Using virtual reality and artificial intelligence in design, training, and implementation.
- Foster collaboration between architects, developers, and decision makers to encourage interactive architecture.

Reference

1. https://www.architecture.com/knowledge-and-resources
2. https://www.uia-architectes.org/en/
3. https://iaac.net/research-departments/?_gl=1*1icj66m*_up*MQ..*_gs*MQ..*_ga*MTcxNjcxMDQ2NS4xNzQxNDYwMDUw&gclid=EAIaIQobChMI7qCIwpT7iwMVpwUGAB1lmiUvEAAYAyAAEgLK3fD_BwE
4. https://smartcitiescouncil.com/
5. https://www.ahr.co.uk/projects/al-bahr-towers
6. Smith, J. (2019). "The Impact of Smart Building Technologies on Energy Efficiency". *Journal of Architectural Science Review*.
7. Leach, N. (2021). *Artificial Intelligence in Architecture: Generative Design and Digital Manufacturing*. Wiley.
8. Fuchs, P. (2018). *Virtual Reality and Augmented Reality in Architecture and Design*. CRC Press.
9. Johnson, M. (2022). "Interactive Façades: The Future of Sustainable Architecture". *Automation in Construction*.
10. https://www.archdaily.com/270592/al-bahar-towers-responsive-facade-aedas
11. https://wilkinsoneyre.com/projects/the-crystal

12. https://www.archdaily.com/49150/media-tic-enric-ruiz-geli
13. https://www.archdaily.com/125125/galleria-centercity-unstudio
14. https://archello.com/project/pavilion-zero-expo-2015
15. https://www.archdaily.com/10233/green-void-lava
16. https://www.archdaily.com/89270/kiefer-technic-showroom-ernst-giselbrecht-partner
17. https://www.archdaily.com/914639/the-shed-a-center-for-the-arts-diller-scofidio-plus-renfro
18. Williams, S. (2020). *3D Printing in Architecture, Engineering and Construction.* Springer.
19. Menges, A., & Aish, R. (2017). *Material Systems for Architecture.* Routledge.