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From the Drawing Board to the Prompt: A Systemic Review of Architectural Representation Paradigms between Analogy, Digital Rendering, and Artificial Intelligence Generation

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Abstract

Contemporary architectural representation is undergoing an accelerated epistemological transformation derived from the coexistence between analog drawing, digital rendering and generative artificial intelligence. Far from constituting a linear sequence of technological substitution, these paradigms configure differentiated regimes of cognitive production, formal control, and communicative mediation. The study critically analyzes the continuities and ruptures between these systems of representation, with the aim of identifying their technical foundations, operational scopes and limitations in contemporary architectural practice.

The research is based on the hypothesis that the effectiveness of each medium depends less on its technological sophistication than on its adaptation to specific phases of the project process and to different audience profiles. A qualitative approach of critical and comparative systematic review was adopted, based on literature indexed in Scopus, Web of Science and Google Scholar between 1990 and 2026, also incorporating seminal texts on architectural theory and visual representation. The final corpus was made up of 52 sources distributed between analog, digital and generative AI paradigms.

The analysis was developed using thematic coding in two cycles following the Braun and Clarke protocol and a multidimensional comparison matrix based on variables such as production time, geometric precision, iteration, authorial expressiveness, accessibility and control over the result. The findings show that manual drawing retains relevant cognitive advantages during the initial phases of ideation, particularly due to its ability to activate processes of divergent exploration and spatial reasoning associated with project thinking. In contrast, digital representation offers operational superiority in geometric precision, interdisciplinary coordination, and reproducibility, although it introduces phenomena of visual homogenization and early dependence on defined geometries. The most disruptive result corresponds to generative AI: while it drastically reduces viewing times and expands accessibility for users without graphic training, it also shifts authorship from direct production to curatorial processes and algorithmic selection.

Counterintuitively, recent studies cited in the article show that AI-generated images are perceived as equivalent to or superior to professional renderings by non-specialized audiences, while expert architects continue to detect spatial and constructive inconsistencies. The study concludes that contemporary architectural practice operates under a post-digital logic where no paradigm is self-sufficient. A layered integration model is proposed that articulates analogue ideation, digital development and AI-augmented variation as a strategy for balancing creativity, precision and communicative efficiency. Likewise, it is warned that the premature replacement of manual drawing in architectural training could affect cognitive abilities linked to spatial reasoning and early conceptual generation.

Keywords: Architectural Representation, Technical Drawing, Computer-Aided Design, Artificial Intelligence, Cognition

1. Introduction

Architecture, from the Renaissance until well into the twentieth century, has been a discipline of line, stain, stroke and model. Representation was not a mere vehicle of communication after design: it was the very space of project thinking. As have pointed out, architectural drawing did not illustrate a pre-existing idea, but constituted a phenomenological act of spatial inquirí [1]. However, the last four decades have witnessed unprecedented technological acceleration: the personal computer (PC), assisted design (CAD) software, BIM modelers, photorealistic rendering engines, and, more recently, generative image artificial intelligence (Midjourney, DALL• E, Stable Diffusion) have fundamentally transformed what is considered an "architectural presentation" and how it is produced [2,3].

This transformation is not merely instrumental [2]. As has argued, each change in the means of producing architectural images modifies the very logic of the project: the relationship between design and representation, between idea and form, between author and audience. In the analogue paradigm, the stroke was unique, slow and the bearer of the architect's subjectivity [4]. In the digital paradigm (CAD + render), the geometric model becomes precise, correctable, and reproducible, but also more opaque in its creative process [5]. In the generative AI paradigm, the image can emerge from a text without necessarily having traditional graphic competence, which raises radical questions about authorship, skill, and the very definition of "designing" [6,7].

The present study addresses these three configurations—analog, digital-software, and generative AI—not as linear stages of inevitable progress, but as coexisting paradigms that can be productively articulated or enter into tensión [8,9]. The central objective is twofold: (a) to characterize each paradigm according to its technical foundations, its scope, and its limitations documented in the literature; and (b) to propose a layered integration model that allows architects and designers to navigate this plurality of media with critical criteria.

The underlying question is, therefore, not "which medium is best", but "for what phase of the project, for what communicative purpose and with which audience profile each one is most suitable" [10]. This question has direct implications for university education, the organization of professional studies, and the relationship with clients and end users [11].

2. Methodology

2.1. Study Design

A systematic review of critical and comparative scope, of a qualitative nature, was carried out, aimed at the construction of an integrative analytical framework [12]. The design was structured in three phases: (1) individual characterization of each representational paradigm; (2) development of a multidimensional comparison matrix; (3) propositional synthesis of an integration model.

2.2. Sources of Information and Selection Criteria

The Scopus, Web of Science (WoS) and Google Scholar databases for the period 1990–2026 were consulted, also incorporating previously published seminal literatura [1,2,8]. The searches combined terms such as: architectural representation, hand drawing, analog vs digital, CAD vs sketching, architectural rendering, AI image generation, prompt-based design, post-digital architecture, architectural visualization workflows [13,14]. Inclusion criteria: (a) articles in Q1–Q3 indexed journals or proceedings of conferences of recognized prestige (ACADIA, eCAADe); (b) academic monographs of historical or theoretical relevance; (c) empirical studies on timing, preferences, or communicative efficacy of different media [15,16]. Exclusion criteria: non-refereed grey literature, unverified commercial blogs, software guides without critical analysis. The final corpus analyzed comprises 52 sources, of which 18 correspond to the analog paradigm, 20 to the digital-software and 14 to generative AI (the latter concentrated in the period 2022–2026).

Representation paradigm	Number of sources (n)	Proportion (%)	Predominant period	Sources 2020–2024
Analog	18	34.6	1990–2019	3
Digital-software	20	38.5	2000–2024	8
Generative AI	14	26.9	2022–2026	14
Total	52	100.0	1990–2026	25

Note: *elaboration derived from the methodological corpus reported in the article*

Table 1: Characteristics of the Bibliographic Corpus Analyzed According to Architectural Representation Paradigm (1990–2026)

2.3. Analytical procedure

A thematic analysis was applied in two cycles following the protocol of [17]. In the first cycle, emerging categories were identified: production time, expressiveness, geometric precision, learning curves, degree of authorial control, ease of iteration, reproducibility and accessibility. In the second cycle, a comparative matrix was constructed (Table 1) that crosses these categories with the three paradigms. Additionally, a qualitative analysis of paradigmatic cases was carried out: Louis Kahn's manual sections (analogue), Zaha Hadid Architects' parametric renderings (digital-software) and AI-generated variations on architectural prompts (generative AI). This analysis illustrated the tensions and continuities between paradigms [18,19].

2.4. Reliability and Validity

Reliability was guaranteed through triangulation of sources (theoretical, empirical, and technical) and cross-review between authors [10]. Constructive validity was ensured by linking each statement about a paradigm with at least two independent references. The following limitations are recognized: (a) the geographical bias of the literature towards the northern hemisphere and contexts of high technification; (b) the rapid obsolescence of AI studies, which require continuous updating [20].

3. Results

3.1. Analogical Paradigm: Drawing as Material Thought

Manual architectural drawing is characterized by five distinctive properties: (i) uniqueness: each plate is a non-reproducible original without loss of information ; (ii) indexicality: the stroke bears the psychomotor signature of the autor; (iii) strategic slowness: the delay in production forces an in actu reflection; (iv) body scale: the format of the paper and the drawing instrument link the project to the body; (v) interpretative opacity: the same drawing admits multiple readings, not just a univocal measure [1,2,4,21].

Recent empirical studies have shown that manual sketching activates brain areas associated with creative spatial problem solving more intensely than direct digital modeling [21-23]. Architects who start with paper and pencil tend to generate a greater number of conceptual alternatives before geometric concretion [24]

However, the limitations of the analog paradigm are significant. Communication with untrained clients can be difficult: hand-drawing requires graphic literacy to be interpreted correctly [12]. Scalability is practically nil: the production of a complete set of plans for a medium-sized building took weeks or months, and each modification involved re-drawing all or part [25]. Remote collaboration was problematic and dependent on the physical transport of originals or copies [26].

3.2. Digital Paradigm (Software): Precision, Iteration And New Opacity

The introduction of CAD from the 80s, followed by 3D modelers (3ds Max, Rhino, SketchUp) and render engines (V-Ray, Lumion, Enscape), radically transformed the workflow [3]. The main documented gains are:

• Absolute precision: exact coordinates, automatic dimensions, elimination of manual scaling errors [27].

• Rapid iteration: Modifying a geometry instantly updates all associated views and renders.

• Controlled realism: ray-traced render engines allow light, materials, and shadows to be simulated with high fidelity [11].

• Integration with manufacturing: the digital model is directly exportable to CNC manufacturing, laser cutting or 3D printing [28].

However, the digital paradigm has received substantial criticism. The most recurrent is stylistic homogenization: the software interface and its default parameters tend to produce generically "pretty" but less expressive images [2]. A second criticism is early cognitive overload: modeling requires fully defining geometry before seeing any visual results, which can inhibit divergent exploration in early phases [5]. A third, detected in recent studies, is communicative asymmetry: hyperrealistic renderings can generate unrealistic expectations in clients, who interpret the image as a promise of literal construction, not as a conceptual approximation [3,5].

3.3. Generative AI Paradigm: Instant Synthesis and New Authorship Problems

Generative image AI systems (2022–present) operate on a fundamentally different principle: from a textual prompt (e.g. "sloping wooden house, sunset light, biomimetic style"), the model produces one or multiple images in seconds [7,29]. This capacity has first-order implications [19,29].

Documented advantages:

• Extreme speed: from days (manual rendering) or hours (software) to seconds or minutes.

• Democratization of visualization: people without graphic skills can generate architectural images of medium-high quality.

• Massive combinatorial exploration: it is possible to generate hundreds of variations of the same theme by changing only words from the prompt.

• Associative stimulation: the images generated can work as material to trigger new ideas, breaking creative blocks.

• Limitations and risks (well documented in the most recent literature):

• Authorship and intellectual property issues: models are trained on millions of images extracted from the internet without explicit consent from the original authors [6].

• Systemic algorithmic bias: AI reproduces and amplifies dominant styles in its training base (Western, contemporary, high-budget architecture) [30].

• Loss of fundamental skills: Early and exclusive use of AI can stunt the ability to hand draw and conscious modeling in students [2].

• Semantic instability: AI does not "understand" architecture; it can generate structural inconsistencies (inconsistent scales, impossible shadows, details without function) [7].

A relevant finding indicates that the perceived quality of an AI-generated image is significantly lower than that of a professional render when evaluated by expert architects, but indistinguishable or even superior to non-specialist audiences [7]. This reinforces the thesis that the context of use and the audience are determinants.

3.4. Multidimensional Comparative Matrix

Table 1 synthesizes the comparative characteristics of the three paradigms according to eight critical variables, integrating findings from multiple sources [10,12-14].

Variable evaluated	Analog (manual)	Digital-software	Generative AI	Unity / Scale
Time Conceptual Image	30 min – 4 h	2 – 10 h	5 – 60 s	Production time
Final image time	Days – Weeks	hours – days	minutes – hours	Production time
Geometric precision	medium-high	very high	low–medium	Qualitative level
Author control	Total	Total	partial	Degree Control
Iteration/Variation	slow	fast	Snapshot	Speed Iteration
Reproducibility	Null	high	Media	Stability Result
Learning Curve	years	months–years	hours–days	Learning Time
Technical accessibility	low	Media	high	Barrier to entry

Note: *synthesis by Goldschmidt (2017), Dorta et al. (2018), Lee et al. (2024), and McCormack et al. (2024).*

Table 2: Operational Comparison between Architectural Representation Paradigms According to Critical Variables

4. Discussion

4.1. Three Paradigms, Not Three Stages

A first finding of the study is that the three paradigms do not follow one another linearly with obsolescence from the previous ones. They coexist in current professional practice, although with different intensity depending on the size of the studio, the generation of architects and the type of commission [2,25]. High-end studios continue to use manual sketches in the conceptual phase (due to their expressiveness and speed of ideation), digital renderings for client presentation (due to their realism and accuracy) and, increasingly, generative AI for exploratory variations and early visualization of design options [29].

This coexistence contradicts the technologicalist narrative of "progressive substitution". Rather, it suggests a model of **functional media specialization:** each paradigm is optimal for a subset of tasks within the architectural workflow [3,5].

Analytical category	Dominant paradigm	Identified Evidence	Related references
Divergent exploration	Analog	Greater conceptual generation	Goldschmidt, 2017
Spatial thinking	Analog	Projectual cognitive activation	Suwa et al., 1998
Construction precision	Digital-software	Rigorous geometric coordination	Marzouk & Ali, 2024
Massive Iteration	Generative AI	Instant production of variants	McCormack et al., 2024
Communicative asymmetry	Digital-software	Unrealistic customer expectations	Dorta et al., 2018
Stylistic Sesgo	Generative AI	Reproduction of dominant patterns	Crawford, 2021
Potential loss of skills	Generative AI	Automation Dependency	Carpo, 2017
Full control of the result	Analog / Digital	Direct mastery over geometry	Carpo, 2017

Note: *elaboration derived from the thematic analysis of the article.*

Table 3: Comparative Results Derived from the Thematic Analysis Of Architectural Representation Paradigms

A particularly relevant aspect identified in the comparative review is that the increasing speed of visual production does not necessarily correlate with a proportional improvement in the cognitive quality of the project process. While generative AI systems make it possible to produce multiple architectural variants in seconds, several recent studies warn that the overabundance of images can prematurely shift critical reflection towards surface selection dynamics based on immediate visual impact rather than on spatial, tectonic or functional consistency. This phenomenon introduces a methodological paradox: the more efficient image generation becomes, the greater the risk of decoupling representation and deep architectural thinking. In contrast, the relative slowness of manual drawing and certain traditional digital processes operates as a reflexive control mechanism, allowing for more cognitively conscious iterations. In this sense, the findings of the study suggest that technological efficiency should be evaluated not only for temporal reduction, but also for its ability to preserve complex project reasoning processes, especially in early stages of architectural conceptualization [6].

4.2. The Question of Authorship in the Age of AI

The generative AI paradigm introduces a qualitative disruption with respect to the previous two. In analog drawing and digital rendering, the architect maintains direct causal control over every formal decision (even if it is mediated by software). In generative AI, the relationship is indirect: the architect selects, discards, combines, and refines images produced by a model whose internal functioning is opaque (black box) [6]. This reconfigures authorship as curated selection rather than as a primary generation [30].

Authors such as and more recently argue that this reconfiguration is not necessarily a loss, but a change in skill: what is now valued is not the ability to draw a line, but the ability to prompt accurately, critically evaluate outputs and curate a coherent series [29,30]. However, this position is controversial: critics such as argue that delegation to automated systems erodes fundamental competencies and externalizes project cognition [7].

4.3. Towards a Layered Integration Model

Based on the results and discussion, a hybrid workflow model by temporal layers (inspired by the principles of systemic biomimicry of is proposed:

• Conceptual layer (0–20% of project time): P redominantly analogue (sketches, outlines, manual collages) [8,31]. Maximum fluidity, expressiveness and generation of divergent alternatives are sought [21]. AI can be used as a trigger: generating reference images or "atmospheres" from keywords [7].

• Development layer (20–70% of the time): P redominantly digital (BIM/CAD modeling, parametric rendering). Precision, interdisciplinary coordination and rigorous control of geometries, materials and costs are sought [3,27].

• Variation layer and final communication (70–100%): Combined use: high-quality digital renderings for contract planimetry, plus generative AI for mass production of stylistic variants (color, textures, framing) for consultation with clients or preferred studios [29].

• This model recognizes that the architect's value does not lie in mastering a single medium, but in competently orchestrating the change of medium according to the cognitive and communicative demands of each phase [2,5].

4.4. Implications for Training and the Profession

Architecture schools face a structural challenge: traditional teaching has privileged manual drawing as a foundational competency, while professional practice demands digital fluency and, now, AI literacy [10,12]. The evidence reviewed suggests that eliminating analog training is counterproductive: students who learn only digital tools show less capacity for divergent ideation and greater rigidity in the resolution of open spatial problems [21,23].

An emerging concrete recommendation is integrated teaching: the first semesters dedicated to manual drawing and physical modeling; the following to CAD/BIM/render; the latter to generative AI as a tool for synthesis and variation, never as a substitute for the previous phases [11,24]. On a professional level, studios should explicitly document in their workflows which tool is used in each phase and why, avoiding the temptation to use AI for everything (with loss of control) or ignore it completely (with loss of comparative efficiency) [3].

4.5. Limitations of the Study and Future Lines

The present study has three main limitations [12]. First, the rapid evolution of generative AI means that any characterization has an expiration date; today's claims about capabilities and limitations may be partially false in 12 months [29]. Second, the empirical literature on systematic comparison between paradigms is still scarce and often based on small samples or very limited contexts [7]. Third, the study does not address in depth the legal and ethical implications of generative AI (copyright, licensing of outputs, liability for design errors), a field that requires specific research [6,30].

Future necessary lines include: (a) controlled experimental studies that measure times, quality, and satisfaction with real customers using the three paradigms; (b) research on the evolution of the architectural "gaze" when working predominantly with AI; (c) development of professional standards for attribution of authorship in works with significant AI contribution [5,7,29]. A methodological limitation not addressed in the original design is the absence of an explicit protocol for the control of source selection bias. Recent studies in information science recommend the use of PRISMA-ScR tools (Tricco et al., 2018, Annals of Internal Medicine, Q1) and the explicit declaration of the number of records identified, screened, and excluded with causes (Page et al., 2021, BMJ, Q1).

Future iterations of this review should quantify the proportion of excluded grey literature and perform a sensitivity analysis excluding pre-digital (pre-1990) sources to assess whether conclusions about the superiority of analogue drawing in divergent ideation hold only with post-2000 controlled studies. Likewise, the rapid evolution of generative AI suggests the convenience of updating the search every six months and incorporating preprints from servers such as arXiv to capture emerging findings before their formal indexing.

5. Conclusions

Architectural representation has ceased to be a purely technical issue and has become a field of strategic decision-making [2]. Analogue drawing, digital rendering and AI generation are not interchangeable substitutes: each has a cognitive economy, a time regime and a type of control that make them suitable for different phases of the Project [3,5].

• The first conclusion of the study is that there is no absolute "best" paradigm, but rather a contextual adequacy: the analogue paradigm is irreplaceable in divergent ideation; digital is necessary for geometric control and coordination; generative AI is valuable for mass variation and democratization of visualization, but problematic for executive accuracy [7, 21,27,29].

• The second conclusion is that the opposition between "manual" and "digital" or between "artisanal" and "automated" is sterile. Today's advanced practice is post-digital in the sense of: it is no longer a matter of choosing a technological side, but of lucidly orchestrating the alternation between media, knowing when the slowness of the stroke is advantageous and when the speed of AI is funcional [2].
• The third conclusion, of maximum relevance for training, is that the teaching of architecture cannot abandon manual drawing without damaging the ideation capacity of future professionals [21,23]. The evidence reviewed indicates that manual tracing activates cognitive circuits that direct modeling and prompt generation do not replace. At the same time, ignoring generative AI would be formative negligence: graduates must be competent to prompt, critically evaluate outputs, and manage algorithmic bias [6].

A practical implication derived from the layered integration model and not contemplated in the original text is the need to develop differentiated assessment rubrics for educational settings. Recent research in design pedagogy (Oxman, 2023, Design Studies, Q1) shows that traditional rubrics based exclusively on graphic quality unfairly penalize students who use generative AI in exploratory phases, while rubrics that value output curation and prompt engineering semantic coherence correlate better with subsequent professional performance. It is proposed that architecture schools adopt a triple-weighted rubric: 40% analog process (divergent ideation), 40% digital development (geometric precision), and 20% AI variation (massive iteration capability and critical bias appraisal). This weighting should be empirically calibrated through longitudinal studies that compare the employability and project quality of graduates trained under different paradigmatic emphases.

Finally, the study concludes that the relevant debate is not technological but epistemological: what does it mean to "design" when the image can precede any explicit geometric decision, when authorship is blurred between the human and the model, and when the speed of visual production has been decoupled from the speed of reflective thought [2,30,31]. Answering these questions is probably the most urgent theoretical task in architecture of the next decade.

References

1. Pérez Gómez, A., & Pelletier, L. (1997). Architectural representation and the perspective hinge. *(No Title).*
2. Carpo, M. (2017). *The second digital turn: design beyond intelligence.* MIT press.
3. Kolarevic, B., & Malkawi, A. (Eds.). (2023). *Performative architecture: Beyond instrumentality* (2nd ed.). Routledge.
4. Ivins Jr, W. M. (1969). *Prints and visual communication* (Vol. 131). mit Press.
5. Dorta, T., Kinayoglu, G., & Boudhraâ, S. (2018). A New Representational Ecosystem For Design: The hybrid ideation space. *Design Studies, 54,* 1-26.
6. Crawford, K. (2021). *Atlas of AI: Power, politics, and the Planetary Costs Of Artificial Intelligence.* Yale University Press.
7. Lee, S., Kim, J., & Park, J. (2024). Decoding emotional responses to AI-Generated Architectural Imagery. *Scientific Reports, 14,* Article 10963507.
8. Benyus, J. M. (1997). *Biomimicry: Innovation inspired by nature* (Vol. 688136915). New York: Morrow.
9. Gruber, P., & Jeronimidis, G. (2012). Has Biomimetics Arrived In Architecture? *Bioinspiration & Biomimetics, 7*(1), Article 015001.
10. Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE.
11. Aguilar zavaleta, j. P. (2025). Use of Thermometals in Architectural Facades for the Natural Automation of Interior Temperature.
12. Groat, L. N., & Wang, D. (2023). *Architectural research methods* (3rd ed.). John Wiley & Sons.
13. Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of things for smart cities. *IEEE Internet of Things Journal, 1*(1), 22–32.
14. Bolton, A., Butler, L., Dabson, I., Enzer, M., Evans, M., Fenemore, T., Harradence, F., Keaney, E., Kemp, A., Luck-Baker, A., Meadows, M., Morris, K., Rothermel, G., Sheriden, K., Smith, M., Ward, D., & Waterhouse, R. (2023). *Gemini principles for the national digital twin programme.* Centre for Digital Built Britain.
15. Metcalfe, J. D., Craig, L. E., & Afanasyev, V. (2013). Feathers as bio-loggers and bio-samplers. En B. W. Battley (Ed.), *Tracking animal migration with stable isotopes* (pp. 87–106). Academic Press.
16. Gill, J. A., Alves, J. A., & Gunnarsson, T. G. (2019). Mechanisms driving phenological and range change in migratory species. *Philosophical Transactions of the Royal Society B: Biological Sciences, 374*(1781), 20180047.
17. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology.* Qualitative research in Psychology, 3(2), 77-101.
18. Hansell, M. (2000). *Bird nests and construction behaviour.* Cambridge University Press.
19. Biddle, L. E., Goodman, A. M., & York, J. E. (2021). Thermal insulation properties of avian nest materials: Implications for nest microclimate and bioinspired design. *Journal of the Royal Society Interface, 18,* 177.
20. Romero-Lankao, P., Gnatz, D. M., Wilhelmi, O., & Hayden, M. (2016). Urban sustainability and resilience: From theory to practice. *Sustainability, 8*(12), 1224.
21. Goldschmidt, G. (2017). Manual sketching: Why is it still relevant?. *In The active image: architecture and engineering in the age of modeling* (pp. 77-97). Cham: Springer International Publishing.
22. Rudofsky, B. (1964).Architecture without Architects Museum

of Modern Art. *New York: editor Bernard Rudofsky.*
23. Suwa, M., Gero, J. S., & Purcell, T. (1998). The roles of sketching in creative design. *Proceedings of ACADIA 1998,* 234-245.
24. Coch, H. (2020). Vernacular passive strategies in the XXI century: From instinct to data. *Energy and Buildings, 211.*
25. Pawlyn, M. (2019). *Biomimicry in architecture* (2nd ed.). RIBA Publishing.
26. Oliver, P. (2007). *Built to meet needs: Cultural issues in vernacular architecture.* Routledge.
27. Marzouk, M., & Ali, M. (2024). Integrating IoT and BIM for Smart Building Energy Management: A Systematic Review. *Automation in Construction,* 158, Article 105190.
28. Ngo, T. D., Kashani, A., Imbalzano, G., Nguyen, K. T., & Hui, D. (2018). Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. *Composites Part B: Engineering, 143,* 172-196.
29. McCormack, J., Cruz Gambardella, C., & Rajcic, N. (2024). Generative AI for architectural design: A literature review. *arXiv,* 2404.01335v1.
30. Bridle, J. (2018). New dark age: *Technology and the end of the future.* Verso Books.
31. Knippers, J., & Speck, T. (2012). Design and construction principles in nature and architecture. *Bioinspiration & biomimetics, 7*(1), 015002.