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REVIEW

Architectural Design in the Age of Generative AI: Toward a Balance Between Efficiency and Responsibility

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Abstract
Since 2022-23, the rapid adoption of generative artificial intelligence (AI) has begun to reshape architectural design practice. Beyond accelerating design efficiency, generative AI is redefining creativity, professional expertise, and the ethical responsibilities of architects. This study examines both optimistic and skeptical perspectives on generative AI in architecture through a critical narrative review drawing on practitioner publications, professional discourse, and academic literature. The optimistic view highlights productivity, creative expansion, and data-driven sustainability, whereas the skeptical view raises concerns about professional deskilling, cultural bias, black-box opacity, and environmental costs. Synthesizing these tensions, the paper proposes an integrated framework built on three practical agendas: (1) redefining the architect's role from passive approver to critical curator who strategically evaluates and integrates AI-generated outcomes; (2) establishing ethical governance to ensure transparency, fairness, and sustainability in AI-assisted design; and (3) reforming architectural education to cultivate integrative practitioners capable of critical reasoning and interdisciplinary collaboration. This study provides a roadmap for integrating generative AI into architectural practice in ways that enhance both efficiency and social responsibility.

Keywords Generative artificial intelligence · Architectural design · Professional ethics · Governance · Architectural education

1 Introduction

1.1 Research Background

Since 2022-23, generative artificial intelligence (AI) has been rapidly introduced to architectural design, indicating fundamental changes in practice. While the evolution of tools from hand drawing to AutoCAD to BIM has brought substantial changes to design methods, collaboration structures, and representation techniques, generative AI shows a different scale of impact. If traditional tool development enabled the same tasks to be performed more efficiently, generative AI demands changes in how architects explore and develop ideas, fundamentally transforming the methods by which design outcomes are generated. For example, text-to-image models such as Midjourney, DALL-E, and Stable Diffusion can rapidly generate conceptual images in various styles with relatively simple text inputs, allowing architects to quickly review multiple design directions (Link 2024). Additionally, tools like Autodesk's Generative Design and Forma (formerly Spacemaker) automatically explore and propose diverse design alternatives considering complex constraints (Symetri 2023).

Meanwhile, as generative AI technology rapidly spreads through architectural design, both expectations and concerns are growing simultaneously. On one side, optimistic views suggest that generative AI will dramatically reduce design time and strengthen architects' creative capacity. Indeed, MBH Architects used Autodesk's AI-based design platform Forma to conduct initial site analysis and design alternative evaluation, completing work that previously took two weeks in approximately six hours (Holmes 2024). Furthermore, Zaha Hadid Architects has integrated design workflows and accelerated visualization and iterative design processes through AI-based simulation using NVIDIA Omniverse and OpenUSD platforms, presenting

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possibilities for architects to materialize design ideas more quickly (Bell 2024). Moreover, Thomas Jefferson University, through the studio course "Designing Tomorrow" jointly offered by the School of Architecture and College of Urban Innovation, teaches students to develop sustainable urban design proposals using generative AI and data-driven simulation tools (Miller 2024). These cases strengthen the optimistic outlook that generative AI has the potential to promote positive changes beyond simply improving design efficiency, encompassing architects' exploratory methods and the overall architectural education paradigm (Onatayo et al. 2024).

However, on the other hand, warnings are raised that such technological advancement could threaten the viability of the architectural profession and architecture's essential values. Although an exaggerated prediction, designer Sebastian Errazuriz claimed that "90% of their (architects) jobs are at risk" (Fairs 2019), and this statement has been repeatedly cited in subsequent futurist discourse. Additionally, academic concerns exist that generative AI may reinforce cultural biases and intensify spatial inequality by excessively prioritizing certain values and images in urban design processes. Campo-Ruiz (2025) analyzed that AI could negatively affect diversity and social justice by representing urban cultural contexts in limited ways. Furthermore, concerns arise that when generative AI's internal decision-making logic is black-boxed and copyright and licensing issues of training data are unclear, ethical and legal controversies regarding public safety, accountability, and copyright infringement may occur (NiFhaolain et al. 2023).

This tension between optimism and skepticism shows that generative AI adoption is not merely a matter of technical acceptance but demands fundamental changes to architectural professional identity, social roles, and educational systems. This study aims to analyze these tensions in depth and propose a practical roadmap for socially responsible and technically efficient generative AI adoption. To this end, this study examines optimistic and skeptical perspectives on generative AI in architecture in a balanced manner, and based on that analysis, identifies key issues facing architecture in the generative AI era.

1.2 Research Gap and Contribution

A number of recent peer-reviewed academic studies have systematically documented the application of generative AI across the architectural design process. Several systematic reviews indicate that the current application of generative AI is primarily focused on the early conceptualization and visualization stages, with limited evidence supporting its use in later design stages, where accountability and licensing requirements arise (Jang et al. 2025; Li et al. 2025a). Furthermore, previous studies have categorized models, such as diffusion models, 3D generators, and large language models, and cataloged specific applications in the architectural field (Li et al. 2025a; Kampelopoulos et al. 2025; Zhuang et al. 2025).

However, existing literature reviews have primarily focused on technical mapping and have failed to provide a conceptual framework that integrates (1) redefining professional roles, (2) governance and legal accountability, and (3) educational transformation into a single, integrated agenda that can be immediately applied to practice.

This study seeks to fill this academic gap through a structured narrative and exploratory review coupled with conceptual synthesis. Its core and original contribution lies in its redefinition of architects as "strategic curators." This represents a professional model that transcends their role as direct producers of outcomes, establishing design intent, critically evaluating AI-generated alternatives, and maintaining authorial leadership as agents responsible for contextual, ethical, and aesthetic accountability. This framework aligns with the principle of "human-centered AI," which emphasizes the need to maintain meaningful human control even in automated environments (Shneiderman 2020; Amershi et al. 2019), and extends this principle to the specific context of architectural practice and education.

1.3 Methods

This study is a critical narrative review and conceptual essay, a form of research synthesis in the review-methods literature (Grant and Booth 2009). The purpose of this study is not to provide a systematic and comprehensive survey of all available sources, but rather to identify and critically examine key issues, tensions, and implications surrounding generative AI in architectural practice and education.

Research data were collected through open web searches, including practitioner publications, professional journalism, industry reports, and academic literature. No formal database search protocols, strict inclusion/exclusion criteria, or thematic coding procedures were employed. This approach reflects the unique nature of this research topic. Generative AI in architecture is in a period of rapid emergence, where professional discourse, media reports, and academic research actively shape professional understanding. Therefore, artificially excluding non-academic sources may risk distorting the landscape of actual debate.

The scope of this review is limited to generative AI in architectural design practice and education, while selectively referring to relevant AEC (Architecture, Engineering, and Construction) discussions. This review primarily covers sources published from 2023 to 2025, a period of rapid public diffusion of generative AI tools in design practice. Identification of sources was conducted through iterative web searches using combinations of “generative AI architecture,” “architectural design AI,” “AI in architectural practice,” and related terms. To improve theoretical grounding, the author additionally incorporated peer-reviewed articles and recent academic studies to contextualize practitioner discourse. Sources were included when they directly addressed architectural practice, education, governance, or professional roles in relation to generative AI.

The author clearly recognizes the limitations of this approach. The search corpus does not encompass all fields, and the selection of data is based on the author’s interpretive judgment rather than reproducible procedures. Claims derived primarily from practitioners or media sources are treated as signals of professional discourse rather than empirical evidence, and these are clearly distinguished from peer-reviewed academic claims throughout the text. The conceptual framework proposed in Sect. 3, “Architects as Strategic Curators,” is the result of the author’s original synthesis and should be understood as a theoretical contribution that requires empirical validation through future research.

2 Two Perspectives on Generative AI

The analysis in this section is based on statements drawn from architectural practitioners, design professionals, technology commentators, and industry reports. These sources reflect the actual landscape of debate through which generative AI is currently being understood and contested within the profession. The author has organized this material into two opposing positions: optimistic and skeptical. This section should be read as a structured mapping of professional discourse rather than a systematic review of empirical literature.

2.1 Optimistic Perspective

(1) Enhanced Efficiency and Productivity.

The introduction of generative AI is being evaluated as a catalyst for fundamentally improving productivity and efficiency across architectural design work. Onatayo et al. (2024) evaluated generative AI as one of the most important innovations that automates repetitive design processes and increases time and cost efficiency in the AEC field. Architectural theorist Carpo (2017) argued that algorithms do not replace designers but expand their work capacity, and this is actually appearing in architectural practice as improvements in work processing speed and accuracy.

Generative AI-based tools show very high efficiency in the early design stages such as site analysis, code review, and feasibility evaluation. Platforms like Autodesk Forma and TestFit simultaneously analyze variables such as site data, solar access, and views along with local regulatory conditions to instantly calculate optimal density or zoning alternatives for each site. Li et al. (2025b) analyzed that such technology transforms the early feasibility study stage into a data-driven decision-making environment, helping designers secure quantitative evidence in shorter time. In actual design office cases, feasibility reviews that previously took several weeks have been reported to be shortened to several hours using Autodesk Forma (Holmes 2024).

Additionally, generative AI automatically generates numerous form and spatial alternatives based on the architect’s initial input conditions. The ARCHITEChTURES platform automatically generates 3D models and floor plans, and comparatively analyzes each alternative’s energy performance or structural efficiency, allowing designers to select the optimal solution in a short time. Albukhari (2025) evaluated that AI-based optimization is one of the effective pathways to shorten design cycles and improve result accuracy, and this automated exploration environment reduces traditional manual iterations and simultaneously improves the quality and speed of design decisions.

In the visualization stage as well, AI introduction dramatically reduces work time. Zaha Hadid Architects used AI-based simulation tools to render complex forms and lighting effects in real time, shortening the design feedback cycle from several days to several hours (Bell 2024).

Consequently, the introduction of generative AI improves architectural design productivity in terms of time efficiency, alternative exploration, and information accuracy, and is qualitatively changing architects’ work methods and organizational workflows. This change provides the foundation for recognizing AI not as a replacement but as ‘collaborative intelligence’ that leads to productivity maximization.

(2) Expansion of Creativity and Exploration Processes.

Generative AI is being recognized as a collaborative tool that expands the manifestation methods and thought structures of architects’ creativity rather than replacing it. This expansion can appear in two dimensions.

First, the temporal and cognitive space secured through productivity improvement enables architects to engage in higher levels of creative thinking. AI automates repetitive and technical tasks, allowing architects to invest more energy in strategic thinking, conceptual exploration, and aesthetic judgment (Holmes 2024). In Gensler’s case, AI reduced administrative processes, enabling designers to concentrate on the early stages of idea generation and concept establishment in projects (Gordon 2025). This aligns with Heo’s (2024) assessment that generative AI is “a subject of collaboration that helps architects concentrate on more creative and unique work by reducing repetitive and exhausting tasks and increasing efficiency."

Second, generative AI leads to the expansion of creativity by presenting new ideas and horizons of thought that go beyond human cognitive limitations. Pellicano (2025) states that "generative AI not only changes the ways architects work—altering the design phases and their traditional means of exploration—but also fundamentally changes the ways we see, image, and imagine the world around us," defining it as a tool that makes "novel connections and identifying unanticipated relationships, patterns, and potentials that were previously withdrawn from our independent human perception." Similarly, architect and designer Hassan Ragab emphasized that "as an architect, you want control, and Midjourney is actually not about control at all," and "if you want to explore something new: you have to break out of the boundary of being an architect," suggesting that AI is an exploratory tool that goes beyond the limits of traditional architectural thinking (Link 2024). Academically, this discussion is expanding. Onatayo et al. (2024) analyzed that generative AI enables a new human-machine collaboration model that expands architects' creative opportunities and broadens the boundaries of design explorationLi et al. (2025a) pointed out that generative AI can open innovative design possibilities through unexpected results.

Consequently, generative AI forms a hybrid design paradigm where efficient thinking and creative thinking mutually reinforce each other, rather than opposing productivity and creativity. This leads to redefining AI not as a simple tool but as a creative partner, and is evaluated as a turning point that fundamentally changes the thinking methods and role distribution of future architecture.

(3) Strengthening Sustainability and Inclusiveness.

The introduction of generative AI is evaluated as an important force that extends the goals of architectural design beyond simply aesthetic creation toward realizing the ethical values of sustainability and social inclusiveness. From this perspective, AI supports decision-making that considers environmental responsibility and public welfare by rapidly and quantitatively analyzing complex and multilayered design constraints.

Particularly in terms of environmental sustainability and economic accessibility, MBH Architects' "Phoenix" project demonstrates the possibilities of generative AI. This project utilized AI-based design tools such as Autodesk Forma to simultaneously analyze various factors including cost, carbon, habitability, and construction period. While calculations were complex or time-consuming in the past, AI could rapidly predict and compare performance indicators such as energy efficiency, carbon emissions, solar access, and wind environment through cloud-based analysis and automatic simulation. As a result, "Phoenix" presented a sustainable affordable housing model aiming to reduce cost and carbon emissions to approximately half the level of existing multifamily housing (Dubey 2024). This suggests the possibility that AI can enable more people to access sustainable housing by simultaneously considering environmental performance and economic accessibility.

In terms of improving residential environment quality, AI also contributes. Finnish architecture firm ARCO, while designing student housing on a site with various constraints such as noise and solar access, utilized Forma's noise prediction and habitability analysis functions. In this project, AI compared and visualized various layout alternatives to present design directions that could reduce noise and secure comfort (Tan 2023). This can be seen as a case where AI performs a supporting role in design decision-making by combining quantitative data and simulation, rather than replacing human architects' intuition.

In this way, generative AI contributes to realizing architecture's social values of sustainability and housing accessibility through objective verification based on data, beyond simply increasing technical efficiency. This forms an important axis of optimism in that AI technology provides architects with a new pathway to effectively fulfill ethical responsibilities.

2.2 Skeptical Perspective

(1) Threats to Architectural Expertise.

Despite the optimism that generative AI can improve efficiency and creativity, the rapid development of this technology is being recognized as a substantial threat to the identity and employment stability of the architectural profession. According to the World Economic Forum's 2025 Future of Jobs report, 40% of employers expect to reduce workforce in areas that AI can automate (Leopold 2025), and this trend is no exception in the architecture field. The U.S. Bureau of Labor Statistics forecasts that AI will affect various professional occupations including architecture and engineering, and predicts that even if demand for architects does not completely disappear, the nature of work and the scale of required workforce will fundamentally change (Bureau of Labor Statistics 2025).

What is particularly concerning is the possibility of rapid reduction in junior architect positions. Bloomberg analyzed that while AI can replace 53% of market research work and 67% of sales work, only 9% and 21% of managerial-level work in those fields can be automated, pointing out that the lower stages of the career ladder are especially vulnerable (Leopold 2025). A similar pattern appears in the architecture field. As initial sketches, code reviews, site analysis, and basic drawing preparation—tasks that junior architects handled—are automated by generative AI, there is a risk that the entry pathway through which new architects can accumulate practical experience and develop expertise will be blocked.

The more serious problem is that this change threatens the identity of the architectural profession itself, beyond simple job reduction. Architects' expertise is based on tacit knowledge and judgment accumulated through years of practical experience, mentoring, and trial and error, but as generative AI automates core stages of the design process, the opportunity to develop such expertise is disappearing. In this regard, Athow (2025) warned that the change in experts' roles due to AI could go beyond simple "de-skilling"[1] to "hollowing out of expertise"[2]. This signifies a fundamental power shift where architects fall from being authors of the design process to consumers of AI-generated products.

This change could call into question the legitimacy of architectural education and architect licensing systems. If generative AI can automate most of architectural design, questions may arise about the rationale for over five years of professional education, years of practical experience, and rigorous licensing examinations. This contains the risk of fundamentally weakening the social status and economic value of the architectural profession.

(2) Erosion of Architectural Diversity and Cultural Bias.

As generative AI technology spreads through architectural design, concerns are raised that the cultural biases in AI models' training data could erode architectural diversity and regional identity. Dutch architects Sandra Baggerman and Cas Esbach pointed out that current AI image generation tools are heading toward "monotony," citing the lack of diversity and richness in datasets as the cause. They emphasized that "AI tools often struggle to create designs outside mainstream modern architecture. They miss out on culturally diverse styles." Additionally, they warned that "architecture is all about reflecting the nuances of different cultures and traditions. If AI can't do that, we risk losing the diversity that makes architecture so rich" (Rogers, 2024).

Professor Kevin Wong pointed out that "Machine Learning techniques, including Generative AI, require a huge amount of 'representative' data to train the complex system," and "bias can occur when the data used is not comprehensive enough, or there is an imbalanced distribution" (Murdoch University, 2024). This data imbalance is structurally inherent in the architecture field. Most architectural images and drawings available on the internet and digital archives are concentrated on modern architecture in Western countries, particularly North America and Europe, creating a risk that AI may simplify and stereotype non-Western or indigenous architecture (Campo-Ruiz 2025).

Cornell University's research team showed that AI's cultural bias can be partially mitigated through a technique called "cultural prompting"[3] (Fleischman 2024), but the problem is more fundamental given that architectural design is a field where cultural background such as regional history, customs, codes, and lifestyles directly permeates design judgments and spatial meanings. If the entities developing and deploying AI are concentrated in specific regions and their perspectives and values are implicitly embedded in system design and performance indicators, this can go beyond simple data diversity deficiency to lead to misreading of local contexts, homogenization of forms or aesthetics, and value misalignment with user groups. Consequently, uncritical use of generative AI risks gradually eroding regional and cultural diversity in architectural design and causing architectural homogenization that spreads specific aesthetic standards and design languages globally.

(3) Black Box Risks and Legal Accountability Gaps.

Another core limitation of generative AI is that its decision-making process operates as a "black box" (Deeks 2019). Deep learning-based generative models have an opaque structure where inputs and outputs can be observed, but internal reasoning processes are difficult to fully understand even for developers. In the architectural design context, this means that architects or clients cannot understand why generative AI proposed a specific form, material, envelope system, or structural type. Moreover, when structural defects, performance degradation, or safety issues occur, the responsible party to trace the cause becomes unclear.

This opacity weakens judgments about legal intent and causation. According to Bathaee (2018), principles such as "proximate cause"[4] can be shaken in black box situations. For example, when an accident occurs in an architectural project, responsibility is distributed among AI developers, architects, professional engineers, contractors, and clients, making it unclear to whom to demand foreseeability and controllability, which are prerequisites for fault liability. As Duffourc and Gerke (2023) point out, whether generative AI generates design alternatives autonomously without architect supervision (autonomous black box AI) or generates design alternatives in a supporting role under architect supervision (non-autonomous black box AI), if the internal

[1] De-skilling refers to the phenomenon where the overall skill level in a field weakens as employees perform less of the work they previously handled themselves due to the introduction of AI tools.

[2] Hollowing out of expertise refers to a structural change phenomenon in which deep expertise gradually disappears within an organization or job function, leaving mid-level or complex capabilities vacant.

[3] Cultural prompting refers to instructing the AI to respond as an average person who was born and lives in a specific country or region.

[4] Proximate cause refers to the direct and dominant cause that is judged to have reasonably and foreseeably resulted from a specific action when damage occurs, serving as the critical basis for attributing legal responsibility in law and insurance.

logic is not explained, accountability gaps inevitably arise across design review, supervision, and permitting systems.

The EU (2024) AI Act grants the "right to explanation" for automated decision-making, but it is unclear whether such legal requirements can be practically met. Gryz and Rojszczak (2021) analyzed that even designers of deep learning systems often do not fully understand the technology they use, and Rahimi (2017) criticized that "machine learning has become alchemy."

Copyright and licensing issues of data learned by generative AI create another legal uncertainty. Most generative AI uses vast amounts of architectural images, drawings, and 3D models collected from the internet as training data, but whether copyright holders explicitly permitted AI learning is often unclear. When AI learns the style or formal characteristics of existing works and generates similar design alternatives, the legal standards for whether this constitutes copyright infringement or falls within the legitimate range of 'inspiration' are not clear. This uncertainty can lead to disputes over ownership and intellectual property rights of design outcomes using AI, and indeed the Getty Images and Stability AI case clearly shows the controversies over whether web-collected images were used without permission for learning and the standards for infringement judgment (Getty Images (US), Inc. v. Stability AI, Inc., 2023). In response to this legal uncertainty, RIBA specifically warns architectural firms of risks of data leakage, retraining exposure, and copyright/ownership loss when inputting in-house drawings, images, and models into open generative AI tools, and recommends checking the tool's data storage and utilization methods in advance (Morris 2025).

(4) Environmental Costs of AI.

Despite the optimism that generative AI can contribute to optimizing building energy efficiency and reducing carbon emissions, concerns are raised that the enormous energy and environmental resources consumed by generative AI models' learning and inference processes could offset or even exceed these benefits.

Generative AI systems have been investigated to use 33 times more energy than traditional software (Noble et al. 2024), and the International Energy Agency predicted that global electricity demand for data centers will increase to approximately 945TWh (similar to Japan's annual electricity consumption) by 2030, more than doubling current levels. More concerning is the forecast that approximately 60% of this increased demand will be met by fossil fuels, resulting in approximately 220 million tons of increased carbon emissions (Zewe 2025). This is being demonstrated by the rapid increase in carbon emissions of major technology companies. Google's carbon emissions increased by approximately 50% in 2023 compared to 2019, Microsoft increased by approximately 40% between 2020 and 2023, and Meta's Scope 3 emissions[5] increased by 65% over two years. Additionally, data centers use approximately 7,100 L of water for cooling per MWh of electricity consumed, with Google's U.S. data centers alone consuming 12.7 billion liters of fresh water in 2021 (Noble et al. 2024).

This environmental burden creates a 'sustainability paradox' when using generative AI in the architecture field. While architects can use AI tools to generate design alternatives that optimize building energy efficiency and reduce carbon emissions, the energy consumed and carbon generated in learning and operating AI systems during the process could offset the carbon saved in buildings. Particularly when generative AI is repeatedly used for multiple design iterations and alternative exploration in architectural projects, these environmental costs accumulate further. This raises fundamental questions about the validity of utilizing generative AI as a sustainable architectural design tool.

2.3 Summary

The optimism and skepticism reviewed above show that the impact of generative AI on the architecture field cannot be predicted in a single direction. Generative AI simultaneously: (1) improves productivity while blocking entry pathways for junior personnel; (2) expands creative exploration while potentially causing architectural homogenization; (3) strengthens sustainability while generating enormous environmental burden itself; and (4) refines decision-making on a data-driven basis while making accountability opaque.

This paradoxical tension raises fundamental questions beyond whether to accept generative AI technologically: (1) How should architects' roles and expertise be redefined? (2) How can ethical responsibility in AI-based design be secured? (3) How should future architectural practitioners be educated? This study aims to concretize these questions into practical tasks of 'redefining architects' roles,' 'establishing governance,' and 'transforming education,' and explore alternative pathways for each task. This is to explore conditions for socially responsible and professionally sustainable integration, beyond the binary of simply accepting or rejecting generative AI.

3 Key Issues for Architectural Design

The three issues identified and developed in this section are the author's original contribution. They are not derived from a specific source, but emerge from the author's critical analysis of the tensions presented in Sect. 2.

[5] Scope 3 emissions refer to indirect greenhouse gas emissions occurring across the entire supply chain of a company's products and services.

Table 1 Architects' Competencies and Roles in Relation to AI

Competency	Limitations of GenAI	Architect's Role
Contextual Appropriateness	Focuses on quantifiable parameters (form, structure, performance); lacks sensitivity to local context	Assess and refine AI outputs to align with site, culture, and community needs
Ethical and Social Value Judgment	Optimizes measurable goals (efficiency, cost) but neglects normative values	Evaluate designs for publicness, inclusiveness, and equity; reject unethical outcomes
Aesthetic and Conceptual Coherence	Optimizes parts without overall narrative integration	Synthesize AI-generated elements into a coherent architectural concept
Position as Final Responsible Agent	Obscures authorship and responsibility due to black-box processes	Review and approve AI results, assuming explicit legal and ethical responsibility

Table 2 Redefining the Architect's Role Across Design Phases

Design Phase		Traditional Role	Key Change in Role
Programming		• Organize client requirements • Conduct site survey and code review • Collect case studies and data	*Evaluator*: Establish criteria for AI-based analysis and critically validate outcomes
Conceptual Design	Concept Formation	• Brainstorm and develop concepts • Gather reference images	*Strategic Planner*: Structure project values into quantitative and qualitative constraints
	Alternative Generation	• Produce design alternatives • Create sketches and models	*Generation Supervisor*: Supervise large-scale AI generation and guide exploration direction
	Critical Selection	• Evaluate and select alternatives • Reflect client preferences	*Critical Curator*: Perform multi-stage filtering and recombination
Design Development		• Elaborate selected design • Collaborate with engineers	*Integration Supervisor*: Oversee the technical validity of AI-driven performance optimization
Documentation		• Prepare drawings and specifications • Develop detailed designs • Estimate quantities	*Legal Responsible Agent*: Inspect and take responsibility for AI/BIM-generated documents

3.1 Redefining Architects' Roles and Establishing Collaborative Processes

The most fundamental threat posed by generative AI adoption is the possibility that architects' roles may regress from active authors to passive approvers. As discussed in Chap. 2, as generative AI automates from initial concepts to alternative generation to performance optimization, the risk is materializing that architects' roles will be reduced to a passive position of selecting and approving one option among those generated by AI. More concerning is that this change could block junior architects' professional development pathways, leading to the "hollowing out of expertise" warned by Athow (2025).

Therefore, the task of redefining architects' roles in the generative AI era should not be simply adapting to new technology, but constructing a new expertise model where architects can maintain leadership in the design process while strategically utilizing AI's capabilities. One of the most viable alternatives for redefining architects' roles is reconceptualizing architects as 'curators.' This means establishing a position as professionals who actively select, adjust, and integrate based on critical judgment and contextual understanding, rather than passively choosing AI-generated outputs.

The curator concept originally refers to professionals who select, arrange, and give meaning to works in art galleries or museums. Similarly, architects in the generative AI era should exercise the following curation capabilities with respect to numerous design alternatives generated by AI (see Table 1).

For architects' role as curators to work practically, the existing linear design process must be redesigned into an iterative and collaborative structure where humans and AI interact. Architectural design generally proceeds through four stages: programming → conceptual design → design development → documentation (construction documents), and while generative AI's influence extends to all stages, it causes the most fundamental changes particularly in the conceptual design stage. This is because conceptual design is the most important moment when the project's direction and architectural identity are determined, and traditionally the area where architects' creativity and expertise are most directly exercised. Table 2 proposes how architects' roles should be redefined at each design stage.

The core of the AI collaboration process is the architect's role shifting from 'direct producer' to 'strategic curator.'

In the concept establishment stage, the architect becomes a strategic planner who structures the project's core values into prompts that AI can understand; in the alternative generation stage, the architect becomes a generation supervisor who oversees the process of AI generating multiple alternatives; and in the critical selection stage, the architect performs the core role as a critical curator who evaluates and selects options based on the four criteria in Table 1.

3.2 Establishing Ethical Governance and Legal Transparency

The second key issue caused by indiscriminate adoption of generative AI is ethical gaps and legal uncertainty. The black box characteristics of generative AI (Sect. 2.2(3)) make accountability for design decisions unclear, intellectual property issues create potential for disputes, cultural biases in training data (Sect. 2.2(2)) risk intensifying spatial inequality, and AI's environmental burden (Sect. 2.2(4)) can conflict with sustainability. Therefore, for responsible AI use in the architecture field, an ethical governance system must be established that secures design transparency, fairness, and sustainability and clarifies accountability principles.

First, to secure AI design transparency, introducing a system that can track and audit AI design history is necessary. This means recording and verifying all processes where AI contributed to design generation (decision-making parameters, training data sources, optimization weights, energy consumption, etc.) in log format. This system mitigates black box risks, clarifies accountability when accidents occur, and provides objective judgment grounds when architects critically curate AI proposals. For this system to have practical effectiveness, standardized log formats and protocols, legal basis (evidentiary power, retention obligations, submission requirements, etc.), multi-layered governance structures (see Sect. 3.2(2)), and balance between privacy protection and transparency (log disclosure levels) must be established.

Second, verifying cultural bias and securing diversity. Architecture firms or professional organizations should systematically verify the regional and cultural representativeness and source transparency of AI tools' training data before adoption. Practically, non-Western architectural cases should be used in parallel as reference data, local experts should be involved in the design process, and in the long term, culturally balanced architectural databases.

should be built.

Third, securing environmental accountability. AI developers should disclose energy consumption and carbon emissions occurring during training and inference of their models, and through established net effect evaluation methodologies, assess whether design using AI is actually environmentally beneficial. If the net effect is negative, such AI utilization would be difficult to justify environmentally.

To pursue these individual tasks in an integrated manner, governance of AI design should aim to realize architecture's social values beyond simple regulatory compliance. This.

study proposes four core principles and stakeholder roles as shown in Table 3.

This governance framework presents baseline criteria enabling the critical curator in Sect. 3.1 to make responsible decisions and constitutes the core foundation for the content of ethics education in Sect. 3.3. In particular, the role distribution by stakeholder presented in the table emphasizes that AI developers, architects, professional organizations, and governments must cooperatively build an ethical ecosystem from their respective positions, rather than shifting responsibility to any single entity.

3.3 Cultivating Integrative Practitioners

The generative AI era demands fundamental transformation of architectural education. As AI replaces repetitive technical tasks, education should be reorganized around new capabilities to utilize and critically control AI, rather.

Table 3 Principles of AI Design Governance and Stakeholder Roles

Principle	Content	Stakeholders		
		AI Developers	Architects	Organizations/Government
Transparency	Ensuring explainability and traceability of AI-assisted design decisions (fulfilling the EU AI Act's "right to explanation")	Document algorithmic logic and data sources	Record and maintain AI design logs for traceability and auditing	Develop log standards and consider mandatory submission requirements
Accountability	Clarifying that ultimate responsibility for errors or ethical issues rests with human architects	Specify liability for product defects	Conduct final review and accept responsibility for outcomes	Include AI-use clauses in architects' codes of ethics
Fairness	Preventing AI from reinforcing biases toward specific regions, cultures, or social groups	Ensure dataset diversity and disclose bias-testing results	Apply bias-verification protocols	Develop guidelines for bias assessment
Sustainability	Establishing norms for minimizing carbon emissions and evaluating the net environmental impact of AI operations	Disclose carbon footprint and use renewable energy	Conduct net-impact assessments	Standardize methodologies for net-impact evaluation

Table 4 Key Areas and Content for Architectural Education Reform

Category	Main Educational Content and Methods	Expected Learning Outcomes
Algorithmic Thinking Education	• Focus on understanding how AI learns from data and derives results, rather than merely using tools • Data literacy: Understanding and critically examining the quality, sources, and biases of training data	*AI-based Technical Competence*: Ability to utilize AI as a collaborative intelligence rather than a passive tool
Critical Literacy Studio	• Assign projects that evaluate whether "optimized" AI designs exclude vulnerable groups • Train curation skills to reject or modify AI outputs • Require justification for final design choices	*Critical Curation Expertise*: Prevent blind acceptance of AI outputs and strengthen human value-based decision-making
AI Ethics and Responsibility Education	• Analyze how biased training data can lead to cultural homogenization • Examine design log case studies and conduct simulations of responsibility allocation and ethical dilemmas	*Ethical and Social Reflection*: Reinforce architects' ethical awareness and understanding of the societal impact of technology
Generative Exploration Design Studio	• Practice strategic prompt design and iterative refinement • Experiment with "unexpected alternatives" generated by AI • Conduct projects combining human intuition with AI-driven creativity	*Creative Exploration Ability*: Develop systematic and strategic exploration skills beyond intuition-based design

than traditional tool mastery at risk of 'deskilling.' This study defines the required talent in the AI era as 'integrative.

practitioners' and explores the need for multidisciplinary learning environments and critical literacy[6] education to cultivate them.

Integrative practitioners refer to professionals who possess integrated humanistic cultivation, ethical judgment, and data analysis capabilities beyond traditional technical proficiency. This is the ability to integrate the efficiency provided by AI with architecture's essential values, ultimately suggesting that 'value judgment and critical thinking,' which AI cannot do, should be established as the core goal of architectural education.

The core competencies that integrative practitioners should possess are as follows: (1) AI-based technical utilization capability. Beyond simply using AI design tools, they should understand what data they were trained on and what logic they use to derive results, critically evaluate the limitations and biases of tools, and be able to select and adjust appropriate tools. (2) Critical curation expertise. They should be able to select and integrate AI-generated outputs based on the contextual, ethical, and aesthetic criteria proposed in Sect. 3.1, and perform the architect's role transformed from direct producer to strategic curator. (3) Reflective capacity for AI ethics and social responsibility. They should recognize technology's impact on society, critically examine algorithmic bias issues, and be able to integrate public good and social equity into design decisions. (4) Creative exploration capability using AI. They should be able to utilize AI's generative exploration capabilities through strategic prompt design and systematically expand design possibilities without relying only on intuitive ideas.

To practically cultivate these competencies, an open attitude toward multidisciplinary collaboration that effectively communicates with data scientists, engineers, social scientists, etc., and an active stance toward lifelong learning that acquires new knowledge and tools in rapidly changing technological environments are essential. These competencies and attitudes are difficult to acquire through traditional design studios and technical education alone, and demand fundamental reorganization of educational goals and curriculum structure. Table 4 presents core educational programs for cultivating integrative practitioners.

3.4 Interdependence of the Three Tasks

The three tasks proposed in this chapter constitute a system that should be pursued interdependently and integratively, not as independent solutions. First, 'role' transformation without 'education' is impossible. The curator role in Sect. 3.1 presupposes algorithmic thinking and critical curation capabilities, which can be systematically cultivated through integrative practitioner education in Sect. 3.3. Second, 'role' without 'governance' cannot secure legitimacy. For curators to make responsible decisions, the transparency mechanisms and ethical principles mentioned in Sect. 3.2 are necessary. Third, 'education' without 'role' redefinition loses direction. For educational transformation to have practical meaning, a clear vision of the roles students will perform after graduation is needed.

Furthermore, these three tasks are difficult to achieve through isolated efforts of the architecture field alone. AI developers must reflect transparency and environmental responsibility in product design, governments must establish legal frameworks, accreditation bodies must revise educational standards, and academia must institutionalize multidisciplinary cooperation. Ultimately, responsible integration of generative AI demands multi-stakeholder governance, which presupposes an open attitude where the architectural profession actively dialogues and cooperates with other fields and society.

[6] Critical literacy refers to the ability to evaluate and judge AI-generated outputs based on contextual and ethical criteria rather than accepting them uncritically.

4 Conclusion

This study analyzed the impact of generative AI on the architecture field from a balanced perspective of optimism and skepticism, and proposed three practical tasks: redefining architects' roles, establishing ethical governance, and transforming education. Generative AI expands design efficiency and creative exploration while containing structural risks of expertise hollowing out, cultural homogenization, accountability gaps, and environmental paradox. This paradoxical tension suggests that beyond simple acceptance or rejection of technology, the identity and social responsibility of the architectural profession must be fundamentally reestablished.

This study reconceptualized architects' role in the generative AI era as 'curators' and proposed a theoretical framework that can maintain leadership in the design process through contextual, ethical, and aesthetic judgment. Additionally, it explored pathways to respond to black box risks and environmental paradox through a governance framework including AI design history tracking systems, bias verification protocols, and net effect evaluation methodologies. In terms of education, it presented directions for curriculum reorganization for cultivating integrative practitioners, and particularly discussed the direction of systematic change by presenting an integrated perspective that these three tasks are interdependent and must be pursued simultaneously.

Beyond summarizing these findings, it is worth reflecting on what the tensions documented in Sect. 2 reveal about how generative AI is fundamentally reshaping architectural practice itself. Three structural changes stand out.

First, architectural ideation is now mediated by "prompts." The ability to translate design intent into machine-interpretable constraints and critically evaluate the resulting output is emerging as a core professional competency, replacing some of the traditional handcrafting techniques and intuitive sketching processes (Shi et al. 2024; Paananen et al. 2024).

Second, the locus of aesthetic authority is shifting. When AI generates hundreds of alternatives from a single design brief, the act of "selection," grounded in cultural knowledge, contextual judgment, and ethical awareness, becomes as crucial as the act of "creation" itself.

Third, the boundaries between individual style and collective norms are collapsing. Generative AI tools trained on similar datasets tend to converge on statistically similar visual vocabularies (Doshi and Hauser 2024), and without intentional curatorial intervention, architectural products risk becoming homogenized within the dominant aesthetics inherent in the learning dataset, ultimately undermining the diversity of built environment shaped by diverse cultures and communities. These changes suggest that the architectural profession must be redefined not as a mastery of fixed tools, but as the ability to critically explore and direct rapidly evolving human-machine collaborative design processes, and to take responsibility for their outcomes.

This study has the following limitations. First, as a critical narrative review drawing primarily on publicly available professional and academic sources, this study lacks in-depth field investigation of actual architecture firms' AI adoption cases. Future research should qualitatively and quantitatively investigate AI utilization conditions, role change experiences, ethical dilemmas, etc., targeting architecture firms of various scales and regions to verify and supplement this study's proposals. Second, the proposed governance framework and educational model did not sufficiently reflect differences in legal systems and educational systems of each country. Particularly in the Korean context, follow-up research on specific linkage plans with the Architects Act and architectural education accreditation systems is needed. Third, as generative AI technology itself is rapidly evolving, this study's analysis is based on the technology level of a specific period (2024–2025), requiring continuous updates.

Generative AI can become not a threat that replaces architects but a collaborator that realizes architecture's social responsibility. However, this positive future does not arrive automatically. Only when architects develop critical capabilities as curators, professional organizations establish ethical governance, and educational institutions cultivate integrative practitioners can generative AI be integrated as a tool that strengthens architecture's creativity, sustainability, and social equity. It is hoped that the integrated vision of role-governance-education presented in this study will become an academic foundation and practical starting point for responsible AI adoption in the architecture field.

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Declarations

Competing interests The authors declare no competing interests.

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