

KINETIC FACADES AND SMART BUILDINGS IN ARCHITECTURE

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Keywords

Article History

Received: 17 June 2025

Accepted: 27 August 2025

Published: 09 September 2025

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Abstract

Kinetic facades and smart building technologies are pioneering a transformative shift in modern architecture by fostering sustainability, energy efficiency, and enhanced occupant comfort. Kinetic facades, with their adaptive, movable elements, dynamically respond to environmental factors such as sunlight and temperature to optimize indoor conditions, reduce energy use, and create engaging aesthetic experiences. Smart buildings leverage advanced sensors, IoT, and automated systems to enable data-driven design, energy management, security, and maintenance, resulting in responsive and sustainable built environments. Together, these innovations redefine buildings as interactive, evolving systems that harmonize architectural beauty with environmental responsibility and human well-being, meeting the complex demands of the 21st century.



INTRODUCTION

Buildings have traditionally been static structures, resulting in limited adaptive capacity to respond to changing environmental conditions and occupant needs. Kinetic facades introduce movement and adaptability into the building envelope, dynamically adjusting geometry or material properties to optimize environmental performance such as daylight access, solar shading, and natural ventilation. Parallely, smart buildings utilize sensor networks, automation, and data analytics to actively control building systems for energy efficiency and occupant comfort. The integration of kinetic facades with smart building technologies marks a transformative paradigm in architectural design, merging aesthetics, sustainability, and intelligent responsiveness. This paper explores the state of research in kinetic facades and smart buildings, assessing their mechanisms, materials, environmental impacts, and future potentials.

Literature Review

Research on kinetic facades has emphasized the significance of material characteristics and transformation strategies to enable precise and energy-efficient façade motion. Mekhamar and Hussein (2021) elaborate on how the nature of components—whether rigid, flexible, or smart materials—affects possible motion patterns such as folding, sliding, rotation, scaling, or deformation. Several case studies demonstrate kinetic façades' capability to reduce solar gain and enhance visual comfort, such as the Al Bahar Towers' origami-inspired shading system.

Smart buildings research outlines how automation and sensor data integration allow dynamic control over building systems, including facades, lighting, and HVAC, optimizing operational efficiency and occupant wellbeing. There is growing focus on integrating AI to enhance predictive adaptation and system autonomy. The synergistic use of kinetic

facades within smart buildings offers a holistic approach to responsive architecture, leveraging real-time environmental data to modify façade behavior. Studies also discuss limitations including high initial costs, technological complexity, and maintenance challenges, highlighting a need for multidisciplinary design frameworks and resilient materials to enhance kinetic façade viability.

Aims and Objectives

The main aim of this research is to provide a comprehensive understanding of kinetic facades and smart building technologies as integrated systems for enhancing building performance and sustainability. Specific objectives include:

- Investigate the material properties and transformation mechanisms underpinning kinetic façade functionality
- Analyze environmental and energy performance impacts of kinetic facades in building applications
- Evaluate technologies and control strategies employed in smart buildings interfacing with kinetic façade systems

- Identify challenges and opportunities for future research and practical implementations.

Research Methodology

This study adopts a qualitative research methodology primarily based on an extensive literature review of peer-reviewed journal articles, conference papers, and case studies focused on kinetic facades and smart building design.

Data was gathered from academic databases and specialized architecture publications to capture recent advancements across materials science, mechanical design, automation, and environmental performance. Comparative analysis of different kinetic façade systems was conducted to understand functional relationships between material characteristics, transformation strategies, and energy outcomes. Additionally, smart building automation technologies were reviewed to assess sensor integration and control algorithms that drive kinetic façade responsiveness.

There are significant insights available regarding kinetic facades and smart buildings in the context of architecture in Lahore from various case studies and research:

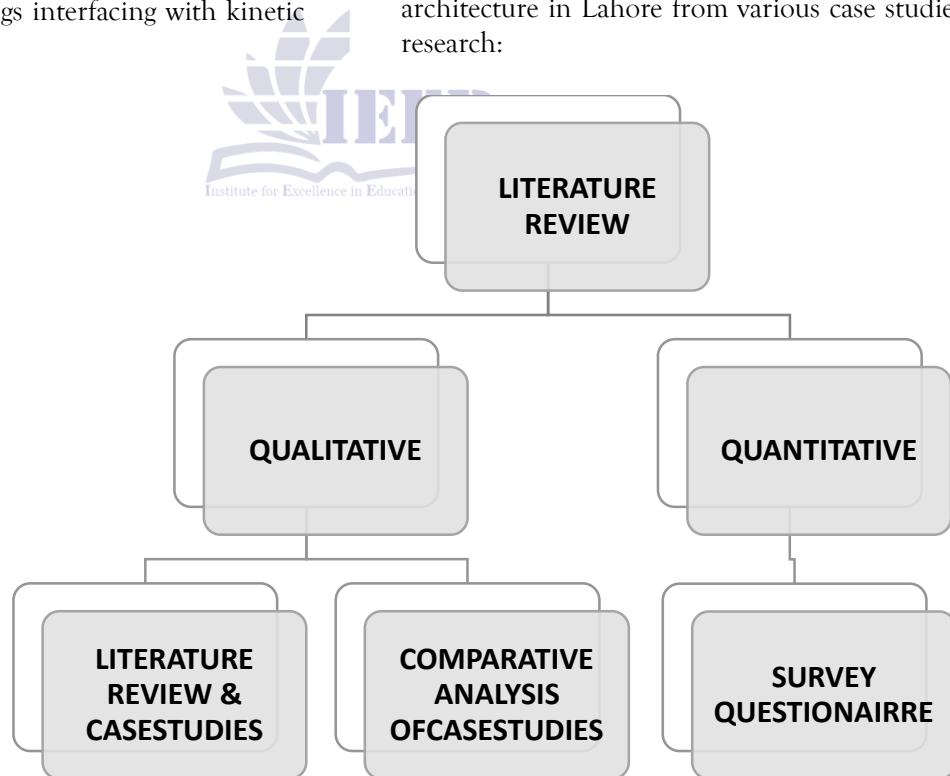


Figure:1 Relationship Diagram of Research Methodology applied in Research

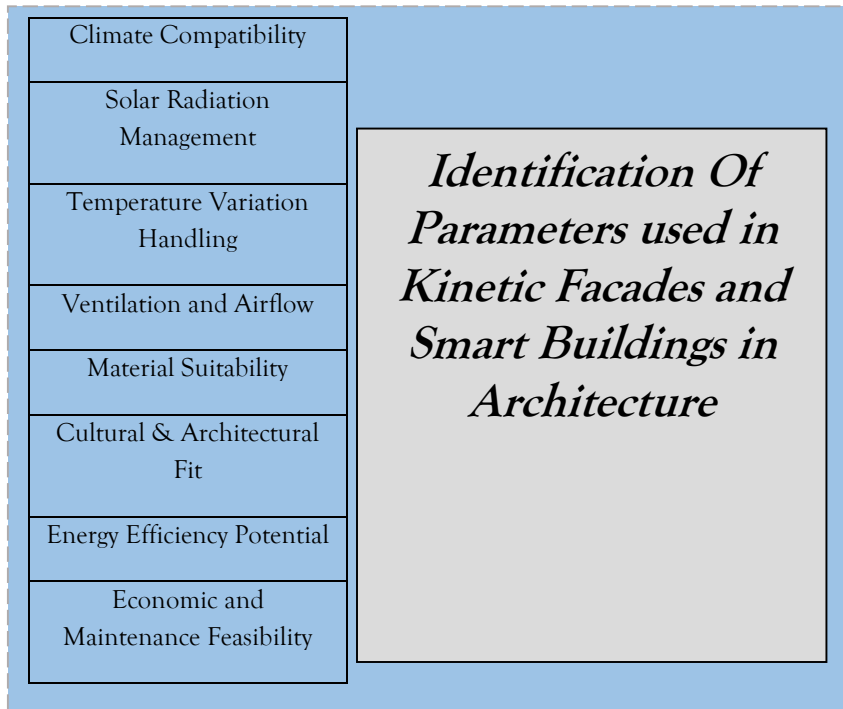


Figure:2 Relationship Diagram of Research Methodology applied Research

Kinetic Facades

Kinetic facades are dynamic architectural elements that respond to environmental stimuli like sunlight, heat, and air flow. They enhance energy efficiency, thermal comfort, and the overall user experience by adjusting in real-time to external conditions.

Case studies highlight applications of kinetic facades that reduce heating and cooling costs by up to 50%, improve lighting quality, and reduce HVAC loads by at least 30%. Materials like shape memory alloys and polymers are often used for their adaptability and cost-effectiveness. Though kinetically adaptive facades are more commonly applied in large-scale or multi-storey buildings for cost efficiency, their integration with renewable energy technologies like photovoltaic cells offers additional sustainability benefits. While effectiveness is proven in places like Gurugram (India), similar principles could be adapted to Lahore’s climate with local material availability challenges and economic factors considered.

Smart Buildings in Lahore

The use of smart materials and technologies in Lahore's architecture is emerging but currently limited, with high costs and material availability being key barriers. Smart buildings integrate sensors and IoT-driven building management systems to optimize energy use, maintenance, and occupant comfort.

Case studies in Lahore focus on energy-efficient commercial buildings that adopt passive design strategies, daylight utilization, efficient HVAC systems, and smart technology integration. There is emphasis on adapting global best practices in smart building technologies to Lahore's unique climate and urban conditions to improve sustainability and efficiency.

Examples from research discuss self-diagnostic materials, adaptive facades, and smart management systems improving the resilience and performance of buildings in Lahore's challenging environmental conditions.

Local Case Study Highlights

Research papers on smart materials application cite the need for responsive materials in Lahore's architecture for enhanced sustainability.

Commercial building case studies in Lahore emphasize the integration of smart technologies alongside traditional and modern materials to reduce carbon footprint and improve occupant well-being. Overall, kinetic facades and smart building technologies present promising pathways for sustainable architecture in Lahore with ongoing research and pilot projects demonstrating their effectiveness and challenges in local contexts.

To conduct a comparative analysis of the three kinetic facade and smart building case studies based on Lahore's atmospheric and climatic conditions, it is important to first outline Lahore's specific climate characteristics and then evaluate the case studies according to those criteria.

Lahore's Climatic and Atmospheric Conditions

Lahore has a hot semi-arid climate with significant temperature variations: average temperatures reaching around 34°C (June) and dropping to about 13°C (January).

- Summers are intensely hot with frequent heatwaves (temperatures can exceed 45°C).
- Winters are mild to cool with notable diurnal temperature variation.
- Prevailing winds come from the west, important for natural ventilation.
- The city experiences strong solar radiation, requiring effective shading and heat management.
- Urban heat island effect is significant due to built-up areas and reduced vegetation.

Traditional architectural responses include use of light-colored materials, shading devices such as stone screens, orientation for solar control, and central courtyards to facilitate ventilation and cooling microclimates.

Al Bahr Towers (Abu Dhabi)

The Al Bahr Towers in Abu Dhabi are a pair of iconic skyscrapers known for their innovative and sustainable architectural design. Designed by AEDAS Architects and constructed between 2009 and 2012,

the towers each stand around 145-165 meters tall with 26-29 floors mainly used for office spaces. The standout feature of the towers is their adaptive facade system inspired by the traditional Islamic mashrabiya wooden screens. This dynamic facade automatically adjusts in response to the sun's movement to reduce solar heat gain significantly, cutting energy consumption by about 50% and reducing CO2 emissions by approximately 1,750 tonnes annually. The facade consists of over 2,000 geometric shading panels that open and close throughout the day, providing shade while allowing natural daylight to penetrate. The project has won several awards including the 2012 Council for Tall Buildings & Urban Habitat Innovation Award and the LEED Silver rating, symbolizing a blend of cultural heritage and cutting-edge technology for sustainability in a desert climate.

Location and Physical Description

- Situated in the financial center of Abu Dhabi, UAE.
- Each tower is about 145-165 meters tall, with 26 to 29 floors.
- Architectural and Sustainable Design
- Adaptive facade inspired by traditional mashrabiya screens.
- Over 2,000 computer-controlled shading panels reduce solar gain by over 50%.
- Reduces energy consumption and CO2 emissions substantially.
- Recognized as one of the "25 best inventions of the year" in 2012.

Engineering and Innovation

The facade's kinetic system was a major engineering challenge, requiring advanced programming and durable materials suited for harsh desert conditions. The design promotes natural daylighting while minimizing air conditioning needs.

Cultural Impact

The mashrabiya design honors Islamic architectural traditions, integrating heritage with modern technology.

The towers contribute to Abu Dhabi's identity as a city blending tradition with innovation.

Awards and Recognition

2012 CTBUH Innovation Award.
LEED Silver rating.

Featured among innovative tall buildings globally.

The Al Bahr Towers stand as a landmark of sustainable and intelligent design, illustrating how biomimicry and cultural elements can drive energy-efficient architecture in hot climates as shown in figure 1



Figure 3: Mashrabiya Design



Figure 4: Diagram of Glass & Mashrabiya Wooden Screen Design

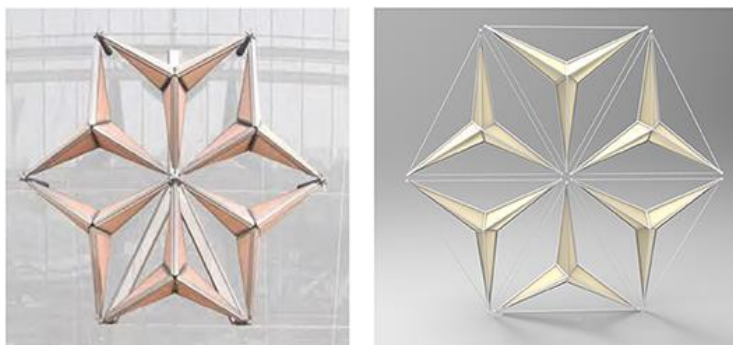


Figure 5: Module Wooden Screen Design

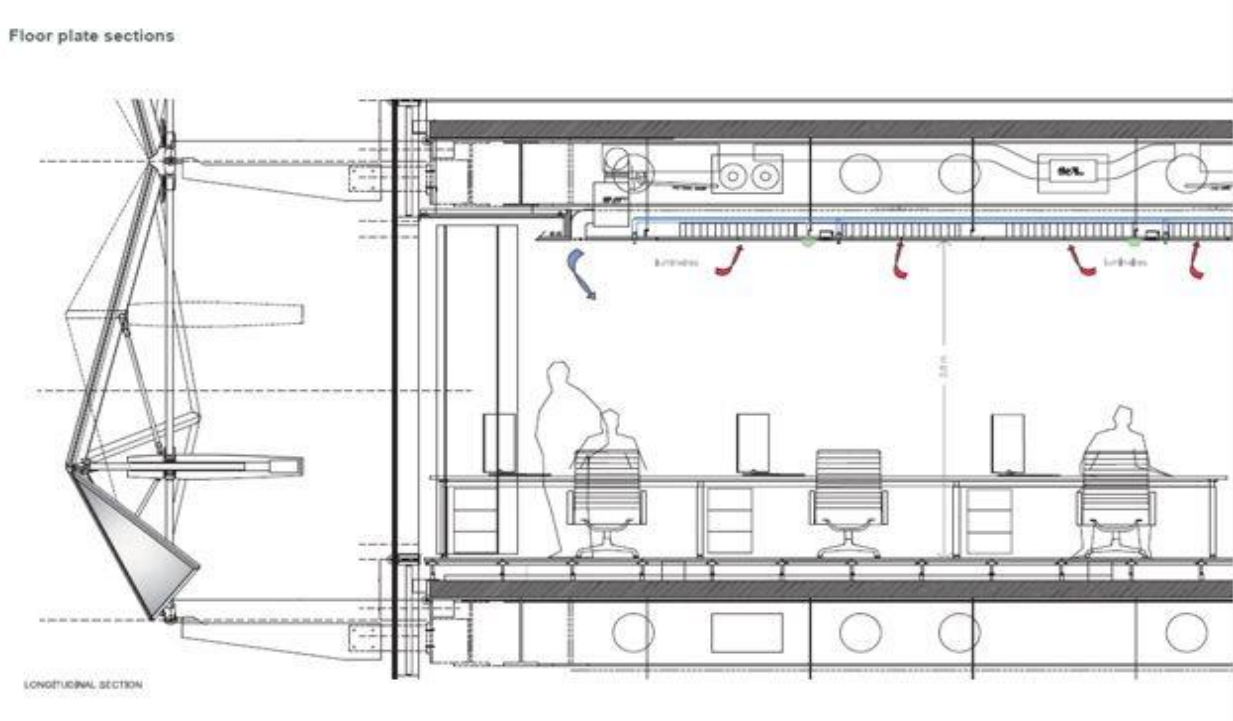


Figure 6: Module Sectional Design Wooden Screen Design

Gurugram Kinetic Fins (India)

Gurugram (Gurgaon), India, has seen innovative use of kinetic facades with kinetic fins that dynamically respond to environmental conditions, especially solar movement. These facades, designed primarily for multilevel office buildings, move throughout the day to control direct solar heat gain and reduce glare, improving thermal comfort and daylight distribution inside buildings.



Figure 7: Wooden Screen Fins Design

The kinetic fins act as a second skin that adjusts hourly based on the sun's position to protect interiors while maintaining balanced lighting.

Research and case studies on Gurugram's kinetic facades show they significantly reduce HVAC loads (by at least 30%) and enhance occupant comfort, making them particularly suitable for office environments where people spend extended hours. The materials used include both traditional and advanced options like shape memory alloys and polymers, which can reduce dead load and maintenance costs.

However, challenges include higher maintenance if inappropriate materials or low-tech solutions are used, and the technology is better suited to larger-scale projects due to complexity and cost. Recommendations emphasize lightweight, durable materials, smart automation with manual override options, and thoughtful placement of kinetic facades based on solar exposure analysis. Overall, kinetic facades in Gurugram represent a promising sustainable architectural solution that enhances energy efficiency and occupant comfort while accommodating the climatic context of the region.

This dynamic facade approach marks a step toward more adaptable, energy-conscious, and user-friendly

The case study of Gurugram (formerly Gurgaon), India, reveals a complex urban development story marked by rapid growth driven primarily by private sector-led real estate and corporate investments but domestically challenged by inadequate public infrastructure and planning.



Figure 8: Kinetic Fins Design

Development History

Gurgaon started as a cluster of villages in the 1970s and transformed into a major satellite city near Delhi. The Haryana government relaxed land laws in the 1970s to enable private developers to acquire farmland and build townships. Private players like DLF and Raheja spearheaded residential and commercial development, imagining the city as prosperous gated enclaves and office hubs. By the 2010s, Gurugram became an IT and corporate hub housing the Indian headquarters of many multinational companies, including Google, Microsoft, and American Express, earning the nickname "Singapore of India." The population grew from about 121,000 in 1991 to around 2.4 million by the mid-2020s.

Urban Design and Infrastructure Challenges The city's growth lacked comprehensive government urban planning and infrastructure.

buildings in India's rapidly urbanizing commercial hubs.

There was little to no municipal authority involvement until 2008, leading to fragmented development. Public services such as sewage, water supply, power, and public transportation are severely lacking or poorly maintained.

Only about one-third of the city is connected to official sewage systems; treatment plants perform poorly. Roads, drainage, and traffic planning have been insufficient, frequently resulting in floods and traffic congestion. The Rapid Metro rail system was privately financed to improve connectivity but remains limited in scope.

Social and Environmental Issues

Rapid privatized growth ignored the need for public amenities like hospitals, affordable housing, and public transport. There is growing water scarcity due to over-extraction and competition with peri-urban and rural areas. Urban flooding has become a recurrent problem because of poor drainage systems and encroachments on natural watercourses. The city also suffers from environmental degradation, including groundwater depletion and poor waste management.

Lessons and Criticism

Gurgaon's model shows the failure of relying heavily on private capital without strong state urban planning and public investment. Experts warn that the absence of integration between public and private sectors leads to unsustainable urban living conditions. The city exemplifies the limits of privatized urbanization where market-driven real estate development leaves critical infrastructure gaps unaddressed. Policymakers face pressure to rethink urban governance combining public planning with private sector capabilities more effectively.

This case study of Gurugram highlights the tensions between rapid economic growth and the urgent need for sustainable urban infrastructure and governance reforms in India's emerging cities .

Comparative Analysis of the 3 Case Studies Against Lahore Climate

Criteria	Al Bahr Towers (Abu Dhabi)	Gurugram Kinetic Fins (India)	Origami Responsive Skin (Lahore Concept)
Climate Compatibility	Hot arid but coastal; uses active shading for intense sun	Hot humid subtropical; addresses high solar exposure	Designed specifically for Lahore's hot semi-arid conditions
Solar Radiation Management	Responsive panels block high-angle summer sun, allow winter sun	Kinetic fins rotate to track and shade, manage glare and heat	Origami folds optimize shading and daylight, adaptable to solar angles
Temperature Variation Handling	Dynamic shading adapts to diurnal cycle	Reduces heat gain, balances cooling load during day/night	Incorporates shading and ventilation to reduce heat buildup
Ventilation and Airflow	Moderate ventilation with shading	Enhanced daylight and airflow through fin design	Emphasizes permeability and airflow, consistent with Lahore's prevailing winds
Material Suitability	Advanced composites suited for desert environment	Combines shape memory alloys with polymers for durability	Integrates flexible, locally adaptable materials for Lahore's economy and climate
Cultural & Architectural Fit	Modern Islamic inspired mashrabiya design	Practical commercial application of kinetic facades	Inspired by traditional origami and screens, sensitive to local architecture
Energy Efficiency Potential	High; significant cooling load reduction	Moderate to high; HVAC load cut by approx. 30%	Conceptual but promising; aligned with Lahore's passive cooling methods
Economic and Maintenance Feasibility	High maintenance and cost, justified by large-scale use	Balance between cost/benefit for commercial buildings	Designed to be cost-effective with local materials and simpler systems

Al Bahr Towers features highly sophisticated kinetic shading that matches hot sunny climates but may be costly and complex for Lahore's economic context. Gurugram's kinetic fins offer a practical, middle-

ground solution balancing cost and performance, relevant for Lahore's hot, sunny days, but they need adaptation to Lahore's stronger diurnal variation and wind patterns.

Lahore’s origami responsive skin concept leverages traditional design principles such as shading, ventilation, and adaptiveness in a way that is culturally respectful and climatically effective specifically for Lahore’s hot semi-arid conditions, showing the greatest potential for local integration. This analysis emphasizes that the best kinetic facade and smart building strategies for Lahore incorporate adaptive shading responsive to solar angles, natural ventilation exploiting prevailing winds, low-cost and locally available materials, and architectural continuity with regional heritage.

To address the query specifically for kinetic facades and smart buildings in architecture with conclusions and strategies tailored for Lahore's atmosphere, it is essential to contextualize the technology with Lahore's climate, which is characterized by a hot semi-arid climate with extreme temperature variations, high solar radiation, and seasonal humidity.

To provide sketches with reference to the discussion on kinetic facades and smart buildings for Lahore's climate, the best approach is to visually represent the concepts like adaptive shading, movable panels, smart

sensor integration, and traditional-modern material blending. Based on typical architectural features seen in kinetic facade projects and tailored for Lahore's hot and dusty climate, here are key sketch elements to conceptualize:

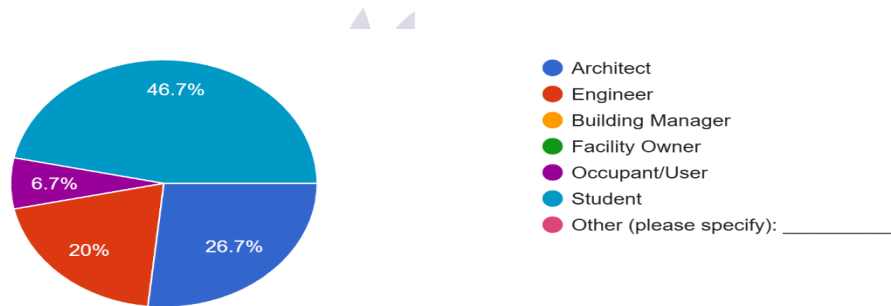
- Exterior building elevation with moveable solar shading panels or louvers that can open/close dynamically for shading and ventilation.
- Integration of traditional architectural elements like lattice screens (jali/mashrabiya) combined with kinetic mechanisms.
- Diagrams showing smart sensors wired to facade panels enabling automated climate response.
- Sketch detail of facade sections indicating photovoltaic panels integration on kinetic elements.
- Interior diagram showing natural light optimization and thermal comfort achieved through the dynamic facade.
- Here are synthesized conclusions and strategies based on the latest research and architectural insights:

Conclusions on Kinetic Facades and Smart Buildings for Lahore

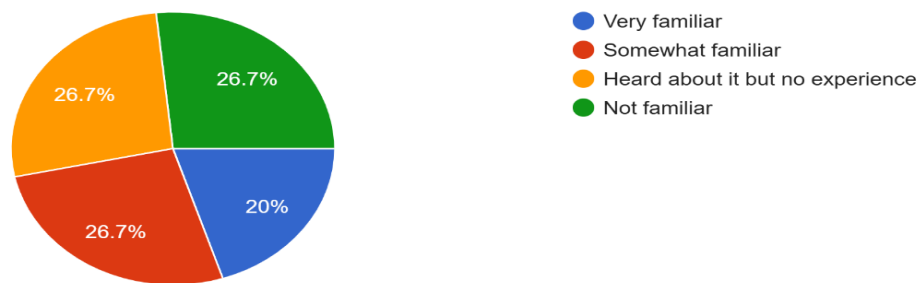
<p>Adaptive Response</p> <p>Environmental</p>	<p>Kinetic facades offer dynamic adaptability to environmental conditions such as solar radiation, temperature fluctuations, and humidity. This adaptability can help mitigate Lahore's intense heat, strong sunlight, and dust storms effectively by adjusting shading and ventilation automatically. This reduces energy consumption for cooling and improves indoor comfort.</p>
<p>Energy Efficiency and Thermal Comfort:</p>	<p>By regulating solar heat gain and enabling natural ventilation, kinetic facades reduce reliance on mechanical cooling systems, leading to significant energy savings. In hot climates like Lahore's, automated shading and ventilation systems can lower peak indoor temperatures and maintain thermal comfort throughout the day</p>

<p>Integration of Smart Technologies:</p>	<p>Smart buildings with sensor-based kinetic facades can optimize building performance by monitoring outdoor environmental variables and occupant needs in real time. This facilitates proactive adjustments in facade configurations such as modulating transparency, opening or closing louvers, and controlling airflow for optimal daylighting and thermal regulation.</p>
<p>Cultural and Aesthetic Harmonization:</p>	<p>Kinetic facade designs can incorporate traditional architectural elements of the region (like mashrabiya or jali) combined with modern technology to respect cultural heritage while addressing climatic challenges, enhancing both aesthetics and performance .</p>

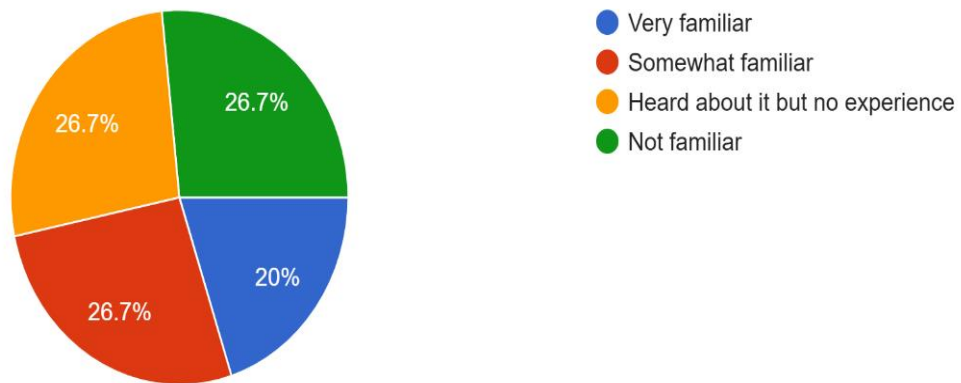
Survey Questionnaire
 Kinetic Facades and Smart Buildings in Architecture
 What is your profession?



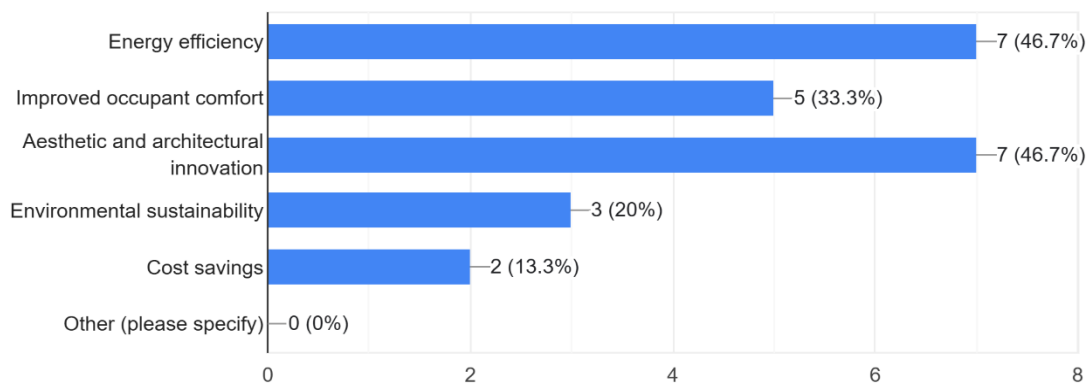
Section 2: Perceptions and Benefits
 How familiar are you with kinetic facade technology?



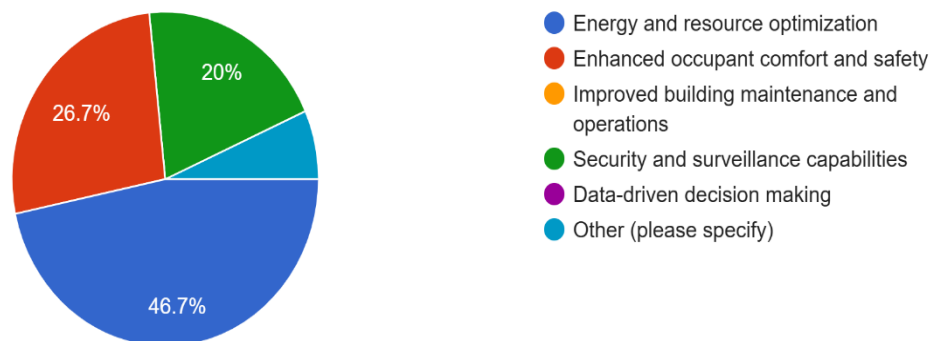
How familiar are you with smart building technologies?



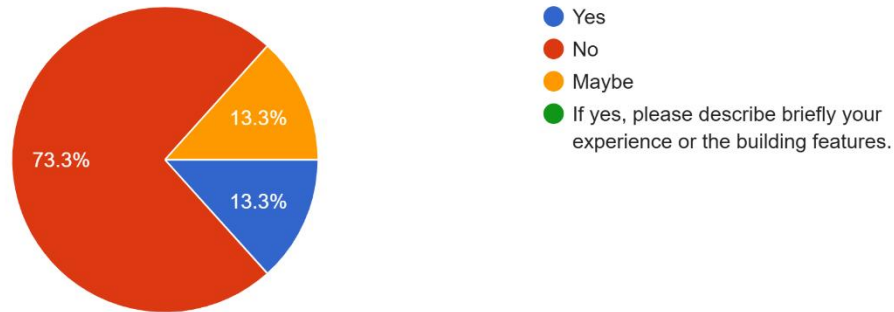
In your opinion, what are the most important benefits of kinetic facades? (Select all that apply)



What benefits do you associate most with smart building technologies? (Select all that apply)

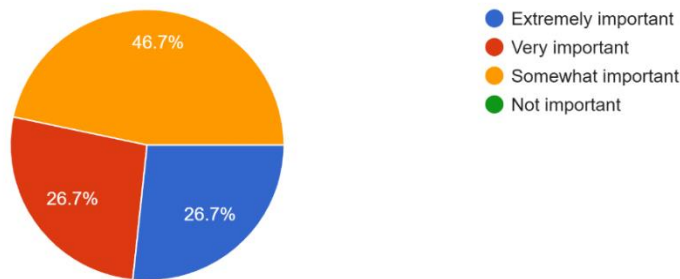


Have you experienced or worked on a building that incorporates either kinetic facades or smart building systems?

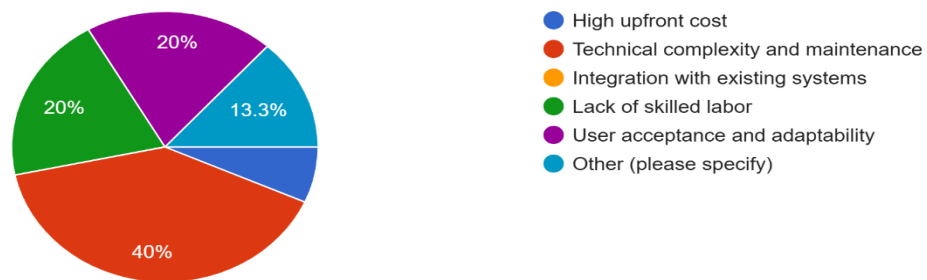


Integration and Functionality

How important do you believe the integration of kinetic facades with smart building systems is for future architecture?

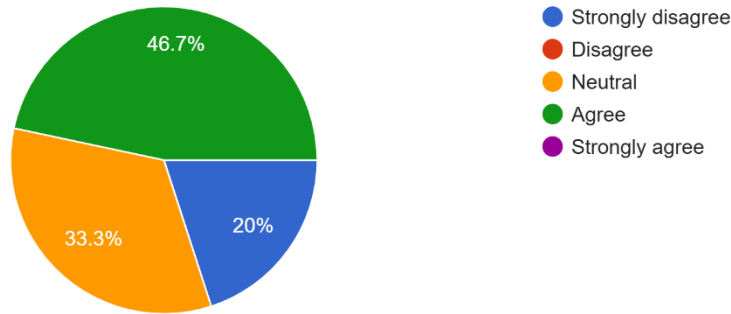


What are the key challenges you foresee or have encountered in implementing kinetic facades? (Select all that apply)

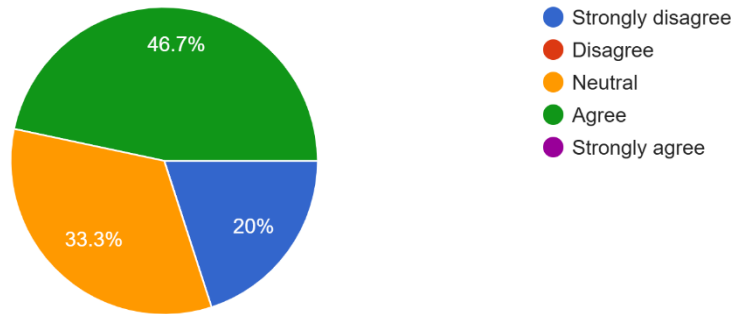


Section 4: Sustainability and Future Trends

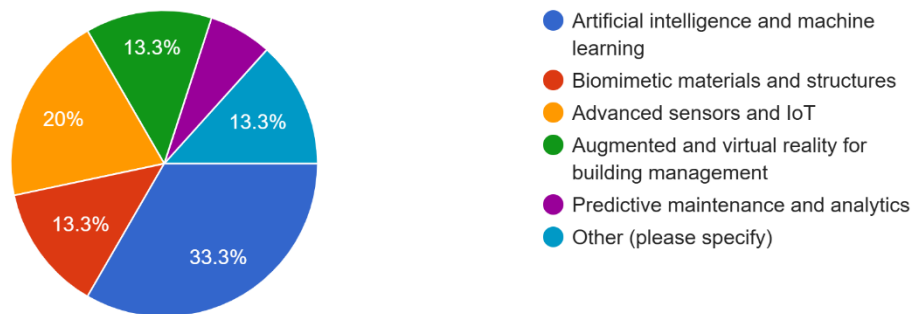
To what extent do you agree that kinetic facades contribute significantly to sustainable architecture?



To what extent do you agree that smart buildings will play a critical role in reducing carbon footprints and environmental impact?



Which emerging technologies do you believe will most impact the future of kinetic facades and smart buildings? (Select up to 3)



What additional features or capabilities would you like to see in kinetic facades or smart buildings in the future?

Section 5: Final Thoughts

What is your overall opinion about the role of kinetic facades and smart buildings in shaping the future of architecture?

In the future, kinetic facades have the potential to evolve beyond merely providing shading and ventilation to become active systems that harvest energy from sunlight, wind, or their own movements,

enhancing a building's sustainability. Powered by AI-driven controls that adapt in real time to user behavior, weather, and energy demand, these facades could optimize energy use while ensuring comfort. While challenges such as maintenance costs, material selection, and technology acceptance remain, the integration of smart energy optimization and disaster alerting technologies shows promise. An ideal future would see kinetic facades that also respond to air quality and noise, contributing to healthier urban environments. Overall, combining renewable energy generation with intelligent AI control could revolutionize building design, making structures more adaptive, efficient, and comfortable.

Please share any examples, case studies, or experiences that highlight effective use of kinetic facades or smart building systems.

(International or Local you have personally experienced)

Al Bahar Towers in Abu Dhabi feature an innovative kinetic facade inspired by the traditional mashrabiya, consisting of over 1,000 umbrella-like panels that dynamically open and close in response to the sun's movement. This responsive shading system reduces solar heat gain by more than 50%, significantly lowering cooling demands while maintaining comfort and celebrating cultural aesthetics. Kinetic structures like this not only enhance the futuristic appeal of buildings but also show promise in protecting electronic devices and appliances inside homes. Although the aesthetic and functional benefits are clear, considerations around maintenance and cost remain important. Overall, such advanced facade systems represent a vital step forward in architectural design, combining physics, material science, and cultural sensitivity to shape the future of the industry.

Strategies for Implementing Kinetic Facades and Smart Buildings in Lahore

Climate-Responsive Design: Facades should be designed with moveable solar shading devices that respond dynamically to harsh sunlight and dust storms typical of Lahore. This includes automated screens or panels that open during mild weather and close during peak heat or dust events to protect and ventilate the building efficiently.

Smart Sensor Integration: Utilize IoT sensors to monitor temperature, humidity, solar radiation, and indoor air quality. These sensors should control kinetic facade elements in real time for optimized energy use, indoor environmental quality, and occupant comfort.

Use of Local Materials and Forms: Combine kinetic technology with traditional materials and forms that naturally reflect or absorb less heat. This synergy can enhance sustainability and reduce the carbon footprint of buildings.

Energy Generation and Efficiency: Incorporate photovoltaic elements into kinetic facades where possible to generate renewable energy. This helps offset the building's energy demands, particularly for cooling, which is high in Lahore's hot climate.

Phased Implementation: Start with pilot projects in residential and commercial sectors to adapt kinetic facade technologies to local climatic and cultural conditions, refine the designs, and prove energy and comfort benefits for wider adoption.

In summary, kinetic facades and smart buildings in Lahore must prioritize dynamic environmental adaptation, energy efficiency, occupant comfort, and cultural integration, leveraging smart sensor technologies and responsive architectural elements to address the city's hot and variable climate effectively.

Discussion

Kinetic facades represent a fusion of architectural design and engineering principles optimized through material innovation and movement strategies. Materials range from lightweight metals to smart composites that morph in response to environmental stimuli. Transformation strategies such as folding, sliding, rotation, and scaling are chosen based on climatic conditions and desired functional outcomes. For instance, folding kinetic facades employing actuator-driven steel panels provide controlled shading and daylight management efficiently.

Integration with smart building systems enhances these dynamic facades by enabling real-time adaptive control based on sensor feedback (temperature, sunlight, occupancy). This synergy supports energy savings by reducing artificial lighting and cooling loads. However, high initial costs and maintenance requirements remain barriers to widespread adoption. Longevity of moving components and complexity of

control systems call for improved design frameworks and resilient material solutions.

Future directions include adopting AI-based predictive algorithms for façade motion, developing energy-autonomous actuators, and expanding use of 3D-printed kinetic components customized for performance and aesthetics. Multiparametric design tools combining environmental data with user preferences will further refine adaptive façade responsiveness.

Conclusion

Kinetic facades, combined with smart building automation, embody next-generation architecture that adapts dynamically to environmental and occupant needs. These systems contribute significantly to energy efficiency, occupant comfort, and architectural expression. Optimizing kinetic façade design requires thorough understanding of material behaviors, transformation mechanisms, and automated control technologies. Addressing challenges related to cost, durability, and operational complexity will enable broader adoption. Ultimately, kinetic facades integrated within intelligent buildings promise sustainable, resilient, and aesthetically innovative environments aligned with global climate and energy goals.

Here is a list of references related to kinetic facades and smart buildings in architecture:

REFERENCES

- Mekhamar, A. A., & Hussein, A. H. (2021). Kinetic Facades: How Nature of Components Affects the Applications of Different Transformation Strategies. *Engineering Research Journal*, 170, A11-A25. This paper discusses the role of materials and their characteristics in kinetic façade applications and transformation strategies.
- Sharaidin, K., & Salim, F. (2012). Design Considerations for Adopting Kinetic Facades in Building Practice. *eCAADe 30, Volume 2*. This research proposes a design framework for kinetic facades and evaluates effective design methods for kinetic façade integration and performance.

IRJET. Scope of Kinetic Architecture in India. A study on kinetic façade mechanisms, technology, and applications in tropical climates, analyzing sustainability and energy efficiency impacts.

ResearchPublish. Kinetic Façade as a Tool for Energy Efficiency. Discusses how dynamic devices in kinetic facades contribute to energy efficiency by adapting to changing conditions.

Tandfonline (2023). The impact of a kinetic façade on lighting performance and architectural preservation, proposing frameworks for kinetic system strategies.

ScienceDirect. Kinetic Facades: An Evolutionary-Based Performance Evaluation Framework. This study develops an integrated design and decision-making framework for kinetic facades.

HRPUB. Application of Kinetic Facades and Its Impact on Daylighting. Examines how kinetic facades adapt to climate to improve daylighting performance and thermal comfort.

IJE. Opportunities and Challenges of Implementing Kinetic Façade. A literature review of concepts, theories, and applications of kinetic facades in architecture.