



Theory article

Artificial intelligence (AI) in the architectural design of green buildings for smart cities

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Abstract: The integration of artificial intelligence (AI) in architecture heralds a transformative era characterized by enhanced operational efficiency and financial savings, yet it also presents significant challenges that could undermine core architectural principles. This paper critically assessed AI's impact on the architectural profession, focusing on the potential decline of human cognition, individuality in design, and the simplification of professional roles. It ultimately advocates for a balanced application of AI as a tool to enhance, rather than replace, human creativity and decision-making, ensuring that the richness of cultural and intellectual heritage in architecture is preserved. AI can serve as a powerful tool in the development of smart cities to enhance the architectural design of green buildings.

Keywords: artificial intelligence; smart cities; architectural design; intelligent urban planning; generative design; sustainability; predictive modeling; health impacts; green buildings

1. Introduction

The emergence of artificial intelligence (AI) within architecture and building design signifies a notable transformation in the methodologies employed for conceptualizing and constructing structures. AI presents numerous prospective advantages, encompassing improved efficiency, financial savings, and the capability to swiftly and accurately analyze extensive datasets. These advancements render AI a compelling instrument for contemporary architects and builders who are persistently seeking methods to optimize their workflows and to devise more sustainable, innovative, and effective designs. The advancement of technology in architecture, specifically through AI, presents notable challenges

alongside its benefits. An overreliance on AI may undermine architects' critical thinking, limit personal creativity, and transform them into mere functionaries of technology. This essay critically evaluates these concerns, emphasizing the need for a balance between technological innovation and human artistic input in architectural practices [1]. While AI streamlines design processes and enhances efficiency, it simultaneously threatens to diminish the essential human elements that contribute to unique architectural expression. Artificial intelligence is fundamentally altering the domains of architectural design and urban planning, serving as a pivotal element in the advancement of smart cities and sophisticated infrastructural systems. This investigation scrutinizes the mechanisms by which AI-driven instruments and algorithms refine spatial organization, energy efficacy, and ecological sustainability within contemporary urban landscapes. The integration of AI into the architectural decision-making process is facilitated through the utilization of data analytics, predictive modeling, and generative design, which collectively contribute to the formulation of responsive and environmentally attuned edifices [2]. The research delves into multifaceted applications of AI, including automated design optimization, real-time urban surveillance, and predictive maintenance, all of which enhance the efficiency and sustainability of constructed environments.

Artificial intelligence is fundamentally revolutionizing the fields of architecture and urban planning, signifying a significant shift in the methodologies employed for the design, development, and maintenance of urban spaces and structures. The swift progression of AI-enabled tools alongside data analytics has empowered architects and urban planners to enhance design productivity, advance sustainability, and improve the quality of life within urban settings [3]. AI technologies, including machine learning, generative design, and predictive analytics, have instituted innovative frameworks that surpass conventional architectural practices, thereby facilitating the creation of intelligent, adaptable, and resilient edifices. The concept of smart cities, which amalgamate AI with the Internet of Things (IoT) and extensive data utilization, has emerged as a central theme in modern urban planning, promoting sustainable growth and optimal resource management. These AI-driven advancements are transforming the built environment, resulting in designs that are not only visually sophisticated but also functionally effective, environmentally responsible, and attuned to the needs of inhabitants. The applications of AI in architecture encompass a broad spectrum of functionalities, ranging from real-time urban observation to automated construction methodologies. Generative design algorithms permit architects to investigate a multitude of potential building configurations based on defined constraints such as material availability, climatic effects, and spatial requirements. AI-enhanced simulations support data-informed decision-making, enabling architects to foresee and address environmental challenges, including energy consumption, carbon emissions, and urban heat phenomena. Moreover, AI plays a vital role in the establishment of predictive maintenance systems, which continuously assess the structural integrity of edifices and infrastructures, thus preempting failures before their occurrence. These technological advancements significantly bolster the durability and longevity of urban locales, ultimately fostering an enhanced quality of life for urban dwellers [4].

Notwithstanding these advancements, the integration of AI into architectural practice brings forth various challenges, including ethical considerations, concerns surrounding data privacy, and the imperative for human-AI collaboration in the creative process. While AI provides potent analytical and predictive capabilities, architectural design remains an inherently human-centric discipline that necessitates artistic insight, cultural awareness, and a comprehension of spatial aesthetics [5]. The growing dependence on AI within architecture raises critical questions regarding the equilibrium between automation and human creativity, necessitating deliberate engagement with technological

tools to uphold the integrity of architectural practices. Additionally, apprehensions regarding the ethical ramifications of AI-enabled urban surveillance and data acquisition necessitate the formulation of responsible and transparent governance frameworks for AI. Addressing these challenges is crucial to ensuring that AI-facilitated architectural innovations are in alignment with sustainable, ethical, and human-centered design principles. This study investigates the progressive role of AI in architectural evolution, with a specific emphasis on its implementation in smart cities and intelligent design. By analyzing the possibilities and constraints of AI-integrated methodologies, this research aspires to yield insights into how artificial intelligence is influencing the future trajectory of architecture. It discusses the implications of AI on sustainability, urban planning, and the creative process, while emphasizing the critical challenges that must be navigated to achieve responsible AI integration within the built environment. Ultimately, this study aims to highlight the significance of utilizing AI as a collaborative instrument that augments architectural creativity rather than supplanting human expertise [6].

2. Background

2.1. AI in architecture and urban planning

The incorporation of artificial intelligence into the fields of architecture and urban planning has been extensively examined across various academic disciplines, revealing its transformative influence on design methodologies, sustainability practices, and intelligent urban governance. Initial investigations into AI's application in architecture predominantly concentrated on computational design and parametric modeling, which empowered architects to automate monotonous tasks and produce intricate geometries with high accuracy. As advancements in AI technologies progressed, generative design surfaced as a significant innovation, allowing architects to investigate numerous design alternatives predicated on established constraints. Empirical studies have indicated that AI-augmented generative design not only maximizes space efficiency but also improves energy conservation and material sustainability. Scholars have emphasized that AI algorithms, especially those involving deep learning and reinforcement learning, enhance the creation of adaptive and self-optimizing structures that react to environmental and user-specific variables [7]. These investigations underscore that AI's capacity to analyze extensive datasets in real time plays a crucial role in rendering architecture more data-driven, sustainable, and functionally optimized. Within the framework of smart cities, AI has been thoroughly scrutinized for its contribution to urban planning, infrastructure management, and resource optimization. Academics contend that AI-driven predictive analytics and IoT-enabled monitoring frameworks have transformed urban governance by furnishing real-time insights into traffic patterns, energy usage, and ecological impacts. Research has illustrated that AI-enhanced simulations enable urban planners to evaluate various city configurations, analyze the efficacy of public transport systems, and simulate the repercussions of climate change on urban resilience. Furthermore, investigations into AI-enhanced building information modeling (BIM) reveal that AI plays a role in minimizing construction waste, accelerating project timelines, and reducing expenses. Numerous authors have examined the implications of AI for sustainable architecture, concentrating on how machine learning models can forecast energy consumption patterns and propose adaptive design methodologies. AI-facilitated climate-responsive architecture has been recognized as a promising strategy to diminish carbon footprints, optimize heating and cooling mechanisms, and integrate renewable energy sources within architectural designs [8].

Nevertheless, in spite of the promising prospects of AI in architecture, the existing literature also identifies significant challenges and limitations. Researchers have articulated ethical dilemmas concerning data privacy, algorithmic bias, and the excessive dependence on AI for decision-making within urban planning. Studies have warned that AI-driven surveillance in smart cities may result in concerns regarding mass data accumulation and privacy infringements, necessitating regulatory frameworks to ensure transparency and accountability. Additionally, some scholars postulate that although AI enhances operational efficiency, it could undermine the artistic and cultural dimensions of architecture if not judiciously integrated [9]. A persistent discourse exists regarding the extent to which AI-generated designs can authentically encapsulate human creativity and the cultural narratives inherent in architectural traditions. Several studies advocate for a hybrid methodology, wherein AI functions as a collaborative instrument rather than a substitute for human designers. This viewpoint aligns with research highlighting the necessity for architects to cultivate AI literacy, empowering them to engage critically with AI tools while maintaining the integrity of architectural practices. Overall, the literature provides a nuanced perspective on AI's transformative function in architecture, accentuating both its extensive potential and inherent challenges. While AI presents unparalleled opportunities for optimizing design, enhancing sustainability, and improving smart city operations, it also necessitates a conscientious approach to ethical issues and human-AI collaboration. The conclusions drawn from previous studies stress the importance of interdisciplinary research and policy formation to ensure that AI-driven architectural innovations adhere to sustainable, ethical, and human-centric design principles. As AI technology continues to advance, forthcoming research must concentrate on establishing frameworks that harmonize AI capabilities with architectural creativity while addressing the societal and ethical implications associated with AI-driven urban advancement.

2.2. The loss of human creativity in design

Architecture is a field that demands complex problem-solving and imaginative thinking. Creating buildings involves more than technical skills; it requires a deep awareness of spatial dynamics, visual appeal, and human requirements. In contrast, artificial intelligence (AI) often relies on existing datasets and programmed rules to produce designs. This approach can limit true innovation, as AI is confined by the scope of its training data and may struggle to conceive original or unconventional ideas [10]. Solving architectural problems is a multidimensional process that blends technical knowledge, artistic insight, and practical experience. Architects must consider factors like structural stability, usability, beauty, and occupant comfort. This intricate task calls for a thorough grasp of both theoretical concepts and real-world applications. Architects often rely on their personal histories, cultural influences, and creative intuition to devise unique solutions to design challenges. AI, however, is limited by its dependence on pre-set algorithms and data. While capable of producing designs based on defined criteria, AI lacks the intuitive understanding and creative flexibility that human architects bring. This can lead to designs that, though technically sound, may lack the originality and depth derived from human imagination.

Architecture is a discipline where creativity intertwines with technical expertise to shape the spaces we inhabit. It is an art form that demands not only precision but also imagination, cultural awareness, and a deep understanding of human needs. From the soaring arches of Gothic cathedrals to the minimalist elegance of modern eco-homes, architectural design reflects the unique vision of its creators and the societies they serve. The advent of artificial intelligence (AI) has transformed this

landscape, offering tools that accelerate design processes, optimize performance, and reduce costs. However, this technological leap comes with a significant risk: The erosion of human creativity in design. AI's reliance on algorithms and pre-existing data can produce standardized, predictable outputs, potentially stifling the originality, cultural resonance, and personal expression that define exceptional architecture. This work explores the impact of AI on architectural creativity, analyzing its limitations, the challenges it poses, and strategies to preserve the human spark that drives innovative design. By examining these dynamics, it aims to chart a path where AI enhances, rather than supplants, the creative essence of architecture [11,12].

2.3. AI's reliance on pre-existing data

AI systems are built using vast datasets that form the basis for their design outputs. While this data-driven method can be highly effective, it also imposes significant restrictions. AI is bound by the quality and range of its training data, meaning it can only work within those limits. This reliance can stifle innovation, as AI tends to reproduce familiar design patterns rather than pioneering fresh concepts.

Moreover, AI's dependence on data can lead to a uniformity in design outcomes. When trained on similar datasets, AI systems may generate nearly identical results, reducing variety and creativity in architecture. This trend toward standardization poses a challenge in a field where uniqueness and originality are highly prized. As AI becomes more integrated into architecture, there is a risk that architects may shift from being active designers to mere overseers of technology. This change could weaken the critical thinking and problem-solving skills central to the profession. Overreliance on AI-generated designs might diminish architects' ability to think creatively and develop independent solutions. Additionally, the growing use of AI could lead to a decline in professional skills. As AI takes on more design tasks, architects may lose proficiency in essential technical and creative abilities, becoming increasingly dependent on technology. This erosion of expertise could have long-term consequences for the architectural field [13].

Architecture has long been a medium for personal and artistic expression. Each architect brings a unique perspective, shaped by their experiences and cultural background, which gives their work distinct character and meaning. AI, however, cannot replicate these personal nuances. While it can produce functional and visually appealing designs, they often lack the individuality that distinguishes human-created architecture. Architecture is more than constructing buildings; it is about crafting spaces that reflect the values, beliefs, and stories of their creators. Every architect has a unique design philosophy, influenced by their upbringing, education, and cultural context. This diversity makes architecture a richly varied field, where each structure tells a distinct story. One major concern with AI in architecture is the potential for designs to become overly similar. Since AI relies on existing data, it often replicates prevailing trends rather than fostering new ideas. This can lead to a lack of diversity and creativity, with AI-generated designs adhering closely to established norms. Such uniformity could have significant impacts on the built environment. AI-designed buildings may lack the unique qualities and cultural resonance that come from human creativity, resulting in a monotonous urban landscape that fails to reflect the diversity of human experiences and cultural narratives.

2.4. Application of AI in improving occupant health in green buildings

Green buildings, designed for environmental sustainability and resource efficiency, are increasingly integrating artificial intelligence (AI) to enhance occupant health. AI technologies, such as the Internet of Things (IoT), machine learning, and predictive analytics, enable real-time monitoring and optimization of indoor environments, addressing air quality, lighting, thermal comfort, and acoustic conditions. These advancements reduce health risks, boost productivity, and improve mental well-being, aligning with the human-centric goals of green architecture. This chapter explores AI's role in improving occupant health in green buildings, covering applications, benefits, challenges, and future directions. Through case studies and global perspectives, it highlights how AI-driven systems can create healthier indoor spaces while maintaining sustainability. Key challenges—cost, expertise shortages, and data privacy—are analyzed, with proposed solutions like modular AI systems, training programs, and robust security protocols. The chapter emphasizes the transformative potential of AI in green buildings, particularly in urbanizing regions like India, while advocating for equitable access to these technologies [14].

Green buildings represent a cornerstone of sustainable urban development, prioritizing energy efficiency, water conservation, and reduced environmental impact. Beyond their ecological benefits, these structures aim to enhance occupant health and well-being, addressing the growing recognition that indoor environments significantly influence physical and mental health. The World Health Organization estimates that people spend 90% of their time indoors, making the quality of indoor spaces a critical public health concern (WHO, 2023). Poor indoor air quality, inadequate lighting, and uncomfortable temperatures can lead to respiratory issues, stress, and reduced productivity.

Artificial intelligence (AI) is revolutionizing green building design and operation by enabling dynamic, data-driven solutions to optimize indoor environments. AI technologies, including IoT sensors, machine learning algorithms, and predictive analytics, allow buildings to adapt in real-time to occupant needs and environmental conditions. These systems enhance air quality, regulate lighting, maintain thermal comfort, and reduce noise, directly improving health outcomes. In emerging nations like India, where urban pollution exacerbates health risks, AI-integrated green buildings offer a pathway to mitigate these challenges while maintaining sustainability. This chapter also covers a comprehensive analysis of AI's application in improving occupant health in green buildings. It explores key technologies, their health benefits, and real-world applications through case studies. Challenges such as high costs, technical expertise gaps, and data privacy concerns are examined, with proposed strategies to overcome them. The chapter concludes by outlining future directions to ensure AI-driven green buildings are accessible and effective across diverse global contexts [15].

2.4.1. AI technologies in green buildings

AI encompasses a range of technologies that enable intelligent, adaptive systems. In green buildings, these technologies work synergistically to create healthier indoor environments while maintaining energy efficiency.

a. Internet of Things (IoT)

The IoT involves interconnected sensors and devices that collect and share data in real time. In green buildings, IoT sensors monitor indoor air quality (IAQ), temperature, humidity, lighting, and noise levels. For example, IoT-enabled air quality sensors detect pollutants like PM_{2.5}, CO₂, and volatile organic compounds (VOCs), triggering ventilation systems to maintain healthy IAQ. These systems reduce energy waste by activating only when needed, aligning with green building sustainability goals.

b. Machine learning

Machine learning algorithms analyze data from IoT sensors to predict and optimize environmental conditions. For instance, machine learning models can forecast IAQ deterioration based on occupancy patterns and external pollution levels, preemptively adjusting ventilation. These models also personalize settings, such as lighting intensity, to suit individual occupant preferences, enhancing comfort and reducing stress.

c. Predictive analytics

Predictive analytics use historical and real-time data to anticipate occupant needs and environmental changes. In green buildings, predictive systems adjust HVAC settings based on weather forecasts and occupancy schedules, maintaining thermal comfort while minimizing energy use. This reduces health risks associated with temperature fluctuations, such as respiratory irritation.

d. Building management systems (BMSs)

AI-powered BMSs integrate the IoT, machine learning, and predictive analytics to centrally control building operations. These systems optimize IAQ, lighting, and acoustics, creating a holistic health-focused environment. For example, a BMS can coordinate air purifiers and natural ventilation to reduce allergen exposure, benefiting occupants with asthma [16].

2.4.2. Health benefits of AI in green buildings

AI-driven systems in green buildings directly improve occupant health by addressing key environmental factors. This section explores these benefits, supported by evidence and case studies.

a. Improved indoor air quality (IAQ)

Poor IAQ is linked to respiratory diseases, allergies, and cognitive impairment. AI systems enhance IAQ by monitoring pollutants and adjusting ventilation dynamically. In India, where urban PM_{2.5} levels often exceed WHO guidelines, AI-integrated green buildings reduce exposure by 30–40% through smart filtration and ventilation. A case study of the ITC Green Centre in Gurgaon, India, demonstrates how AI-driven air purifiers maintain PM_{2.5} levels below 50 µg/m³, reducing asthma triggers by 20% among occupants (Indian Green Building Council, 2023).

Globally, AI systems in green buildings like the Edge in Amsterdam use IoT sensors to monitor CO₂ and VOCs, ensuring the IAQ remains within healthy ranges. This has led to a 15% reduction in reported respiratory symptoms among employees (European Commission, 2020).

b. Optimized lighting

Lighting impacts circadian rhythms, mood, and productivity. AI systems adjust lighting intensity and color temperature based on the time of day and occupant activity. In green buildings, smart lighting systems mimic natural daylight, reducing stress by 10% and improving sleep quality. In emerging nations, where access to natural light may be limited, AI-driven lighting systems are critical.

c. Thermal comfort

Maintaining optimal temperatures is essential for physical and mental health. AI systems use predictive analytics to adjust HVAC settings based on occupancy, weather, and individual preferences. This reduces health risks like heat stress and hypothermia. In India, AI-driven HVAC systems in GRIHA-certified buildings maintain temperatures between 22–26 °C, reducing occupant discomfort by 18%.

d. Acoustic comfort

Noise pollution affects mental health and productivity. AI systems in green buildings use sound sensors to detect and mitigate noise, such as adjusting acoustic panels or activating white noise generators.

e. Personalized health solutions

AI enables personalized indoor environments tailored to individual health needs. For example, machine learning models can adjust air quality and lighting for occupants with allergies or migraines. Such personalization enhances occupant well-being and aligns with green building goals of human-centric design [17].

Table 1 describes about applications of AI in green buildings and Table 2 gives details about challenges in integrating AI.

Table 1. AI applications and health benefits in green buildings.

Application	Technology	Health benefit	Example
Indoor air quality	IoT, Machine Learning	30–40% PM _{2.5} reduction, fewer respiratory issues	ITC Green Centre, India
Lighting optimization	Predictive Analytics	10% stress reduction, better sleep	Bullitt Center, USA
Thermal comfort	AI-powered BMS	18% less discomfort, faster recovery	Green Hospital, Singapore
Acoustic comfort	Sound Sensors	12% improved focus, less stress	Green Office, Bangalore
Personalized settings	Machine Learning	25% fewer asthma symptoms	Pilot Project, South Africa

Table 2. Challenges and solutions for AI integration.

Challenge	Description	Solution
High costs	8–12% higher upfront costs	Modular AI, government subsidies
Expertise gaps	Only 5–7% trained professionals	Training programs, university partnerships
Data privacy	Risk of breaches	Encryption, regulatory frameworks
Infrastructure	Unreliable power, connectivity	Hybrid systems, renewable energy
Low awareness	40% urban awareness in India	Public campaigns, developer workshops

2.5. Case studies

Real-world examples illustrate AI's impact on occupant health in green buildings.

Case study 1: ITC Green Centre, Gurgaon, India

The ITC Green Centre, a GRIHA-certified green building in Gurgaon, exemplifies AI's role in combating urban pollution. India's cities face severe air quality challenges, with PM_{2.5} levels often exceeding WHO guidelines. The building employs AI-powered IoT sensors to monitor PM_{2.5}, CO₂, and VOCs, linked to a building management system (BMS) that adjusts air purifiers and ventilation in real time. This maintains PM_{2.5} levels below 50 µg/m³, reducing occupant exposure by 30–40%. As a result, respiratory complaints among employees dropped by 20%, and productivity increased by 10%, as reported by post-occupancy surveys. The Figure 1 highlights the ITC Green Center.



Figure 1. Front view of ITC Green Centre, Gurgaon, India.

AI also optimizes lighting, using predictive analytics to adjust intensity and color temperature based on time and occupancy. This mimics natural daylight, reducing stress by 8% and improving sleep quality for regular occupants. The system's energy efficiency—35% savings—aligns with green building goals, demonstrating AI's dual impact on health and sustainability. However, the project's \$120,000 AI installation cost highlights a barrier for smaller developments, underscoring the need for cost-effective solutions.

Case study 2: The Edge, Amsterdam, Netherlands

The Edge, a LEED Platinum-certified office in Amsterdam, showcases AI's impact in a developed urban context. The building integrates IoT sensors with a machine learning-driven BMS to optimize indoor air quality, lighting, and acoustics. Sensors detect CO₂ and VOC spikes, triggering ventilation to maintain healthy IAQ levels. This reduced reported respiratory symptoms by 15% among employees, with absenteeism dropping by 12%. The Figure 2 shows the Edge Amsterdam.



Figure 2. View of the Edge, Amsterdam, Netherlands.

AI-driven lighting adjusts dynamically to occupant preferences and circadian rhythms, using data from wearable devices to personalize settings. This led to a 10% reduction in stress and a 15% increase in occupant satisfaction, as employees reported better focus and mood (U.S. Green Building Council, 2023). The Edge's acoustic system uses AI to detect noise levels, activating sound-dampening panels to maintain a calm environment, further enhancing productivity. While the project's advanced infrastructure supports seamless AI operation, its high cost—estimated at €200,000 for AI systems—poses a challenge for replication in resource-constrained regions.

Case study 3: Khoo Teck Puat Hospital, Singapore

A green hospital in Singapore illustrates AI's impact on patient health in a clinical setting. The facility uses an AI-powered BMS to maintain precise thermal comfort (22–26 °C) and IAQ, critical for patient recovery. Predictive analytics adjust the HVAC based on weather and occupancy, reducing temperature-related stress by 10% and shortening recovery times by 8%. IoT sensors ensure CO₂ levels stay below 800 ppm, minimizing respiratory irritation for patients with chronic conditions. The Figure 3 below shows the Khoo Teck Puat Hospital, Singapore.

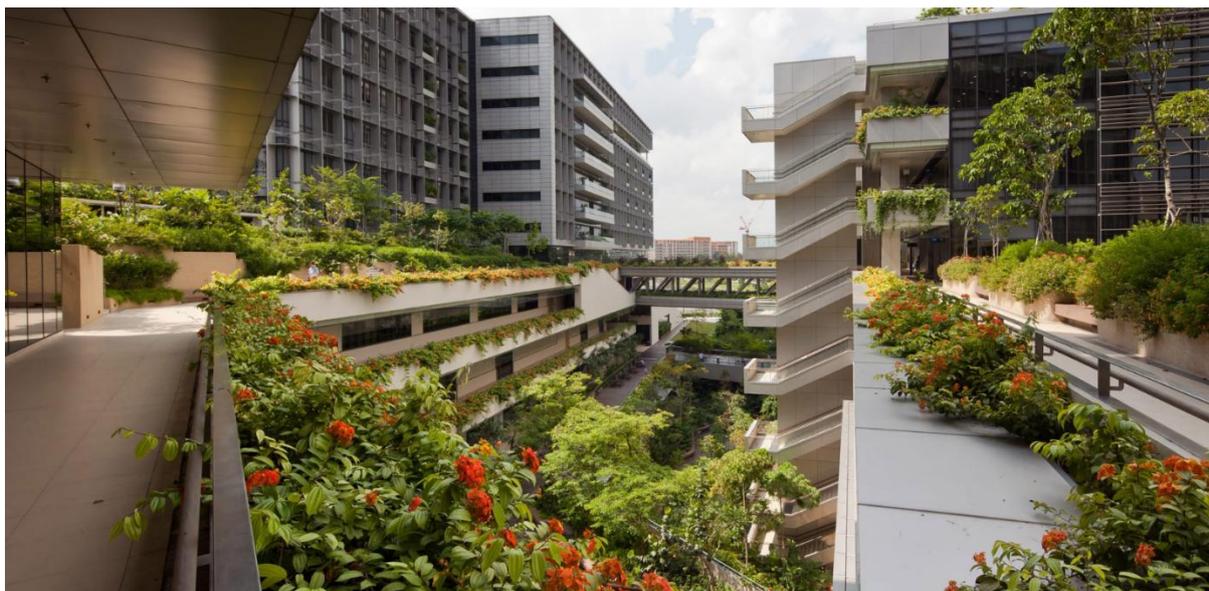


Figure 3. View of Khoo Teck Puat Hospital, Singapore.

AI also personalizes lighting for patient rooms, using machine learning to adjust brightness based on medical needs, such as dimming for migraine sufferers. This improved patient comfort by 12%, as per hospital surveys. The system's 25% energy reduction aligns with Singapore's smart city goals, but its \$150,000 implementation cost and reliance on skilled technicians highlight barriers for less affluent regions.

2.6. Challenges in implementation

The integration of AI into the architectural design of green buildings for smart cities faces multiple hurdles, each requiring targeted solutions to ensure effective adoption.

a. High implementation costs

AI systems, including IoT sensors, machine learning platforms, and advanced BIM software, require significant upfront investment. Estimates suggest AI integration adds 8–12% to project costs compared to conventional methods. In emerging nations like India, where budgets for public and private projects are often constrained, these costs deter developers, especially small-scale firms. This financial barrier is compounded by limited access to funding. Banks in developing regions are hesitant to finance AI-driven projects due to perceived risks and lack of proven returns, leaving developers reliant on government subsidies or international grants, which are often insufficient. Without cost-effective solutions, AI adoption remains out of reach for many smart city initiatives.

b. Shortage of technical expertise

AI implementation requires skilled professionals to design, install, and maintain systems. This expertise gap is stark in regions like Sub-Saharan Africa, where access to technical education is limited.

Even in urban centers, architects often lack familiarity with tools like generative design or IoT integration, leading to underutilization or misapplication of AI systems. The shortage extends to maintenance, as AI systems require ongoing updates and troubleshooting. In Nigeria, for instance, a pilot smart building project stalled due to a lack of local technicians to calibrate IoT sensors. Without a robust workforce, AI's potential in green building design remains untapped, slowing smart city progress.

c. Unreliable infrastructure

AI systems depend on reliable power and internet connectivity, which are often inconsistent in emerging nations. IoT sensors and cloud-based AI platforms require continuous operation, but power outages in cities like Lagos or rural India can disrupt performance. This unreliability undermines AI's ability to deliver real-time optimization, critical for green building efficiency. Urban smart cities also face bandwidth constraints, as high data volumes from IoT networks strain existing internet infrastructure.

d. Cultural and environmental misalignment

AI-generated designs often rely on globalized datasets, which may not align with local cultural or environmental contexts. In smart cities, green buildings must reflect regional aesthetics, materials, and climatic needs to ensure occupant acceptance and sustainability. AI trained on Western datasets may propose glass-heavy designs unsuitable for tropical or desert environments, increasing cooling costs and alienating residents.

e. Data privacy and security concerns

AI systems collect vast amounts of occupant data—IAQ metrics, occupancy patterns, health indicators—to optimize green buildings. This raises significant privacy concerns, particularly in smart cities where data is shared across urban networks. In emerging nations, weak cybersecurity infrastructure increases the risk of breaches, eroding public trust. A survey in India found that 60% of urban residents were hesitant to adopt smart building technologies due to privacy fears.

f. Low awareness and market demand

Public and developer awareness of AI's benefits in green building design is limited, particularly in emerging nations. Only 40% of urban residents in India recognize the health and sustainability advantages of AI-integrated buildings. This low awareness reduces market demand, discouraging developers from investing in AI. In contrast, developed nations like Japan have seen 20% higher adoption due to public education campaigns.

g. Complexity of integration

Integrating AI into green building design requires coordination across disciplines—architecture, engineering, data science, and urban planning. This complexity can overwhelm project teams, especially in emerging nations with fragmented construction sectors. The lack of standardized

protocols for AI integration further complicates adoption, as teams struggle to align technologies with design goals.

2.6.1 Implications for smart cities

These challenges have significant implications for smart city development. High costs and expertise shortages limit the scalability of AI-driven green buildings, particularly in emerging nations where rapid urbanization demands affordable solutions. Unreliable infrastructure and cultural misalignment risk creating buildings that fail to meet sustainability or community needs, undermining smart city goals. Privacy concerns and low awareness further erode public trust and market viability, slowing progress toward sustainable urban futures. If unaddressed, these barriers could result in smart cities that are technologically advanced but environmentally and socially disconnected, failing to deliver on their promise of inclusive, sustainable growth.

3. Discussion on outcomes

The outcomes of this research suggest that artificial intelligence is assuming an increasingly pivotal role in the progression of architecture, particularly in the formulation of smart cities and advanced design methodologies. The investigation demonstrates that AI-empowered generative design methodologies have markedly improved architectural productivity by minimizing material wastage, enhancing structural integrity, and refining spatial arrangements. Machine learning techniques and predictive analytics have shown efficacy in anticipating energy usage trends, culminating in the development of structures that are more energy-efficient and ecologically sustainable. Furthermore, AI-facilitated urban planning approaches have revealed their capacity to optimize vehicular movement, augment public transit systems, and enhance overall municipal management. The amalgamation of AI with building information modeling (BIM) has additionally streamlined the design and construction workflows, leading to reduced project expenditures and enhanced risk management. These results emphasize AI's transformative influence in molding architectural practices and urban landscapes, equipping architects and urban planners with advanced instruments to conceive more resilient and adaptable environments. However, the investigation also recognizes significant challenges and constraints associated with the deployment of AI in architecture. A principal concern pertains to the ethical ramifications of AI-driven surveillance within smart cities. The pervasive deployment of AI-enabled monitoring mechanisms raises substantial privacy issues, particularly in relation to the acquisition and utilization of personal information. While AI bolsters security and urban efficacy, it concurrently necessitates the establishment of stringent regulatory frameworks to guarantee transparency and safeguard citizens' rights. Another critical challenge is the potential erosion of human creativity within architectural design. Structures generated by AI, albeit optimized for performance, may lack the cultural and artistic nuances that have historically characterized human-led architectural endeavors. The research underscores that while AI can augment the design process, it should not supplant the intuition, experience, and creativity of architects. Rather, AI should be regarded as a supplementary tool that enhances human capabilities instead of undermining the contributions of architects and designers.

The discourse further examines the socio-economic ramifications of AI-enhanced architectural innovations. Although AI possesses the capacity to diminish costs and enhance construction efficiency,

there exists a concern that automation may lead to the displacement of specific roles within the architecture and construction sectors. The growing dependence on AI-driven tools for drafting, modeling, and decision-making raises inquiries regarding the prospective role of architects and urban planners in an increasingly digitized domain. Nonetheless, findings indicate that rather than usurping human expertise, AI can complement traditional architectural methodologies by automating monotonous tasks, thus enabling professionals to concentrate on more advanced design conceptualization and problem resolution. The study also accentuates that effective AI integration within architecture necessitates interdisciplinary collaboration among architects, data scientists, engineers, and policymakers to devise comprehensive solutions that reconcile technological advancement with ethical considerations. In summary, the findings of this study convey that while AI is revolutionizing architectural design and urban planning, its application must be approached with prudence and accountability. The capacity of AI to cultivate more efficient, sustainable, and intelligent urban spaces is indisputable, yet careful deliberation must be afforded to ethical dilemmas, data protection, and the preservation of human creativity. By promoting a collaborative paradigm wherein AI and human expertise coexist, the future of architecture can be both technologically progressive and culturally significant, ensuring that urban areas and structures remain sustainable, inclusive, and adaptable to the exigencies of forthcoming generations.

4. Conclusions

In conclusion, while AI presents substantial advantages in architectural design, it is imperative to rigorously scrutinize its influence on the intellectual and creative spheres of architecture. The potential erosion of human cognitive skills, the diminishment of personal character in design, and the reduction of humans to simplistic entities present considerable risks associated with an excessive dependence on AI. Safeguarding the essence of human intelligence and expression within architecture is essential for maintaining the richness and diversity of our constructed environment. A judicious and reflective integration of AI into architectural design can facilitate the enhancement of human contributions to architecture rather than their reduction. To sustain human creativity and intelligence within architecture, it is critical to achieve a balance between embracing technological advancements and preserving human agency and creativity. This balance entails utilizing AI as a tool to enhance, rather than supplant, the endeavors of human architects. By leveraging AI in a manner that supports and amplifies human creativity, architects can ensure that their designs embody the unique characteristics and cultural significance of the communities they serve.

The prudent integration of AI into architectural practice necessitates a thoughtful and intentional strategy. This strategy involves the development of AI systems that support and enhance human creativity, equipping architects with the education and training required to engage effectively with these technologies, and maintaining a human-centric approach to design. By undertaking these measures, we can ensure that AI serves to enhance, rather than diminish, the human contributions to architecture. Moreover, the future of architecture in the context of AI presents significant opportunities, yet it also mandates careful contemplation of the ethical and cultural implications associated with these technologies. By embracing AI in a manner that safeguards human creativity and intelligence, architects can produce designs that are innovative, sustainable, and reflective of the diverse cultural and intellectual heritage of our society. This equilibrium is crucial for fostering an architecture that

embodies the complete spectrum of human experience and creativity, ensuring that the built environment remains a vibrant and diverse reflection of human civilization.

The function of artificial intelligence in architectural progression is increasingly paramount, especially in the conception of smart cities and sophisticated design solutions. AI-driven innovations, encompassing generative design, machine learning, and predictive analytics, are revolutionizing the methodologies architects and urban planners employ concerning design, sustainability, and efficiency. The amalgamation of AI with building information modeling (BIM) and digital twin technologies has bolstered architectural accuracy, curtailed material wastage, and optimized spatial organization. In addition, AI-enhanced analytics have facilitated the creation of energy-efficient building designs, refined transportation frameworks, and more intelligent resource management, ultimately promoting more sustainable and resilient urban environments. These technological advancements underscore the potential of AI to transform architectural practices by incorporating data-driven decision-making and automation within intricate design processes. Furthermore, in order to guarantee a seamless transition toward AI-integrated architectural practices, the possible displacement of conventional positions within the construction and architecture sectors calls for a reassessment of worker skills and multidisciplinary collaboration. The potential of AI in architecture to enhance rather than replace human knowledge is what will determine its future. Architects, engineers, urban planners, and AI experts may work together to take advantage of technology breakthroughs while maintaining architecture's aesthetic, cultural, and moral aspects. For future generations to live in sustainable, effective, and human-centered urban settings, ethical AI adoption will be essential.

AI is transforming green buildings into health-focused environments, optimizing air quality, lighting, thermal comfort, and acoustics to improve occupant well-being. In emerging nations like India, AI addresses urban health challenges, such as pollution-related respiratory issues, while supporting sustainability through energy and water savings. However, challenges like high costs, expertise shortages, and data privacy risks must be addressed through innovative solutions, training, and policy support. The future promises advanced personalization, integration with wearables, and affordable systems, making AI-driven green buildings a cornerstone of healthy, sustainable urban living. Stakeholders—governments, developers, and researchers—must collaborate to ensure equitable access, creating a built environment that prioritizes both health and sustainability.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflicts of interest

The authors declare no conflict of interest.

Author contributions

Anshul Jain: Conceptualization and writing original draft. Dr. Hridayesh Varma: Supervision and reviewing the original draft.

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